BASIC Stamp® Programming Manual

Version 1.9

PARALLAX®

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Internet BASIC Stamp Discussion List

We maintain an email discussion list for people interested in BASIC Stamps. The list works like this: lots of people subscribe to the list, and then all questions and answers to the list are distributed to all subscribers. It's a fun, fast, and free way to discuss issues.

To subscribe to the Stamp list, send email to *majordomo@parallaxinc.com* and write *subscribe stamps* in the body of the message.

This manual is valid with the following software and firmware versions:

BASIC Stamp I:
- STAMP.EXE software version 2.1
- Firmware version 1.4

BASIC Stamp II:
- STAMP2.EXE software version 1.1
- Firmware version 1.0

Newer versions will usually work, but older versions may not. New software can be obtained for free on our Internet web and ftp site. New firmware, however, must usually be purchased in the form of a new BASIC Stamp. If you have any questions about what you may need, please contact Parallax.

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BASIC Stamp I:

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Thank you for purchasing a BASIC Stamp product. We've been making BASIC Stamp computers for years, and most customers find them useful and fun. Of course, we hope your experience with BASIC Stamps will be useful and fun, as well. If you have any questions or need technical assistance, please don't hesitate to contact Parallax or the distributor from which you purchased your BASIC Stamps.

This manual is divided into two sections. The first section deals with the BASIC Stamp I, and the second section deals with the BASIC Stamp II. The BASIC Stamp I has been around for some time, and therefore has more data in the way of application notes. If you have prior experience with BASIC Stamp I, you should consult Appendix C, for details on converting to the Basic Stamp II.

PBASIC Language: the BASIC Stamps are programmed in a simple version of the BASIC language, called *PBASIC*. We developed PBASIC to be easy to understand, yet well-suited for the many control and monitoring applications that BASIC Stamps are used in. The PBASIC language includes familiar instructions, such as GOTO, FOR...NEXT, and IF...THEN, as well as specialized instructions, such as SERIN, PWM, BUTTON, COUNT, and DTMFOUT.

Hardware: the BASIC Stamps discussed in this manual are the "BS1-IC" and "BS2-IC." Both represent the latest versions of the BASIC Stamp I and BASIC Stamp II. Both include a small circuit board with a PBASIC interpreter chip, EEPROM, 5-volt regulator, reset circuit, and resonator. These five components form a complete computer in a very small space. The modular design of the BS1-IC and BS2-IC makes them perfect for use in breadboards and printed circuit boards.

Each of the BASIC Stamp modules has a corresponding "carrier board." The carrier boards provide 9-volt battery clips, connectors for programming, and a small prototyping area. Although they are optional, we recommend that you purchase at least one carrier board as a means of easily programming your BASIC Stamps.

System Requirements

To program the BASIC Stamp I, you'll need the following system:

- IBM PC or compatible computer
- 3.5-inch disk drive
- Parallel port
- 128K of RAM
- MS-DOS 2.0 or greater

If you have the BASIC Stamp I carrier board, you can use a 9-volt battery as a convenient means to power the BASIC Stamp. You can also use a 5-15 volt power supply (5-40 volts on the BS1-IC rev. b), but you should be careful to connect the supply to the appropriate part of the BASIC Stamp. A 5-volt supply should be connected directly to the +5V pin, but a higher voltage should be connected to the PWR pin. **Connecting a high voltage supply (greater than 6 volts) to the 5-volt pin can permanently damage the BASIC Stamp.**

Packing List

If you purchased the BASIC Stamp Programming Package, you should have received the following items:

- BASIC Stamp manual (this manual)
- BASIC Stamp I programming cable (parallel port DB25-to-3 pin)
- BASIC Stamp II programming cable (serial port DB9-to-DB9)
- 3.5-inch diskette

If you purchased the BASIC Stamp I Starter Kit, you should have received the following items:

- BASIC Stamp Manual (this manual)
- BASIC Stamp I programming cable (parallel port DB25-to-3 pin)
- 3.5-inch diskette
- BS1-IC module
- BASIC Stamp I Carrier Board

If any items are missing, please let us know.

Connecting to the PC

To program a BASIC Stamp I, you'll need to connect it to your PC and then run the editor / downloader software. In this section of the manual, it's assumed that your BASIC Stamp is a BS1-IC, and that you have the corresponding carrier board.

To connect the BASIC Stamp to your PC, follow these steps:

1) Plug the BS1-IC onto the carrier board. The BS1-IC plugs into a 14-pin SIP socket, located near the battery clips on the carrier. When plugged onto the carrier board, the components on the BS1-IC should face the battery clips.

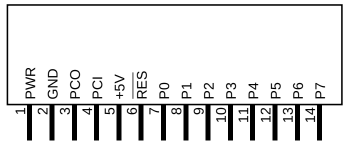
2) In the BASIC Stamp Programming Package, you received a cable to connect the BASIC Stamp to your PC. The cable has two ends, one with a DB25 connector and the other with a 3-pin connector. Plug the DB25 end into an available **parallel** port on your PC.

3) Plug the remaining end of the cable onto the 3-pin header on the carrier board. On the board and the cable, you'll notice a double-arrow marking; the markings on the cable and board should match up.

4) Supply power to the carrier board, either by connecting a 9-volt battery or by providing an external power source.

With the BASIC Stamp connected and powered, run the editor / downloader software as described later in this manual.

BS1-IC



Shown at 125% of actual size

PWR **Unregulated power in:** accepts 6-15 VDC (6-40 VDC on BS1-IC rev. b), which is then regulated to 5 volts. May be left unconnected if 5 volts is applied to the +5V pin.

GND **System ground:** connects to PC parallel port pin 25 (GND) for programming.

PCO **PC Out:** connects to PC parallel port pin 11 (BUSY) for programming.

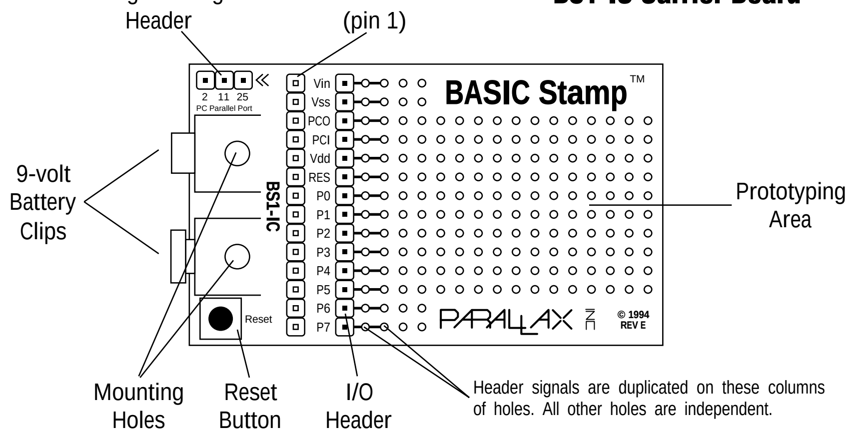
PCI **PC In:** connects to PC parallel port pin 2 (D0) for programming.

+5V **5-volt input/output:** if an unregulated voltage is applied to the **PWR** pin, then this pin will output 5 volts. If no voltage is applied to the **PWR** pin, then a regulated voltage between 4.5V and 5.5V should be applied to this pin.

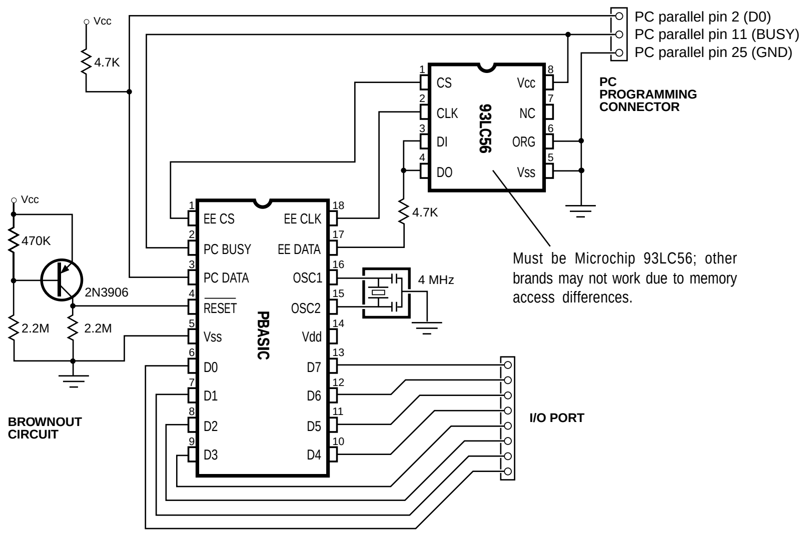
RES **Reset input/output:** goes low when power supply is less than 4 volts, causing the BS1-IC to reset. Can be driven low to force a reset. Do not drive high.

P0-P7 **General-purpose I/O pins:** each can sink 25 mA and source 20 mA. However, the total of all pins should not exceed 50 mA (sink) and 40 mA (source).

BS1-IC Carrier Board



General Stamp Schematic*:



* The BS1-IC has a slightly different schematic (it uses a different reset circuit, and it includes a 5-volt regulator). However, this schematic serves as an example of how simple the BASIC Stamp circuit is to implement.

Current Limits of the On-Board Regulator

In some cases, you may want to know how much current the BS1-IC can handle with its on-board regulator. At higher supply voltages, the regulator can handle less current. The BS1-IC itself takes 1-2 mA, so any current "left over" can be used to drive external circuits. The table below shows the approximate current limits at various voltages:

Power Supply (volts)	Total Current (mA)
5-9	50
12	40
25	10
40	2-3

We recommend a supply voltage on the low end (5-15 VDC). However, the BS1-IC will run at higher voltages, as shown.

The BASIC Stamp I has 16 bytes of RAM devoted to I/O and the storage of variables. The first two bytes are used for I/O (1 for actual pins, 1 for direction control), leaving 14 bytes for data. This arrangement of variable space is shown below:

Word Name	Byte Names	Bit Names	Special Notes
Port	Pins Dirs	Pin0-Pin7 Dir0-Dir7	I/O pins; bit addressable. I/O pin direction control; bit addressable.
W0	B0 B1	Bit0-Bit7 Bit8-Bit15	Bit addressable. Bit addressable.
W1	B2 B3		
W2	B4 B5		
W3	B6 B7		
W4	B8 B9		
W5	B10 B11		
W6	B12 B13		Used by GOSUB instruction. Used by GOSUB instruction.

The PBASIC language allows a fair amount of flexibility in naming variables and I/O pins. Depending upon your needs, you can use the variable space and I/O pins as bytes (Pins, Dirs, B0-B13) or as 16-bit words (Port, W0-W6). Additionally, the I/O pins and the first two data bytes can be used as individual bits (Pin0-Pin7, Dir0-Dir7, Bit0-Bit15). In many cases, a single bit may be all you need, such as when storing a status flag.

Port is a 16-bit word, which is composed of two bytes, **Pins** and **Dirs:**

> **Pins** (byte) and **Pin0-Pin7** (corresponding bits) are the I/O port pins. When these variables are read, the I/O pins are read directly. When these variables are written to, the corresponding RAM is written to, which is then transferred to the I/O pins before each instruction.
>
> **Dirs** (byte) and **Dir0-Dir7** (corresponding bits) are the I/O port direction bits. A "0" in one of these bits causes the corresponding I/O pin to be an input; a "1" causes the pin to be an output. This byte of data is transferred to the I/O port's direction register before each instruction.
>
> **When you write your PBASIC programs, you'll use the symbols described above to read and write the BASIC Stamp's 8 I/O pins.**
>
> Normally, you'll start your program by defining which pins are inputs and which are outputs. For instance, "dirs = %00001111" sets bits 0-3 as outputs and bits 4-7 as inputs (right to left).
>
> After defining which pins are inputs and outputs, you can read and write the pins. The instruction "pins = %11000000" sets bits 6-7 high. For reading pins, the instruction "b2 = pins" reads all 8 pins into the byte variable b2.
>
> Pins can be addressed on an individual basis, which may be easier. For reading a single pin, the instruction "Bit0 = Pin7" reads the state of I/O pin 7 and stores the reading in bit variable Bit0. The instruction "if pin3 = 1 then start" reads I/O pin 3 and then jumps to start (a location) if the pin was high (1).

The BASIC Stamp's editor software recognizes the variable names shown on the previous page. If you'd like to use different names, you can start your program with instructions to define new names:

```
symbol switch = pin0            'Define label "switch" for I/O pin 0
symbol flag = bit0              'Define label "flag" for bit variable bit0
symbol count = b2               'Define label "count" for byte variable b2
```

Can I expand the BASIC Stamp's program memory?:

No; the PBASIC interpreter only addresses 8 bits of program space, which results in the 256-byte limitation. Using a larger EEPROM, such as the Microchip 93LC66, won't make any difference.

What voltage range can I use to power the BASIC Stamp:

We encourage people to use a 9-volt battery to power the BASIC Stamp, especially if they have the carrier board. The battery is simple and can power the BASIC Stamp for days, even weeks if sleep mode is used.

However, if you want to use an external power supply, you can use anything that supplies 5-15 volts DC (5-40 VDC on BS1-IC rev. b) at a minimum of 2 mA (not including I/O current needs).

If you have a 5-volt supply, connect it to the BASIC Stamp's +5V pin. This will route power directly to the BASIC Stamp circuit, bypassing the voltage regulator.

If you have a 6-15 (6-40 VDC on BS1-IC rev. b) volt supply, connect it to the BASIC Stamp's PWR pin. This will route power through the on-board 5-volt regulator.

Can I use the Stamp to power external circuits?:

Yes; if you need to supply 5 volts, connect your circuit to the BASIC Stamp's **+5V** pin. If you need the unregulated input voltage, connect your circuit to the **PWR** pin.

How long can the BASIC Stamp run on a 9-volt battery?:

This depends on what you're doing with the BASIC Stamp. If your program never uses sleep mode and has several LED's connected to I/O lines, then the BASIC Stamp may only run for several hours. If, however, sleep mode is used and I/O current draw is minimal, then the BASIC Stamp can run for weeks.

What are the sink and source capabilities of the BASIC Stamp's I/O lines?:

The I/O pins can each sink 25 mA and source 20 mA. However, the total sink and source for all 8 I/O lines should not exceed 50 mA (sink) and 40 mA (source).

Does the BASIC Stamp support floating point math?:

No; the BASIC Stamp only works with integer math, which means that no fractions are allowed. Expressions must be given as integers, and any results are given as integers. For instance, if you gave the BASIC Stamp an instruction to divide 5 by 2, it would return a result of 2, not 2.5; the remainder (.5) is simply lost.

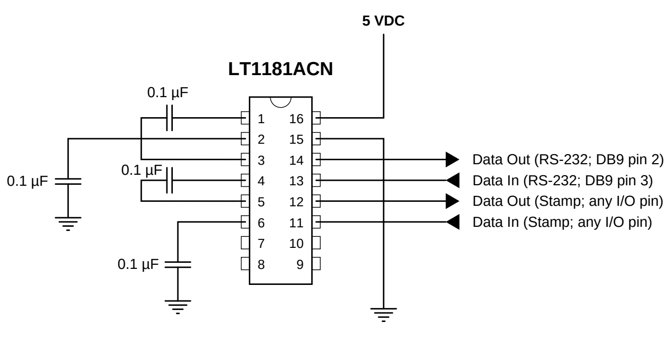
How does the BASIC Stamp evaluate mathematical expressions?:

Mathematical expressions are evaluated strictly left to right. This is important, since you may get different results than you expect. For instance, under normal rules, the expression 2 + 3 x 4 would be solved as 2 + (3 x 4), since multiplication takes priority over addition. The result would be 14. However, since the BASIC Stamp solves expressions from left to right, it would be solved as (2 + 3) x 4, for a result of 20.

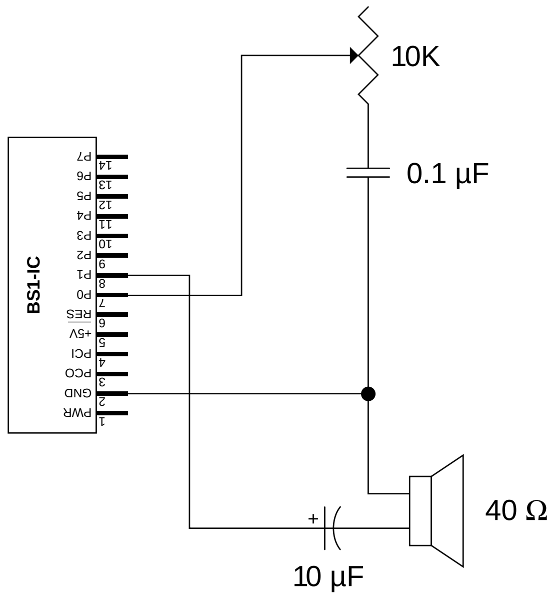
When writing your programs, please remember that the left-to-right evaluation of expressions may affect the results.

What do I need to make the BASIC Stamp support RS-232 voltages?

The BASIC Stamp's I/O pins operate at TTL voltages (0-5 volts), so the SERIN and SEROUT instructions operate at these voltages. This is fine for most applications, such as BASIC Stamps communicating with other BASIC Stamps. However, some PCs may not accept TTL voltages, especially when the PC is receiving data. If you need real RS-232 voltages, you can use the circuit shown below. The LT1181ACN is available from various distributors, including Digi-Key (call 800-344-4539).



This page shows a simple application using a BS1-IC. The purpose of the application is to read the value of the potentiometer and then generate a corresponding tone on the speaker. As the potentiometer value changes, so does the tone. For interesting variations, the potentiometer could easily be changed to a thermistor or photocell.




```
loop:
    pot 0,100,b2                'Read potentiometer on pin 0 and
                                'store result in variable b2.

    b2=b2/2                     'Divide result so highest value
                                'will be 128.

    sound 1,(b2,10)             'Generate a tone using speaker
                                'on pin 1. Frequency is set by
                                'value in b2. Duration of tone
                                'is set to 10.

    goto loop                   'Repeat the process.
```

Starting the Editor

With the BASIC Stamp connected and powered, run the editor software by typing the following command from the DOS prompt:

```
STAMP
```

Assuming you're in the proper directory, the BASIC Stamp software will start running after several seconds. The editor screen is dark blue, with one line across the top that names various functions.

Program Formatting

There are few restrictions on how programs are entered. However, you should know the rules for entering constants, labels, and comments, as described in the following pages:

- **Constants:** constant values can be declared in four ways: decimal, hex, binary, and ASCII.

  Hex numbers are preceded with a dollar sign ($), binary numbers are preceded with a percent sign (%), and ASCII values are enclosed in double quotes ("). If no special punctuation is used, then the editor will assume the value is decimal. Following are some examples:

  ```
  100           'Decimal
  $64           'Hex
  %01100100     'Binary
  "A"           'ASCII "A" (65)
  "Hello"       'ASCII "H", "e", "l", "l", "o"
  ```

  Most of your programs will probably use decimal values, since this is most common in BASIC. However, hex and binary can be useful. For instance, to define pins 0-3 as outputs and pins 4-7 as inputs, you could use any of the following, but the binary example is the most readable:

  ```
  dirs = 15           'Decimal
  dirs = $0F          'Hex
  dirs = %00001111    'Binary
  ```

- **Address Labels:** the editor uses labels to refer to addresses (locations) within your program. This is different from some versions of BASIC, which use line numbers.

  Generally speaking, label names can be any combination of letters, numbers, and underscores (_), but the first character of the name must not be a number. Also, label names cannot use reserved words, such as instruction names (serin, toggle, goto, etc.) and variable names (port, w2, b13, etc.)

  When first used, label names must end with a colon (:). When called elsewhere in the program, labels are named without the colon. The following example illustrates how to use a label to refer to an address:

```
loop:   toggle 0                        'Toggle pin 0

        for b0 = 1 to 10
        toggle 1                        'Toggle pin 1 ten times
        next

        goto loop                       'Repeat the process
```

- **Value Labels:** along with program addresses, you can use labels to refer to variables and constants. Value labels share the same syntax rules as address labels, but value labels don't end with a colon (:), and they must be defined using the "symbol" directive. The following example shows several value labels:

```
symbol start = 1                        'Define two constant
symbol end = 10                         'labels

symbol count = b0                       'Define a label for b0

loop:   for count = start to end
        toggle 1                        'Toggle pin 1 ten times
        next
```

- **Comments:** comments can be added to your program to make it more readable.

  Comments begin with an apostrophe (') and continue to the end of the line. You can also designate a comment using the standard REM statement found in many versions of BASIC...

```
symbol relay = 3                    'Make label for I/O pin 3
symbol length = w2                  'Make label for w2

        dirs = %11111111            'Make all pins outputs
        pins = %00000000            'Make all pins low

REM this is the main loop

main:   length = length + 10        'Increase length by 10
        gosub sub                   'Call pulse out routine
        goto main                   'Loop back

sub:    pulsout relay,length : toggle 0 : return
```

- **General Format:**

  The editor is not case sensitive, except when processing strings (such as “hello”).

  Multiple instructions and labels can be combined on the same line by separating them with colons (:).

  The following example shows the same program as separate lines and as a single-line...

  Multiple-line version:

```
        dirs = 255                  'Make all pins outputs
        for b2 = 0 to 100           'Count from 0 to 100
        pins = b2                   'Make pins = count (b2)
        next                        'Continue counting til 100
```

  Single-line version:

```
        dirs = 255 : for b2 = 0 to 100 : pins = b2 : next
```

- **Mathematical Operators:** the following operators may be used in mathematical expressions:

+	add
-	subtract
*	multiply (returns low word of result)
**	multiply (returns high word of result)
/	divide (returns quotient)
//	divide (returns remainder)
min	keep variable greater than or equal to value
max	keep variable less than or equal to value
&	logical AND
|	logical OR
^	logical XOR
&/	logical AND NOT
|/	logical OR NOT
^/	logical XOR NOT

Some examples:

```
count = count + 1           'Increment count
timer = timer * 2           'Multiply timer by 2
b2 = b2 / 8                 'Divide b2 by 8
w3 = w3 & 255               'Isolate lower byte of w3
b0 = b0 + 1 max 99          'Increment b0, but don't
                            'allow b0 to exceed 99
b3 = b3 - 1 min 10          'Decrement b3, but don't
                            'allow b3 to drop below 10
```

Entering & Editing Programs

As covered in the previous pages, there are some rules to remember about the use of constants, labels, and comments. However, for the most part, you can format your programs as you see fit.

We've tried to make the editor as intuitive as possible: to move up, press the *up arrow*; to highlight one character to the right, press *shift-right arrow*; etc.

Most functions of the editor are easy to use. Using single keystrokes, you can perform the following common functions:

- Load, save, and run programs.
- Move the cursor in increments of one character, one word, one line, one screen, or to the beginning or end of a file.
- Highlight text in blocks of one character, one word, one line, one screen, or to the beginning or end of a file.
- Cut, copy, and paste highlighted text.
- Search for and / or replace text.

Editor Function Keys

The following list shows the keys that are used to perform various functions:

Alt-R	Run program in BASIC Stamp *(download the program on the screen, then run it)*
Alt-L	Load program from disk
Alt-S	Save program on disk
Alt-Q	Quit editor and return to DOS
Enter	Enter information and move down one line
Tab	Same as Enter
Left arrow	Move left one character
Right arrow	Move right one character

Up arrow	Move up one line
Down arrow	Move down one line
Ctrl-Left	Move left to next word
Ctrl-Right	Move right to next word
Home	Move to beginning of line
End	Move to end of line
Page Up	Move up one screen
Page Down	Move down one screen
Ctrl-Page Up	Move to beginning of file
Ctrl-Page Down	Move to end of file
Shift-Left	Highlight one character to the left
Shift-Right	Highlight one character to the right
Shift-Up	Highlight one line up
Shift-Down	Highlight one line down
Shift-Ctrl-Left	Highlight one word to the left
Shift-Ctrl-Right	Highlight one word to the right
Shift-Home	Highlight to beginning of line
Shift-End	Highlight to end of line
Shift-Page Up	Highlight one screen up
Shift-Page Down	Highlight one screen down
Shift-Ctrl-Page Up	Highlight to beginning of file
Shift-Ctrl-Page Down	Highlight to end of file
Shift-Insert	Highlight word at cursor
ESC	Cancel highlighted text
Backspace	Delete one character to the left
Delete	Delete character at cursor
Shift-Backspace	Delete from left character to beginning of line
Shift-Delete	Delete to end of line
Ctrl-Backspace	Delete line
Alt-X	Cut marked text and place in clipboard
Alt-C	Copy marked text to clipboard
Alt-V	Paste (insert) clipboard text at cursor
Alt-F	Find string (establish search information)
Alt-N	Find next occurrence of string
Alt-P	Calibrate potentiometer scale *(see POT instruction for more information)*

Running Your Program

To run the program shown on the screen, press Alt-R. The editor software will check all available parallel ports, searching for a BASIC Stamp. If it finds one, it will download and run your program. Note that any program already in the BASIC Stamp will be overwritten. If the editor is unable to locate a BASIC Stamp, it will display an error.

Assuming that you have a BASIC Stamp properly connected to your PC, the editor will display a bargraph, which shows how the download of your program is progressing. Typical downloads take only several seconds, so the graph will fill quickly.

As the graph fills, you'll notice that some of the graph fills with white blocks, while the remainder fills with red blocks. These colors represent how much of the BASIC Stamp's EEPROM space is used by the program. White represents available space, and red represents space occupied by the program.

When the download is complete, your program will automatically start running in the BASIC Stamp. If you used the debug directive in your program, it will display its data when it's encountered in the program.

To remove the download graph from the screen, press any key.

Loading a Program from Disk

To load a PBASIC program from disk, press Alt-L. A small box will appear, prompting you for a filename. If you entered the filename correctly, the program will be loaded into the editor. Otherwise, an error message will be displayed.

If you decide not to load a program, press ESC to resume editing.

Saving a Program on Disk

To save a PBASIC program on disk, press Alt-S. A small box will appear, prompting you for a filename. After the filename is entered, the editor will save your program.

Using Cut, Copy, and Paste

Like most word processors, the editor can easily cut, copy, and paste text. If you need to make major changes to your program, or your program has many repetitive routines, these functions can save a lot of time.

The function of the cut, copy, and paste routines is to cut or copy highlighted text to the *clipboard* (the clipboard is an area of memory set aside by the editor). Text in the clipboard can later be pasted (inserted) anywhere in your program. Both *cut* and *paste* copy text to the clipboard, but *cut* also removes the text from its current location.

Please note that *cutting* text is different from *deleting* it. While both functions remove text from its current location, only *cut* saves the text to the clipboard – *delete* removes it entirely.

As an example of cut and paste, let's cut a section of text and then paste it elsewhere. The following steps will guide you through the process:

- First, you need to **highlight some text**. For this example, let's highlight everything from the cursor to the end of the line. To do this, press Shift-End (everything from the cursor to the end of the line should become highlighted).
- Second, with the line highlighted, **press Alt-X** (cut). The text should disappear.
- Third, move the cursor to another location – anywhere is fine. Then, **press Alt-V** (paste). The text should appear where the cursor was, pushing any following text down as necessary.

The first step could be replaced with copy (Alt-C), instead of cut (Alt-X). The only difference would be that the text would appear in its original location, as well as the pasted location.

Using Search & Replace

The editor has a function that allows you to search for and / or replace text. In many instances, this function can be very useful. For example, you may decide to change a variable name throughout your program. Doing so manually would take a lot of time, but with search and replace, it takes just seconds.

To set the search criteria, **press Alt-F** (find). A small box will appear in the center of the screen, requesting a search string and an optional replacement string. To perform the search, follow these steps:

- **Enter the search string**. If you want to search for a string that contains the *Tab* or *Return* keys, you can do so by typing *Ctrl-Tab* or *Ctrl-Return*; "•" will appear for each tab, "↓" for each return.
- **Enter the replacement string, if necessary**. If you enter a replacement string, it will be copied to the *clipboard* (the clipboard is an area of memory set aside by the editor). During the search, you will have the option to replace individual occurrences of the search string with the replacement string.

  If you only want to search (without the option to replace), just press *Enter* for the replacement string.
- The editor will remove the search criteria box and highlight the **first occurrence** of the search string.

  To replace the highlighted string with the replacement string, press Alt-V (paste).

  To find the next occurrence of the search string, **press Alt-N**.

BRANCHING

IF...THEN	*Compare and conditionally branch.*
BRANCH	*Branch to address specified by offset.*
GOTO	*Branch to address.*
GOSUB	*Branch to subroutine at address. Up to 16 GOSUB's are allowed.*
RETURN	*Return from subroutine.*

LOOPING

FOR...NEXT	*Establish a FOR...NEXT loop.*

NUMERICS

{LET}	*Perform variable manipulation, such as A=5, B=A+2, etc. Possible operations are add, subtract, multiply, divide, max. limit, min. limit, and logical operations AND, OR, XOR, AND NOT, OR NOT, and XOR NOT.*
LOOKUP	*Lookup data specified by offset and store in variable. This instruction provides a means to make a lookup table.*
LOOKDOWN	*Find target's match number (0-N) and store in variable.*
RANDOM	*Generate a pseudo-random number.*

DIGITAL I/O

OUTPUT	*Make pin an output.*
LOW	*Make pin output low.*
HIGH	*Make pin output high.*
TOGGLE	*Make pin an output and toggle state.*
PULSOUT	*Output a timed pulse by inverting a pin for some time.*
INPUT	*Make pin an input*
PULSIN	*Measure an input pulse.*
REVERSE	*If pin is an output, make it an input. If pin is an input, make it an output.*
BUTTON	*Debounce button, perform auto-repeat, and branch to address if button is in target state.*

SERIAL I/O

SERIN	*Serial input with optional qualifiers and variables for storage of received data. If qualifiers are given, then the instruction will wait until they are received before filling variables or continuing to the next instruction. Baud rates of 300, 600, 1200, and 2400 are possible. Data received must be with no parity, 8 data bits, and 1 stop bit.*
SEROUT	*Send data serially. Data is sent at 300, 600, 1200, or 2400 baud, with no parity, 8 data bits, and 1 stop bit.*

ANALOG I/O

PWM	*Output PWM, then return pin to input. Used to output analog voltages (0-5V) using a capacitor and resistor.*
POT	*Read a 5-50K potentiometer and scale result.*

SOUND

SOUND	*Play notes. Note 0 is silence, notes 1-127 are ascending tones, and notes 128-255 are white noises.*

EEPROM ACCESS

EEPROM	*Store data in EEPROM before downloading BASIC program.*
READ	*Read EEPROM byte into variable.*
WRITE	*Write byte into EEPROM.*

TIME

PAUSE	*Pause execution for 0–65536 milliseconds.*

POWER CONTROL

NAP	*Nap for a short period. Power consumption is reduced.*
SLEEP	*Sleep for 1-65535 seconds. Power consumption is reduced to approximately 20 µA.*
END	*Sleep until the power cycles or the PC connects. Power consumption is reduced to approximately 20 µA.*

PROGRAM DEBUGGING

DEBUG	*Send variables to PC for viewing.*

BRANCH offset,(address0,address1,...addressN)

Go to the address specified by offset (if in range).

- **Offset** is a variable / constant that specifies the address to branch to (0–N).
- **Addresses** are labels that specify where to branch.

Branch works like the ON x GOTO command found in other BASICs. It's useful when you want to write something like this:

```
if b2 = 0 then case_0  ' b2=0: go to label "case_0"
if b2 = 1 then case_1  ' b2=1: go to label "case_1"
if b2 = 2 then case_2  ' b2=2: go to label "case_2"
```

You can use Branch to organize this into a single statement:

```
BRANCH b2,(case_0,case_1,case_2)
```

This works exactly the same as the previous IF...THEN example. If the value isn't in range (in this case if b2 is greater than 2), Branch does nothing. The program continues with the next instruction after Branch.

Branch can be teamed with the Lookdown instruction to create a simplified SELECT CASE statement. See Lookdown for an example.

Sample Program:

```
Get_code:
    serin 0,N2400,("code"),b2           ' Get serial input.
                                        ' Wait for the string "code",
                                        ' then put next value into b2.
    BRANCH b2,(case_0,case_1,case_2)    ' If b2=0 then case_0
                                        ' If b2=1 then case_1
                                        ' If b2=2 then case_2
goto Get_code                           ' If b2>2 then Get_code.

    case_0:         ...                 ' Destinations of the
    case_1:         ...                 ' Branch instruction.
    case_2:         ...
```

BUTTON pin,downstate,delay,rate,bytevariable,targetstate,address

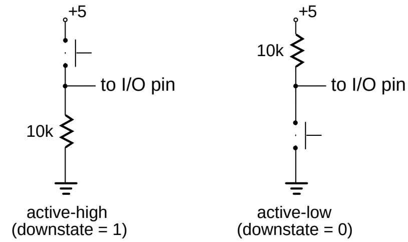
Debounce button input, perform auto-repeat, and branch to address if button is in target state. Button circuits may be active-low or active-high (see the diagram on the next page).

- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.
- **Downstate** is a variable / constant (0 or 1) that specifies which logical state is read when the button is pressed.
- **Delay** is a variable / constant (0–255) that specifies how long the button must be pressed before auto-repeat starts. The delay is measured in cycles of the Button routine. Delay has two special settings: 0 and 255. If set to 0, the routine returns the button state with no debounce or auto-repeat. If set to 255, the routine performs debounce, but no auto-repeat.
- **Rate** is a variable / constant (0–255) that specifies the auto-repeat rate. The rate is expressed in cycles of the Button routine.
- **Bytevariable** is the workspace for Button. It must be cleared to 0 before being used by Button for the first time.
- **Targetstate** is a variable / constant (0 or 1) that specifies which state the button should be in for a branch to occur (0=not pressed, 1=pressed).
- **Address** is a label that specifies where to branch if the button is in the target state.

When you press a button or flip a switch, the contacts make or break a connection. A burst of electrical noise occurs as the contacts bounce against each other. Button's debounce feature prevents this noise from being interpreted as more than one switch action.

Button also lets the Stamp react to a button press the way your PC keyboard does to a key press. When you press a key, a character appears on the screen. If you hold the key down, there's a delay, then a rapid-fire stream of characters appears on the screen. Button's autorepeat function can be set up to work the same way.

Button is designed to be used inside a program loop. Each time through the loop, Button checks the state of the specified pin. When it first matches *downstate*, Button debounces the switch. Then, in accordance with *targetstate*, it either branches to *address* (targetstate = 1) or doesn't (targetstate = 0).



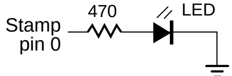
Example button circuits.

If the switch is kept in *downstate*, Button tracks the number of program loops that execute. When this count equals *delay*, Button again triggers the action specifed by *targetstate* and *address*. Hereafter, if the switch remains in *downstate*, Button waits *rate* number of cycles between actions.

The important thing to remember about Button is that it does not stop program execution. In order for its delay and autorepeat functions to work, Button must execute from within a loop.

Sample Program:

```
' This program toggles (inverts) the state of an LED on pin 0 when the
' active-low switch on pin 7 is pressed. When the switch is held down, Button
' waits, then rapidly autorepeats the Toggle instruction, making the LED
' flash rapidly. When the switch is not pressed, Button skips the Toggle
' instruction. Note that b2, the workspace variable for Button, is cleared
' before its first use. Don't clear it within the loop.

        let b2 = 0                              ' Button workspace cleared.
Loop:
        BUTTON 7,0,200,100,b2,0,skip            ' Go to skip unless pin7=0.
        Toggle 0                                ' Invert LED.
        ...                                     ' Other instructions.
skip:
        goto Loop                               ' Skip toggle and go to Loop.
```



LED hookup for sample program.

DEBUG variable{,variable}

Displays the specified variable (bit, byte, or word) in a window on the screen of a connected PC. Debug works only after a "run" (ALT-R) download has finished.

Debug accepts formatting modifiers as follows:

- No modifiers: prints "variable = value"
- # before variable, as in #b2, prints the decimal value, without the "variable =" text.
- $ before variable, as in $b2, prints hex value.
- % before variable, as in %b2, prints binary value.
- @ before variable, as in @b2, prints the ASCII character corresponding to the value of the variable.
- Text in quotes appears as typed.
- cr (carriage return) causes printing in the Debug window to start a new line.
- cls (clear screen) clears the Debug window.
- commas must separate all variables used with Debug.

Samples:

```
DEBUG b2                    ' Print "b2 = " + value of b2
DEBUG #b2                   ' Print value of b2
DEBUG "reading is ",b2      ' Print "reading is " & value of b2
DEBUG #%b2                  ' Print value of b2 in binary
DEBUG #@b2                  ' Display the ASCII character
                            ' corresponding to the value in b2.
DEBUG "inputs ",b2,b3,cr    ' Print "inputs" & value of b2 & value
                            ' of b3 & carriage return.
```

EEPROM {location},(data,data,...)

Store values in EEPROM before downloading the BASIC program.

- **Location** is an optional variable/constant (0–255) that specifies the starting location in the EEPROM at which data should be stored. If no location is given, data is written starting at the next available location.
- **Data** are variables/constants (0–255) to be stored sequentially in the EEPROM.

EEPROM is useful for storing values to be used by your program. One application is to store long messages for use by Serout as shown below:

Program Sample 1:

```
' Sends the text "A very long message indeed..." then reads address 255 for
' the last instruction location of the program.
        serout 0,N2400,("A very long message indeed...")
        read 255,b2               ' Get last program location (reflects length of program)
        debug b2                  ' Display it on the screen.
```

Program Sample 2:

```
' Sends the text "A very long message indeed..." then reads address 255 for
' the last instruction location of the program.
        EEPROM 0,("A very long message indeed...")
        for b2 = 0 to 28          ' Send message 1 char at a time.
        read b2,b3                ' Read data at location b2 of
        serout 0,N2400,(b3)       ' EEPROM into b3. Transmit b3.
        next                      ' Send next character.
        read 255,b2               ' Get last program location (reflects length of program)
        debug b2                  ' Display it on the screen.
```

The first program sample shows an endpoint of 197, meaning that it uses 58 bytes of program memory to send the 29-byte message. Sample 2 has an endpoint of 232 (23 bytes of program memory used). When you add 29 bytes for the storage of the message, sample 2 is 6 bytes more efficient. The savings are greater when the messages are used at several points in a program.

END

Enter sleep mode indefinitely. The Stamp wakes up when the power cycles or the PC connects. Power consumption is reduced to about 20 µA, assuming no loads are being driven.

If you do leave Stamp pins in an output-high or output-low state driving loads when End executes, two things will happen:

- The loads will continue to draw current from the Stamp's power supply.
- Every 2.3 seconds, current to those loads will be interrupted for a period of approximately 18 milliseconds (ms).

The reason for the output glitch every 2.3 seconds has to do with the design of the PBASIC interpreter chip. It has a free-running clock called the "watchdog timer" that can periodically reset the processor, causing a sleeping Stamp to wake up. Once awake, the Stamp checks its program to determine whether it should remain awake or go back to sleep. After an End instruction, the Stamp has standing orders to go back to sleep.

Unfortunately, the watchdog timer cannot be shut off, so the Stamp actually gets its sleep as a series of 2.3-second naps. At the end of each nap, the watchdog timer resets the PBASIC chip. Among other things, a reset causes all of the chip's pins to go into input mode. It takes approximately 18 ms for the PBASIC firmware to get control, restore the pins to their former state, and put the Stamp back to sleep.

If you use End, Nap, or Sleep in your programs, make sure that your loads can tolerate these periodic power outages. The easy solution is often to connect pull-up or pull-down resistors as appropriate to ensure a continuing supply of current during the reset glitch.

FOR variable = start TO end {STEP {-} increment}...NEXT {variable}

Establish a For...Next loop. *Variable* is set to the value *start*. Code between the For and Next instructions is then executed. *Variable* is then incremented / decremented by *increment* (if no increment value is given, the variable is incremented by 1). If *variable* has not reached or passed the value *end*, the instructions between For and Next are executed again. If *variable* has reached or passed *end*, then the program continues with the instruction after Next. The loop is executed at least once, no matter what values are given for *start* and *end*.

Your program can have as many For...Next loops as necessary, but they cannot be nested more than eight deep (in other words, your program can't have more than eight loops within loops).

- **Variable** is a bit, byte, or word variable used as an internal counter. *Start* and *end* are limited by the capacity of *variable* (bit variables can count from 0 to 1, byte variables from 0 to 255, and word variables from 0 to 65535).
- **Start** is a variable / constant which specifies the initial value of *variable*.
- **End** is a variable / constant which specifies the ending value of *variable*.
- **Increment** is an optional variable / constant by which the counter increments or decrements (if negative). If no step value is given, the variable increments by 1.
- **Variable** (after Next) is optional. It is used to clarify which of a series of For...Next loops a particular Next refers to.

Program Samples:

Programmers most often use For...Next loops to repeat an action a fixed number of times, like this:

```
FOR b2 = 1 to 10                    ' Repeat 10 times.
  debug b2                          ' Show b2 in debug window.
NEXT                                ' Again until b2>10.
```

Don't overlook the fact that all of the parameters of a For...Next loop can be variables. Not only can your program establish these values itself, it can also modify them while the loop is running. Here's an example in which the step value increases with each loop:

```
let b3 = 1
FOR b2 = 1 to 100 STEP b3          ' Each loop, add b3 to b2.
debug b2                           ' Show b2 in debug window.
let b3 = b3+2                      ' Increment b3.
NEXT                               ' Again until b2>15.
```

If you run this program, you may notice something familiar about the numbers in the debug window (1,4,9,16,25,36,49...). They are all squares (1^2=1, 2^2=4, 3^2=9, 4^2=16, etc.), but our program used addition, not multiplication, to calculate them. This method of generating a polynomial function is credited to Sir Isaac Newton.

There is a potential bug in the For...Next structure. PBASIC uses 16-bit integer math to increment / decrement the counter variable and compare it to the *end* value. The maximum value a 16-bit variable can hold is 65535. If you add 1 to 65535, you get 0 (the 16-bit register rolls over, much like a car's odometer does when you exceed the maximum mileage it can display).

If you write a For...Next loop whose *step* value is larger than the difference between the *end* value and 65535, this rollover will cause the loop to execute more times than you expect. Try the following:

```
FOR w1 = 0 to 65500 STEP 3000      ' Each loop add 3000 to w1.
  debug w1                         ' Show w1 in debug window.
NEXT                               ' Again until w1>65500.
```

The value of w1 increases by 3000 each trip through the loop. As it approaches the stop value, an interesting thing happens: 57000, 60000, 63000, 464, 3464... It passes the *end* value and keeps going. That's because the result of the calculation 63000 + 3000 exceeds the maximum capacity of a 16-bit number. When the value rolls over to 464, it passes the test "is w1 > 65500?" used by Next to determine when to end the loop.

The same problem can occur when the step value is negative and larger (in absolute value) than the difference between the *end* value and 0.

GOSUB address

Store the address of the instruction following Gosub, branch to *address*, and continue execution there. The next Return instruction takes the program back to the stored address, continuing the program on the instruction following the most recent Gosub.

- **Address** is a label that specifies where to branch. Up to 16 GOSUBs are allowed per program. Up to 4 nested GOSUBs are allowed.

PBASIC stores data related to Gosubs in variable w6. Make sure that your program does not write to w6 unless all Gosubs have Returned, and don't expect data written to w6 to be intact after a Gosub.

If a series of instructions is used at more than one point in your program, you can turn those instructions into a subroutine. Then, wherever you would have inserted that code, you can simply write Gosub *label* (where *label* is the name of your subroutine).

Sample Program:

```
' In this program, the subroutine test takes a pot measurement, then performs
' a weighted average by adding 1/4 of the current measurement to 3/4 of a
' previous measurement. This has the effect of smoothing out noise.
      for b0 = 1 to 10
      GOSUB test              ' Save this address & go to test.
      serout 1,N2400,(b2)     ' Return here after test.
      next                    ' Again until b0 > 10.
      end                     ' Prevents program from running into test.
test:
      pot 0,100,b2            ' Take a pot reading.
      let b2 = b2/4 + b4      ' Make b2 = (.25*b2)+b4.
      let b4 = b2 * 3 / 4     ' Make b4 = .75*b2.
return                        ' Return to previous address+1 instruction.
```

The Return instruction at the end of *test* sends the program to the instruction immediately following Gosub *test*; in this case Serout.

Make sure that your program cannot wander into a subroutine without Gosub. In the sample, what if End were removed? After the loop , execution would continue in *test*. When it reached Return, the program would jump back into the the For...Next loop at Serout because this was the last return address assigned. The For...Next loop would execute forever.

GOTO address

Branch to *address*, at which point execution continues.

- **Address** is a label that specifies where to branch.

Sample Program:

```
abc:
        pulsout 0,100           ' Generate a 1000-µs pulse on pin 0.
        GOTO abc                ' Repeat forever.
```

HIGH pin

Make the specified pin output high. If the pin is programmed as an input, it changes to an output.

- **Pin** is a variable/constant (0–7) that specifies the I/O pin.

You can think of the High instruction as the equivalent of:

```
output 3            ' Make pin 3 an output.
let pin3 = 1        ' Set pin 3 high.
```


Notice that the Output command accepts the pin number (3), while Let requires the pin's variable name *pin3*. So, in addition to saving one instruction, High allows you to make a pin output-high using only its number. When you look at the sample program below, imagine how difficult it would be to write it using Output and Let.

This points out a common bug involving High. Programmers sometimes substitute pin names like *pin3* for the pin number. Remember that those pin names are really bit variables. As bits, they can hold values of 0 or 1. The statement "High pin3" is a valid BASIC instruction, but it means, "Get the state of *pin3*. If *pin3* is 0, make *pin 0* output high. If *pin3* is 1, make *pin 1* output high."

Sample Program:

```
' One at a time, change each of the pins to output and set it high.
    for b2 = 0 to 7         ' Eight pins (0-7).
    HIGH b2                 ' Set pin no. indicated by b2.
    pause 500               ' Wait 1/2 second between pins.
    next                    ' Do the next pin.
```

IF variable ?? value {AND/OR variable ?? value...} THEN address

Compare variable(s) to value(s) and branch if result is true.

- **??** is one of the following operators: = (equal), <> (not equal), > (greater than), < (less than), >= (greater than or equal to), <= (less than or equal to)
- **Variable** is a variable that is compared to value(s)
- **Value** is a variable or constant for comparison
- **Address** is a label that specifies where to branch if the result of the comparison(s) is true

Unlike those in some other flavors of BASIC, this If...Then statement can only go to an address label. It does not support statements like "IF x > 30 THEN x = 0." To do the same thing neatly in PBASIC requires a little backwards thinking:

```
IF x <= 30 THEN skip          ' If x is less than or equal
let x = 0                     ' to 30, don't make x=0.
skip: ...                     ' Program continues.
```

Unless x > 30, the program skips over the instruction "let x = 0."

PBASIC's If...Then can evaluate two or more comparisons at one time with the conjunctions *And* and *Or*. It works from left to right, and does not accept parentheses to change the order of evaluation. It can be tricky to anticipate the outcome of compound comparisons. We suggest that you set up a test of your logic using debug as shown in the sample program below.

Sample Program:

```
' Evaluates the If...Then statement and displays the result in a debug window.
    let b2 = 7                          ' Assign values.
    let b3 = 16
    IF b3 < b2 OR b2 = 7 THEN True      ' B3 is not less than b2, but
                                        ' b2 is 7: so statement is true.
    debug "statment is false"           ' If statement is false, goto here.
end
True:
    debug "statement is true"           ' If statement is true, goto here.
end
```

INPUT pin

Make the specified pin an input. This turns off the pin's output drivers, allowing your program to read whatever state is present on the pin from the outside world.

- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.

There are several ways to set pins to input. When a program begins, all of the Stamp's pins are inputs. Input instructions (Pulsin, Serin) automatically change the specified pin to input and leave it in that state. Writing 0s to particular bits of the variable *dirs* makes the corresponding pins inputs. And then there's the Input instruction.

When a pin is set to input, your program can check its state by reading its value. For example:

```
Hold:     if pin4 = 0 then Hold          ' Stay here until pin4 is 1.
```

The program is reading the state of pin 4 as set by external circuitry. If nothing is connected to pin 4, it could be in either state (1 or 0) and could change states apparently at random.

What happens if your program writes to a pin that is set up as an input? The state is written to the output latch assigned to the pin. Since the output drivers are disconnected when a pin is an input, this has no effect. If the pin is changed to output, the last value written to the latch will appear on the pin. The program below shows how this works.

Sample Program:

```
' To see this program in action, connect a 10k resistor from pin 7 to +5V.
' When the program runs, a debug window will show you the state at pin 7
' (a 1, due to the +5 connection); the effect of writing to an input pin (none);
'  and the result of changing an input pin to output (the latched state appears
' on the pin and may be read by your program). Finally, the program shows
' how changing pin 7 to output writes a 1 to the corresponding bit of dirs.
    INPUT 7                               ' Make pin 7 an input.
    debug "State present at pin 7: ",#pin7,cr,cr
    let pin7 = 0                          ' Write 0 to output latch.
    debug  "After 0 written to input: ",#pin7,cr,cr
    output 7                              ' Make pin 7 an output.
    debug  "After pin 7 changed to output: ",#pin7,cr
    debug "Dirs (binary): ",#%dirs        ' Show contents of dirs.
```

{LET} variable = {-}value ?? value...

Assign a value to the variable and / or perform logic operations on the variable. All math and logic is done at the word level (16 bits).

The instruction “Let” is optional. For instance, “A=10” is identical to “Let A=10”.

- **??** is one of the following operators:

+	add
–	subtract
*	multiply (returns low word of result)
**	multiply (returns high word of result)
/	divide (returns quotient)
//	divide (returns remainder)
min	keep variable greater than or equal to value
max	keep variable less than or equal to value
&	logical AND
|	logical OR
^	logical XOR
&/	logical AND NOT
|/	logical OR NOT
^/	logical XOR NOT

- **Variable** is assigned a value and / or manipulated.
- **Value(s)** is a variable / constant which affects the variable.

When you write programs that perform math, bear in mind the limitations of PBASIC’s variables: all are positive integers; bits can represent 0 or 1; bytes, 0 to 255; and words, 0 to 65535. PBASIC doesn’t understand floating-point numbers (like 3.14), negative numbers (–73), or numbers larger than 65535.

In most control applications, these are not serious limitations. For example, suppose you needed to measure temperatures from -50° to +200°F. By assigning a value of 0 to –50° and 65535 to +200° you would have a resolution of 0.0038°!

The integer restriction doesn’t mean you can’t do advanced math with the Stamp. You just have to improvise . Suppose you needed to use the constant þ (3.14159...) in a program. You would like to write:

```
Let w0 = b2 * 3.14
```

However, the number “3.14” is a floating-point number, which the Stamp doesn’t understand. There is an alternative. You can express such quantities as fractions. Take the value 1.5. It is equivalent to the fraction 3/2. With a little effort you can find fractional substitutes for most floating-point values. For instance, it turns out that the fraction 22/7 comes very close to the value of þ. To perform the calculation *Let w0 = b2 * 3.14*, the following instruction will do the trick:

```
Let w0 = b2 * 22 / 7
```


PBASIC works out problems from left to right. You cannot use parentheses to alter this order as you can in some other BASICs. And there is no “precedence of operators” that (for instance) causes multiplication to be done before addition. Many BASICs would evaluate the expression “2+3*4” as 14, because they would calculate “3*4” first, then add 2. PBASIC, working from left to right, evaluates the expression as 20, since it calculates “2+3” and multiplies the result by 4. When in doubt, work up an example problem and use debug to show you the result.

Sample Program:

```
pot 0,100,b3          ' Read pot, store result in b3.
LET b3=b3/2           ' Divide result by 2.
b3=b3 max 100         ' Limit result to 0-100.
                      ' Note that "LET" is not necessary.
```

LOOKDOWN target,(value0,value1,...valueN),variable

Search *value(s)* for *target* value. If target matches one of the values, store the matching value's position (0–N) in *variable*.

If no match is found, then the variable is unaffected.

- **Target** is the variable/constant being sought.
- **Value0, value1,...** is a list of values. The target value is compared to these values
- **Variable** holds the result of the search.

Lookdown's ability to convert an arbitrary sequence of values into an orderly sequence (0,1,2...) makes it a perfect partner for Branch. Using Lookdown and Branch together, you can create a SELECT CASE statement.

Sample Program:

```
' Program receives the following one-letter instructions over a serial
' linkand takes action: (G)o, (S)top, (L)ow, (M)edium, (H)igh.
Get_cmd: serin 0,N2400,b2 ' Put input value into b2.
        LOOKDOWN b2,("GSLMH"),b2            ' If b2="G" then b2=0 (see note)
                                            ' If b2="S" then b2=1
                                            ' If b2="L" then b2=2
                                            ' If b2="M" then b2=3
                                            ' If b2="H" then b2=4
        branch b2,(go,stop,low,med,hi)      ' If b2=0 then go
                                            ' If b2=1 then stop
                                            ' If b2=2 then low
                                            ' If b2=3 then med
                                            ' If b2=3 then hi
goto Get_cmd                                ' Not in range; try again.
go:   ...                     ' Destinations of the
stop: ...                     ' Branch instruction.
low:  ...
med:  ...
hi:        ...
' Note: In PBASIC instructions, including EEPROM, Serout, Lookup and
' Lookdown, strings may be formatted several ways. The Lookdown command
' above could also have been written:
'       LOOKDOWN b2,(71,83,76,77,72),b2     ' ASCII codes for "G","S","L"...
' or
'       LOOKDOWN b2,("G","S","L","M","H"),b2
```

LOOKUP offset,(value0,value1,...valueN),variable

Look up data specified by *offset* and store it in *variable*. For instance, if the values were 2, 13, 15, 28, 8 and *offset* was 1, then *variable* would get the value “13”, since “13” is the second value in the list (the first value is #0, the second is #1, etc.). If *offset* is beyond the number of values given, then *variable* is unaffected.

- **Offset** specifies the index number of the value to be looked up.
- **Value0, value1,...** is a table of values, up to 256 elements in width.
- **Variable** holds the result of the lookup.

Many applications require the computer to calculate an output value based on an input value. When the relationship is simple, like “out = 2*in”, it’s no problem at all. But what about relationships that are not so obvious? In PBASIC you can use Lookup.

For example, stepper motors work in an odd way. They require a changing pattern of 1s and 0s controlling current to four coils. The sequence appears in the table to the right.

Repeating that sequence makes the motor turn. The program below shows how to use a Lookup table to generate the sequence.

Step#	Binary	Decimal
0	1010	10
1	1001	9
2	0101	5
3	0110	6

Sample Program:

```
' Output the four-step sequence to drive a stepper motor w/on-screen simula-
tion.
        let dirs = %00001111                    ' Set lower 4 pins to output.
Rotate:
        for b2 = 0 to 3
          LOOKUP b2,(10,9,5,6),b3               ' Convert offset (0-3)
                                                ' to corresponding step.
         let pins = b3                          ' Output the step pattern.
          LOOKUP b2,("|/-\"),b3                 ' Convert offset (0-3)
                                                ' to "picture" for debug.
          debug cls,#%pins,"  ",#@b3            ' Display value on pins,
        next                                    ' animated "motor."
goto Rotate                                     ' Do it again.

' Note: In the debug line above, there are two spaces between the quotes.
```

LOW pin

Make the specified pin output low. If the pin is programmed as an input, it changes to an output.

- **Pin** is a variable/constant (0–7) that specifies the I/O pin to use.

You can think of the Low instruction as the equivalent of:

```
output 3            ' Make pin 3 an output.
let pin3 = 0        ' Make pin 3 low.
```

Notice that the Output command accepts the pin number (3), while Let requires the pin's variable name *pin3*. So, in addition to saving one instruction, Low allows you to make a pin output-low using only its number. When you look at the sample program below, imagine how difficult it would be to write it using Output and Let.

This also points out a common bug involving Low. Programmers sometimes substitute pin names like *pin3* for the pin number. Remember that those pin names are really bit variables. As bits, they can hold values of 0 or 1. The statement "Low pin3" is a valid PBASIC instruction, but it means, "Get the state of *pin3*. If *pin3* is 0, make *pin 0* output low. If *pin3* is 1, make *pin 1* output low."

Sample Program:

```
' One at a time, change each of the pins to output and make it low.
    for b2 = 0 to 7         ' Eight pins (0-7).
    LOW b2                  ' Clear pin no. indicated by b2.
    pause 500               ' Wait 1/2 second between pins.
    next                    ' Do the next pin.
```

NAP period

Enter sleep mode for a short period. Power consumption is reduced to about 20 µA, assuming no loads are being driven.

- **Period** is a variable/constant which determines the duration of the reduced power nap. The duration is (2^period) * approximately 18 ms. *Period* can range from 0 to 7, resulting in the nap lengths shown in the table.

Period	2^{period}	Nap Length
0	1	18 ms
1	2	36 ms
2	4	72 ms
3	8	144 ms
4	16	288 ms
5	32	576 ms
6	64	1152 ms
7	128	2304 ms

Nap uses the same shutdown/startup mechanism as Sleep, with one big difference. During sleep, the Stamp compensates for variations in the speed of the watchdog timer that serves as its alarm clock. As a result, longer sleep intervals are accurate to about ±1 percent. Naps are controlled by the watchdog timer without compensation. Variations in temperature, voltage, and manufacturing of the PBASIC chip can cause the actual timing to vary by as much as –50, +100 percent (i.e., a period-0 nap can range from 9 to 36 ms).

If your Stamp application is driving loads (sourcing or sinking current through output-high or output-low pins) during a nap, current will be interrupted for about 18 ms when the Stamp wakes up. The reason is that the reset that awakens the Stamp also switches all of the pins input mode for about 18 ms. When PBASIC regains control, it restores the I/O direction dictated by your program.

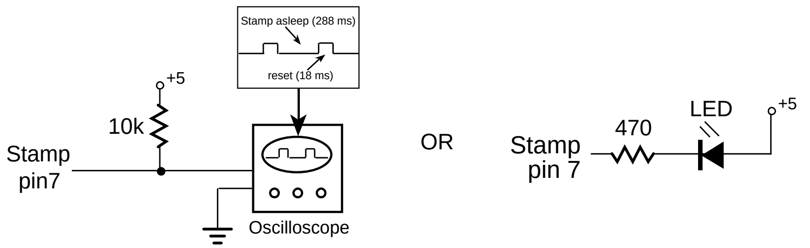
When you use End, Nap, or Sleep, make sure that your loads can tolerate these glitches. The simplest way is often to connect resistors high or low (to +5V or ground) as appropriate to ensure a continuing supply of current during reset.

The sample program on the next page can be used to demonstrate the effects of the nap glitch with either an LED and resistor, or an oscilloscope, as shown in the diagram.

Sample Program:

```
' During the Nap period, the Stamp will continue to drive loads connected to
```

```
' pins that are configured as outputs. However, at the end of a Nap, all pins
' briefly change to input, interrupting the current. This program may be
' used to demonstrate the effect.

        low 7                   ' Make pin 7 output-low.
Again:
        NAP 4                   ' Put the Stamp to sleep for 288 ms.
goto Again                      ' Nap some more.
```



OUTPUT pin

Make the specified pin an output.

- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.

When a program begins, all of the Stamp's pins are inputs. If you want to drive a load, like an LED or logic circuit, you must configure the appropriate pin as an output.

Output instructions (High, Low, Pulsout, Serout, Sound and Toggle) automatically change the specified pin to output and leave it in that state. Although not technically an output instruction, Pot also changes a pin to output. Writing 1s to particular bits of the variable *Dirs* causes the corresponding pins to become outputs. And then there's Output.

When a pin is configured as an output, you can change its state by writing a value to it, or to the variable *Pins*. When a pin is changed to output, it may be a 1 or a 0, depending on values previously written to the pin. To guarantee which state a pin will be in, either use the High or Low instructions to change it to output, or write the appropriate value to it immediately before switching to output.

Sample Program:

```
' To see this program in action, connect a 10k resistor from pin 7 to the +5
' power-supply rail. When the program runs, a debug window will show you the
' the state at pin 7 (a 1, due to the +5 connection); the effect of writing
' to an input pin (none); and the result of changing an input pin to output
' (the latched state appears on the pin and may be read by your program).
' Finally, the program will show how changing pin 7 to output wrote
' a 1 to the corresponding bit of the variable Dirs.

    input 7                                 ' Make pin 7 an input.
    debug "State present at pin 7: ",#pin7,cr,cr
    let pin7 = 0                            ' Write 0 to output latch.
    debug  "After 0 written to input: ",#pin7,cr,cr
    OUTPUT 7                                ' Make pin 7 an output.
    debug  "After pin 7 changed to output: ",#pin7,cr
    debug "Dirs (binary): ",#%dirs
```

PAUSE milliseconds

Pause program execution for the specified number of milliseconds.

- **Milliseconds** is a variable/constant (0–65535) that specifies how many milliseconds to pause.

The delays produced by the Pause instruction are as accurate as the Stamp's ceramic resonator timebase, ±1 percent. When you use Pause in timing-critical applications, keep in mind the relatively low speed of the BASIC interpreter (about 2000 instructions per second). This is the time required for the PBASIC chip to read and interpret an instruction stored in the EEPROM.

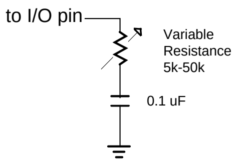
Since the PBASIC chip takes 0.5 milliseconds to read in the Pause instruction, and 0.5 milliseconds to read in the instruction following it, you can count on loops involving Pause taking at least 1 millisecond longer than the Pause period itself. If you're programming timing loops of fairly long duration, keep this (and the 1-percent tolerance of the timebase) in mind.

Sample Program:

```
abc:
        low 2                   ' Make pin 2 output low.
        PAUSE 100               ' Pause for 0.1 second.
        high 2                  ' Make pin 2 output high.
        PAUSE 100               ' Pause for 0.1 second.
goto abc
```

POT pin,scale,variable

Read a 5–50k potentiometer, thermistor, photocell, or other variable resistance. The pin specified by Pot must be connected to one side of a resistor, whose other side is connected through a capacitor to ground. A resistance measurement is taken by timing how long it takes to discharge the capacitor through the resistor. If the pin is an input when Pot executes, it will be changed to output.



- **Pin** is a variable/constant (0–7) that specifies the I/O pin to use.
- **Scale** is a variable/constant (0–255) used to scale the instruction's internal 16-bit result. The 16- bit reading is multiplied by (scale/256), so a scale value of 128 would reduce the range by approximately 50%, a scale of 64 would reduce to 25%, and so on. The Alt-P option (explained below) provides a means to find the best scale value for a particular resistor.
- **Variable** is used to store the final result of the reading. Internally, the Pot instruction calculates a 16-bit value, which is scaled down to an 8-bit value. The amount by which the internal value must be scaled varies with the size of the resistor being used.

Finding the best Pot scale value:

- To find the best scale value, connect the resistor to be used with the Pot instruction to the Stamp, and connect the Stamp to the PC.
- Press Alt-P while running the Stamp's editor software. A special calibration window appears, allowing you to find the best value.
- The window asks for the number of the I/O pin to which the resistor is connected. Select the appropriate pin (0-7).
- The editor downloads a short program to the Stamp (this overwrites any program already stored in the Stamp).
- Another window appears, showing two numbers: scale and value. Adjust the resistor until the smallest possible number is shown for scale (we're assuming you can easily adjust the resistor, as with a potentiometer).

Once you've found the smallest number for scale, you're done. This number should be used for the scale in the Pot instruction.

Optionally, you can verify the scale number found above by pressing the spacebar. This locks the scale and causes the Stamp to read the resistor continuously. The window displays the value. If the scale is good, you should be able to adjust the resistor, achieving a 0–255 reading for the value (or as close as possible). To change the scale value and repeat this step, just press the spacebar. Continue this process until you find the best scale.

Sample Program:

```
abc:
    POT 0,100,b2              ' Read potentiometer on pin 0.
    serout 1,N300,(b2)        ' Send potentiometer reading
                              ' over serial output.
goto abc                      ' Repeat the process.
```

PULSIN pin,state,variable

Change the specified pin to input and measure an input pulse in 10µs units.

- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.
- **State** is a variable / constant (0 or 1) that specifies which edge must occur before beginning the measurement.
- **Variable** is a variable used to store the result of the measurement. The variable may be a word variable with a range of 1 to 65535, or a byte variable with a range of 1 to 255.

Many analog properties (voltage, resistance, capacitance, frequency, duty cycle) can be measured in terms of pulse durations. This makes Pulsin a valuable form of analog-to-digital conversion.

You can think of Pulsin as a fast stopwatch that is triggered by a change in state (0 or 1) on the specified pin. When the state on the pin changes to the state specified in Pulsin, the stopwatch starts counting. When the state on the pin changes again, the stopwatch stops.

If the state of the pin doesn't change (even if it is already in the state specified in the Pulsin instruction), the stopwatch won't trigger. Pulsin waits a maximum of 0.65535 seconds for a trigger, then returns with 0 in *variable*.

The variable can be either a word or a byte. If the variable is a word, the value returned by Pulsin can range from 1 to 65535 units of 10µs. If the variable is a byte, the value returned can range from 1 to 255 units of 10µs. Internally, Pulsin always uses a 16-bit timer. When your program specifies a byte, Pulsin stores the lower 8 bits of the internal counter into it. Pulse widths longer than 2550µs will give false, low readings with a byte variable. For example, a 2560µs pulse returns a Pulsin reading of 256 with a word variable and 0 with a byte variable.

Sample Program:

```
PULSIN 4,0,w2          ' Measure an input pulse on pin 4.
serout  1,n300,(b5)    ' Send high byte of 16-bit pulse measurement
 . . .                 '  over serial output.
```

PULSOUT pin,time

Generate a pulse by inverting a pin for a specified amount of time. If the pin is an input when Pulsout is executed, it will be changed to an output.

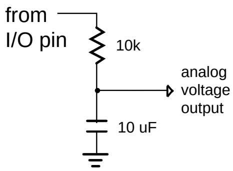
- **Pin** is a variable/constant (0–7) that specifies the I/O pin to use.
- **Time** is a variable/constant (0–65535) that specifies the length of the pulse in 10µs units.

Sample Program:

```
abc:
      PULSOUT 0,3            ' Invert pin 0 for 30
                             ' microseconds.
      pause 1                ' Pause for 1 ms.
goto abc                     ' Branch to abc.
```

PWM pin,duty,cycles

Output pulse-width-modulation on a pin, then return the pin to input state. PWM can be used to generate analog voltages (0-5V) through a pin connected to a resistor and capacitor to ground; the resistor-capacitor junction is the analog output (see circuit). Since the capacitor gradually discharges, PWM should be executed periodically to update and/or refresh the analog voltage.



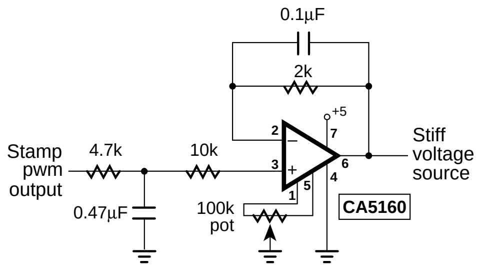
- **Pin** is a variable/constant (0–7) which specifies the I/O pin to use.
- **Duty** is a variable/constant (0–255) which specifies the analog level desired (0–5 volts).
- **Cycles** is a variable/constant (0–255) which specifies the number of cycles to output. Larger capacitors require multiple cycles to fully charge. Each cycle takes about 5 ms.

PWM emits a burst of 1s and 0s whose ratio is proportional to the *duty* value you specify. If *duty* is 0, then the pin is continuously low (0); if *duty* is 255, then the pin is continuously high. For values in between, the proportion is *duty*/255. For example, if *duty* is 100, the ratio of 1s to 0s is 100/255 = 0.392, approximately 39 percent.

When such a burst is used to charge a capacitor arranged as shown in the schematic, the voltage across the capacitor is equal to (*duty*/255) * 5. So if *duty* is 100, the capacitor voltage is (100/255) * 5 = 1.96 volts.

This voltage will drop as the capacitor discharges through whatever load it is driving. The rate of discharge is proportional to the current drawn by the load; more current = faster discharge. You can combat this effect in software by refreshing the capacitor's charge with frequent doses of PWM.

You can also buffer the output to greatly reduce the need for frequent PWM cycles. The schematic on the next page shows an example. Feel free to substitute more sophisticated circuits; this "op-amp follower" is merely a suggestion.



Op-amp buffer for PWM.

If you use a buffer circuit, you will still have to refresh the capacitor from time to time. When the pin is configured to input after PWM executes, it is effectively disconnected from the resistor/capacitor circuit. However, leakage currents of up to 1µA can flow into or out of this "disconnected" pin. Over time, these small currents will cause the voltage on the capacitor to drift. The same applies for leakage current from the op-amp's input, as well as the capacitor's own internal leakage. Executing PWM occasionally will reset the capacitor voltage to the intended value.

One more thing: The name "PWM" may lead you to expect a neat train of fixed-width pulses for a given duty value. That's not the case. When viewed on an oscilloscope, the PWM output looks like a noisy jumble of varying pulsewidths. The only guarantee is that the overall ratio of highs to lows is in the proportion specified by *duty*.

Sample Program:

```
abc:
        serin 0,n300,b2         ' Receive serial byte.
        PWM 1,b2,20             ' Output an analog voltage proportional to
                                ' the serial byte received
```

RANDOM wordvariable

Generate the next pseudo-random number in *wordvariable*.

- **Wordvariable** is a variable (0–65535) that acts as the routine's workspace and its result. Each pass through Random leaves the next number in the pseudorandom sequence.

The Stamp uses a sequence of 65535 essentially random numbers to execute this instruction. When Random executes, the value in wordvariable determines where to "tap" into the sequence of random numbers. If the same initial value is always used in *wordvariable,* then the same sequence of numbers is generated. Although this method is not absolutely random, it's good enough for most applications.

To obtain truly random results, you must add an element of uncertainty to the process. For instance, your program might execute Random continuously while waiting for the user to press a button.

Sample Program:

```
loop:
        RANDOM w1            ' Generate a 16-bit random number.
        sound 1,(b2,10)      ' Generate a random tone on pin 1 using the low
                             ' byte of the random number b2 as the note number.
        goto loop            ' Repeat the process
```

READ location,variable

Read EEPROM location and store value in *variable*.

- **Location** is a variable/constant (0–255) that specifies which location in the EEPROM to read from.
- **Variable** receives the value read from the EEPROM (0–255).

The EEPROM is used for both program storage (which builds downward from address 254) and data storage (which builds upward from address 0). To ensure that your program doesn't overwrite itself, read location 255 in the EEPROM before writing any data. Location 255 holds the address of the last instruction in your program. Therefore, your program can use any space below the address given in location 255. For example, if location 255 holds the value 100, then your program can use locations 0–99 for data.

Sample Program:

```
        READ 255,b2             ' Get location of last program instruction.
loop:
        b2 = b2 - 1             ' Decrement to next available EEPROM location
        serin 0,N300,b3         ' Receive serial byte in b3
        write b2,b3             ' Store received serial byte in next EEPROM location
if b2 > 0 then loop             ' Get another byte if there's room left to store it.
```

RETURN

Return from subroutine. Return branches back to the address following the most recent Gosub instruction, at which point program execution continues.

Return takes no parameters. For more information on using subroutines, see the Gosub listing.

Sample Program:

```
for b4 = 0 to 10
gosub abc                 ' Save return address and then branch to abc.
next
abc:
    pulsout 0,b4          ' Output a pulse on pin 0.
                          ' Pulse length is b4 x 10 microseconds.
    toggle 1              ' Toggle pin 1.
    RETURN                ' Return to instruction following gosub.
```

REVERSE pin

Reverse the data direction of the given pin. If the pin is an input, make it an output; if it's an output, make it an input.

- **Pin** is a variable/constant (0–7) that specifies the I/O pin.

See the Input and Output commands for more information on configuring pins' data directions.

Sample Program:

```
dir3 = 0            ' Make pin 3 an input.
REVERSE 3           ' Make pin 3 an output.
REVERSE 3           ' Make pin 3 an input.
```

SERIN pin,baudmode,(qualifier,qualifier,...)

SERIN pin,baudmode,{#}variable,{#}variable,...

SERIN pin, baudmode, (qualifier,qualifier,...), {#}variable, {#}variable,...

Set up a serial input port and then wait for optional qualifiers and / or variables.

- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.
- **Baudmode** is a variable / constant (0–7) that specifies the serial port mode. *Baudmode* can be either the # or symbol shown in the table. The other serial parameters are preset to the most common format: no parity, eight data bits, one stop bit, often abbreviated N81. These cannot be changed.

#	Symbol	Baud Rate	Polarity
0	T2400	2400	true
1	T1200	1200	true
2	T600	600	true
3	T300	300	true
4	N2400	2400	inverted
5	N1200	1200	inverted
6	N600	600	inverted
7	N300	300	inverted

- **Qualifiers** are optional variables / constants (0–255) which must be received in exact order before execution can continue.
- **Variables** (optional) are used to store received data (0–255). If any qualifiers are given, they must be satisfied before variables can be filled. If a # character precedes a variable name, then Serin will convert numeric text (e.g., numbers typed at a keyboard) into a value to fill the variable.

Serin makes the specified pin a serial input port with the characteristics set by *baudmode*. It receives serial data one byte at a time and does one of two things with it:

- Compares it to a *qualifier*.
- Stores it to a *variable*.

In either case, the Stamp will do nothing else until all qualifiers have been exactly matched in the specified order and all variables have been filled. A single Serin instruction can include both variables to fill and qualifiers to match.

Here are some examples:

```
SERIN 0,T300,b2
```

Stop the program until one byte of data is received serially (true polarity, 300 baud) through pin 0. Store the received byte into variable b2 and continue. For example, if the character "A" were received, Serin would store 65 (the ASCII character code for "A") into b2.

```
SERIN 0, T1200,#w1
```

Stop the program until a a numeric string is received serially (true polarity, 1200 baud) through pin 0. Store the value of the numeric string into variable w1. For example, suppose the following text were received: "XYZ: 576%." Serin would ignore "XYZ: " because these are non-numeric characters. It would collect the characters "5", "7", "6" up to the first non-numeric character, "%". Serin would convert the numeric string "576" into the corresponding value 576 and store it in w1. If the # before w1 were omitted, Serin would receive only the first character, "X", and store its ASCII character code, 88, into w1.

```
SERIN 0,N2400,("A")
```

Stop the program until a byte of data is received serially (inverted polarity, 2400 baud) through pin 0. Compare the received byte to 65, the ASCII value of the letter "A". If it matches, continue the program. If it doesn't match, receive another byte and repeat the comparison. The program will not continue until "A" is received. For example, if Serin received "LIMIT 65,A", program execution would not continue until the final "A" was received.

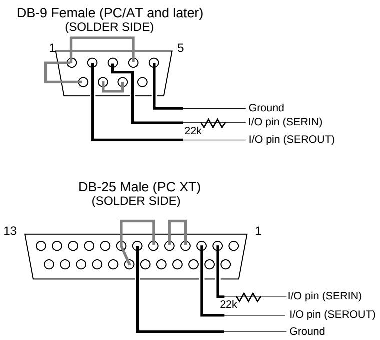
```
SERIN 0,N2400,("SESAME"),b2,#b4
```

Stop the program until a string of bytes exactly matching "SESAME" is received serially (inverted polarity, 2400 baud) through pin 0. Once the qualifiers have been received, store the next byte into b2. Then receive a numeric string, convert it to a value, and store it into b4. For example, suppose Serin received, "...SESESAME! *****19*". It would ignore the string "...SE", then accept the matching qualifier string "SESAME". Then Serin would put 33, the ASCII value of "!", into b2. It would ignore the non-numeric "*" characters, then store the characters "1" and "9". When Serin received the first non-numeric character ("*"), it would convert the text "19" into the value 19 and store it in b4. Then, having matched all qualifiers and filled all variables, Serin would permit the Stamp to go on to the next instruction.

Speed Considerations. The Serin command itself is fast enough to catch multiple bytes of data, no matter how rapidly the host computer sends them. However, if your program receives data, stores or processes it, then loops back to perform another Serin, it may miss data or receive it incorrectly because of the time delay. Use one or more of the following steps to compensate for this:

- Increase the number of stop bits at the sender from 1 to 2 (or more, if possible).
- Reduce the baud rate.
- If the sender is operating under the control of a program, add delays between transmissions.
- Reduce the amount of processing that the Stamp performs between Serins to a bare minimum.

Receiving data from a PC. To send data serially from your PC to the Stamp, all you need is a 22k resistor, some wire and connectors, and terminal communication software. Wire the connector as shown in the diagram for Serin. The wires shown in gray disable your PC's hardware handshaking, which would normally require additional connections to control the flow of data. These aren't required in communication with the Stamp, because you're not likely to be sending a large volume of data as you might to a modem or printer.



When you write programs to receive serial data using this kind of hookup, make sure to specify "inverted" baudmodes, such as N2400.

If you don't have a terminal program, you can type and run the following QBASIC program to configure the serial port (2400 baud, N81) and transmit characters typed at the keyboard. QBASIC is the PC dialect of BASIC that comes with DOS versions 5 and later.

QBASIC Program to Transmit Data:

```
' This program transmits characters typed at the keyboard out the PC's
' COM1: serial port. To end the program, press control-break.
' Note: in the line below, the "0" in "CD0,CS0..." is a zero.

OPEN "COM1:2400,N,8,1,CD0,CS0,DS0,OP0" FOR OUTPUT AS #1
CLS
Again:
        theChar$ = INKEY$
        IF theChar$ = "" then Goto Again
        PRINT #1,theChar$;
GOTO Again
```

Sample Stamp Program:

```
' To use this program, download it to the Stamp. Connect
' your PC's com1: port output to Stamp pin 0 through a 22k resistor
' as shown in the diagram. Connect a speaker to Stamp pin 7 as
' shown in the Sound entry. Run your terminal software or the QBASIC
' program above. Configure your terminal software for 2400 baud,
' N81, and turn off hardware handshaking. The QBASIC
' program is already configured this way. Try typing random
' letters and numbers--nothing will happen until you enter
' "START" exactly as it appears in the Stamp program.
' Then you may type numbers representing notes and
' durations for the Sound command. Any non-numeric text
' you type will be ignored.

        SERIN 0,N2400,("START")         ' Wait for "START".
        sound 7,(100,10)                ' Acknowledging beep.
Again:
        SERIN 0,N2400,#b2,#b3           ' Receive numeric text and
                                        ' convert to bytes.
        sound 7,(b2,b3)                 ' Play corresponding sound.
        goto Again                      ' Repeat.
```

SEROUT pin,baudmode,({# }data,{# }data,...)

Set up a serial output port and transmit data.

- **Pin** is a variable/constant (0–7) that specifies the I/O pin to use.
- **Baudmode** is a variable/constant (0–15) that specifies the serial port mode. *Baudmode* can be either the # or symbol shown in the table. The other serial parameters are preset to the most common format: no parity, eight data bits, one stop bit, often abbreviated N81. These cannot be changed.

#	Symbol	Baud Rate	Polarity and Output Mode
0	T2400	2400	true always driven
1	T1200	1200	true always driven
2	T600	600	true always driven
3	T300	300	true always driven
4	N2400	2400	inverted always driven
5	N1200	1200	inverted always driven
6	N600	600	inverted always driven
7	N300	300	inverted always driven
8	OT2400	2400	true open drain (driven high)
9	OT1200	1200	true open drain (driven high)
10	OT600	600	true open drain (driven high)
11	OT300	300	true open drain (driven high)
12	ON2400	2400	inverted open source (driven low)
13	ON1200	1200	inverted open source (driven low)
14	ON600	600	inverted open source (driven low)
15	ON300	300	inverted open source (driven low)

- **Data** are byte variables/constants (0–255) that are output by Serout. If preceded by the # sign, data items are transmitted as text strings up to five characters long. Without the #, data items are transmitted as a single byte.

Serout makes the specified pin a serial output port with the characteristics set by *baudmode*. It transmits the specified data in one of two forms:

- A single-byte value.
- A text string of one to five characters.

Here are some examples:

```
SEROUT  0,N2400,(65)
```

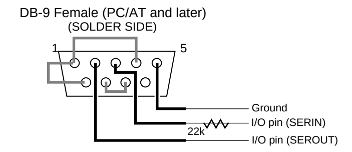
Serout transmits the byte value 65 through pin 0 at 2400 baud, inverted. If you receive this byte on a PC running terminal software, the character “A” will appear on the screen, because 65 is the ASCII code for “A”.

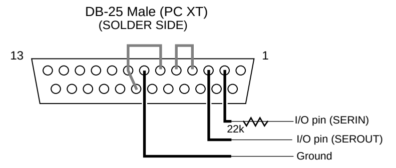
```
SEROUT 0,N2400,(#65)
```

Serout transmits the text string “65” through pin 0 at 2400 baud, inverted. If you receive this byte on a PC running terminal software, the text “65” will appear on the screen. When a value is preceded by the # sign, Serout automatically converts it to a form that reads correctly on a terminal screen.

When should you use the # sign? If you are sending data from the Stamp to a terminal for people to read, use #. If you are sending data to another Stamp, or to another computer for further processing, it's more efficient to omit the #.

Sending data to a PC. To send data serially to your PC from the Stamp, all you need is some wire and connectors, and terminal communication software. Wire the connector as shown in the Serout connections in the diagram at right and use the inverted baudmodes, such as N2400. Although the Stamp's serial output can only switch between 0 and +5 volts (not the ±10 volts of legal RS-232), most PCs receive it without problems.



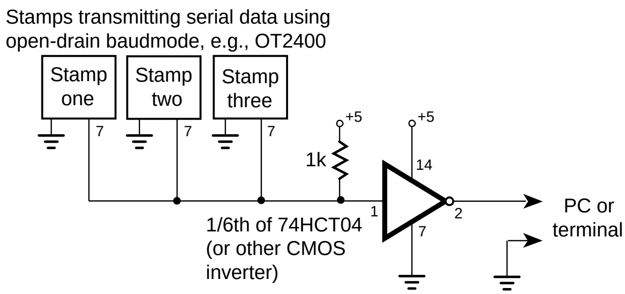


If you don't have a terminal program, you can type and run the following QBASIC program to configure the serial port and receive characters from the Stamp.

QBASIC Program to Receive Data:

```
' This program receives data transmitted by the Stamp through the PC's
' COM1: serial port and displays it on the screen. To end the program,
' press control-break. Note: in the line below, the "0" in "CD0,CS0..." is a zero.

OPEN "COM1:2400,N,8,1,CD0,CS0,DS0,OP0" FOR INPUT AS #1
CLS
Again:
      theChar$ = INPUT$(1,#1)
      PRINT theChar$;
GOTO Again
```

Open-drain/open-source signaling. The last eight configuration options for Serout begin with "O" for open-drain or open-source signaling. The diagram below shows how to use the open-drain mode to connect two or more Stamps to a common serial output line to form a network. You could also use the open-source mode, but the resistor would have to be connected to ground, and a buffer



(non-inverting driver) substituted for the inverter to drive the PC.

To understand why you must use the “open” serial modes on a network, consider what would happen if you didn’t. When none of the Stamps are transmitting, all of their Serout pins are output-high. Since all are at +5 volts, no current flows between the pins. Then a Stamp transmits, and switches to output-low. With the other Stamps’ pins output-high, there’s a direct short from +5 volts to ground. Current flows between the pins, possibly damaging them.

If the Stamps are all set for open-drain output, it’s a different story. When the Stamps aren’t transmitting, their Serout pins are inputs, effectively disconnected from the serial line. The resistor to +5 volts maintains a high on the serial line. When a Stamp transmits, it pulls the serial line low. Almost no current flows through the other Stamps’ Serout pins, which are set to input. Even if two Stamps transmit simultaneously, they can’t damage each other.

Sample Program:

```
abc:
        pot 0,100,b2                ' Read potentiometer on pin 0.
        SEROUT 1,N300,(b2)          ' Send potentiometer
                                    ' reading over serial output.
        goto abc                    ' Repeat the process.
```

SLEEP seconds

Enter sleep mode for a specified number of seconds.

- **Seconds** is a variable/constant (1–65535) that specifies the duration of sleep in seconds. The length of sleep can range from 2.3 seconds (see note below) to slightly over 18 hours. Power consumption is reduced to about 20 µA, assuming no loads are being driven.

Note: The resolution of Sleep is 2.304 seconds. Sleep rounds the *seconds* up to the nearest multiple of 2.304. Sleep 1 causes 2.3 seconds of sleep, while Sleep 10 causes 11.52 seconds (5 x 2.304).

Sleep lets the Stamp turn itself off, then turn back on after a specified number of seconds. The alarm clock that wakes the Stamp up is called the watchdog timer. The watchdog is an oscillator built into the BASIC interpreter. During sleep, the Stamp periodically wakes up and adjusts a counter to determine how long it has been asleep. If it isn't time to wake up, the Stamp goes back to sleep.

To ensure accuracy of sleep intervals, the Stamp periodically compares the period of the watchdog timer to the more accurate resonator timebase. It calculates a correction factor that it uses during sleep. Longer sleep intervals are accurate to ±1 percent.

If your Stamp application is driving loads during sleep, current will be interrupted for about 18 ms when the Stamp wakes up every 2.3 seconds. The reason is that the reset that awakens the Stamp causes all of the pins to switch to input mode for approximately 18 ms. When the BASIC interpreter regains control, it restores the I/O direction dictated by your program.

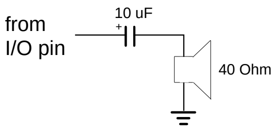
If you plan to use End, Nap, or Sleep in your programs, make sure that your loads can tolerate these periodic power outages. The simplest solution is to connect resistors high or low (to +5V or ground) as appropriate to ensure a supply of current during reset.

Sample Program:

```
SLEEP 3600          ' Sleep for about 1 hour.
goto xyz            ' Continue with program
                    ' after sleeping.
```

SOUND pin,(note,duration,note,duration,...)

Change the specified pin to output, and generate square-wave notes with given durations. The output pin should be connected as shown in the diagram. You may substitute a resistor of 220 ohms or more for the capacitor, but the speaker coil will draw current even when the speaker is silent.



- **Pin** is a variable / constant (0–7) that specifies the I / O pin to use.
- **Note(s)** are variables / constants (0–255) which specify type and frequency. Note 0 is silent for the given duration. Notes 1-127 are ascending tones. Notes 128-255 are ascending white noises, ranging from buzzing (128) to hissing (255).
- **Duration(s)** are variables / constants (1–255) which specify how long (in units of 12 ms) to play each note.

The notes produced by Sound can vary in frequency from 94.8 Hz (1) to 10,550 Hz (127). If you need to determine the frequency corresponding to a given note value, or need to find the note value that will give you best approximation for a given frequency, use the equations below.

Sample Program:

```
for b2 = 0 to 256
      SOUND  1,(25,10,b2,10)          ' Generate a constant tone (25)
                                      ' followed by an ascending tone
                                      ' (b2). Both tones have the
next                                  ' same duration(10).
```

$$\text{Note} = 127 - \frac{\frac{1}{\text{Frequency (Hz)}} - 95 \times 10^{-6}}{83 \times 10^{-6}}$$

$$\text{Frequency (Hz)} = \frac{1}{95 \times 10^{-6} + ((127 - \text{Note}) \times 83 \times 10^{-6})}$$

TOGGLE pin

Make pin an output and toggle state.

- **Pin** is a variable/constant (0–7) that specifies the I/O pin to use.

Sample Program:

```
for b2 = 1 to 25
TOGGLE 5                    'Toggle state of pin 5.
next
```

WRITE location,data

Store data in EEPROM location.

- **Location** is a variable/constant (0–255) that specifies which EEPROM location to write to.
- **Data** is a variable/constant (0–255) that is stored in the EEPROM location.

The EEPROM is used for both program storage (which builds downward from address 254) and data storage (which builds upward from address 0). To ensure that your program doesn't overwrite itself, read location 255 in the EEPROM before writing any data. Location 255 holds the address of the first instruction in your program. Therefore, your program can use any space below the address given in location 255.For example, if location 255 holds the value 100, then your program can use locations 0–99 for data.

Sample Program:

```
read 255,b2                 ' Get location of last
                            ' program instruction.
loop:
      b2 = b2 - 1           ' Decrement to next
                            ' available EEPROM location
      serin 0,N300,b3       ' Receive serial byte in b3.
      WRITE b2,b3           ' Store received serial
                            ' byte in next EEPROM location.
if b2 > 0 then loop         ' Get another byte if there's room.
```

Introduction. This application note presents a program in PBASIC that enables the BASIC Stamp to operate as a simple user-interface terminal.

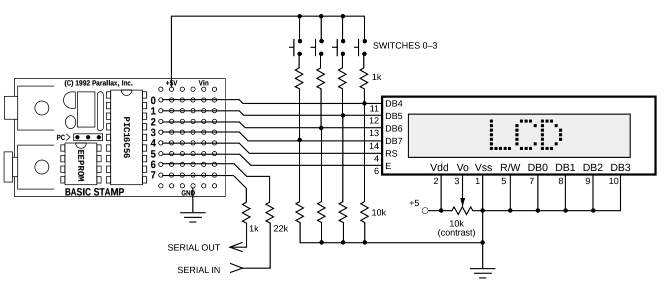
Background. Many systems use a central host computer to control remote functions. At various locations, users communicate with the main system via small terminals that display system status and accept inputs. The BASIC Stamp's ease of programming and built-in support for serial communications make it a good candidate for such user-interface applications.

The liquid-crystal display (LCD) used in this project is based on the popular Hitachi 44780 controller IC. These chips are at the heart of LCD's ranging in size from two lines of four characters (2x4) to 2x40.

How it works. When power is first applied, the BASIC program initializes the LCD. It sets the display to print from left to right, and enables an underline cursor. To eliminate any stray characters, the program clears the screen.

After initialization, the program enters a loop waiting for the arrival of a character via the 2400-baud RS-232 interface. When a character arrives, it is checked against a short list of special characters (backspace, control-C, and return). If it is not one of these, the program prints it on the display, and re-enters the waiting-for-data loop.

If a backspace is received, the program moves the LCD cursor back one



Schematic to accompany program TERMINAL.BAS.

space, prints a blank (space) character to blot out the character that was there, and then moves back again. The second move-back step is necessary because the LCD automatically advances the cursor.

If a control-C is received, the program issues a clear instruction to the LCD, which responds by filling the screen with blanks, and returning the cursor to the leftmost position.

If a return character is received, the program interprets the message as a query requiring a response from the user. It enters a loop waiting for the user to press one of the four pushbuttons. When he does, the program sends the character (“0” through “3”) representing the button number back to the host system. It then re-enters its waiting loop.

Because of all this processing, the user interface cannot receive characters sent rapidly at the full baud rate. The host program must put a little breathing space between characters; perhaps a 3-millisecond delay. If you reduce the baud rate to 300 baud and set the host terminal to 1.5 or 2 stop bits, you may avoid the need to program a delay.

At the beginning of the program, during the initialization of the LCD, you may have noticed that several instructions are repeated, instead of being enclosed infor / next loops. This is not an oversight. Watching the downloading bar graph indicated that the repeated instructions actually resulted in a more compact program from the Stamp’s point of view. Keep an eye on that graph when running programs; it a good relative indication of how much program space you’ve used. The terminal program occupies about two-thirds of the Stamp’s EEPROM.

From an electronic standpoint, the circuit employs a couple of tricks. The first involves the RS-232 communication. The Stamp’s processor, a PIC 16C56, is equipped with hefty static-protection diodes on its input / output pins. When the Stamp receives RS-232 data, which typically swings between -12 and +12 volts (V), these diodes serve to limit the voltage actually seen by the PIC’s internal circuitry to 0 and +5V. The 22k resistor limits the current through the diodes to prevent damage.

Sending serial output without an external driver circuit exploits another loophole in the RS-232 standard. While most RS-232 devices expect the signal to swing between at least -3 and +3V, most will accept the 0 and +5V output of the PIC without problems.

This setup is less noise-immune than circuits that play by the RS-232 rules. If you add a line driver/receiver such as a Maxim MAX232, remember that these devices also invert the signals. You'll have to change the baud/mode parameter in the instructions serin and serout to T2400, where T stands for true signal polarity. If industrial-strength noise immunity is required, or the interface will be at the end of a mile-long stretch of wire, use an RS-422 driver/receiver. This will require the same changes to serin and serout.

Another trick allows the sharing of input/output pins between the LCD and the pushbuttons. What happens if the user presses the buttons while the LCD is receiving data? Nothing. The Stamp can sink enough current to prevent the 1k pullup resistors from affecting the state of its active output lines. And when the Stamp is receiving input from the switches, the LCD is disabled, so its data lines are in a high-impedance state that's the next best thing to not being there. These facts allow the LCD and the switches to share the data lines without interference.

Finally, note that the resistors are shown on the data side of the switches, not on the +5V side. This is an inexpensive precaution against damage or interference due to electrostatic discharge from the user's fingertips. It's not an especially effective precaution, but the price is right.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' PROGRAM: Terminal.bas
' The Stamp serves as a user-interface terminal. It accepts text via RS-232 from a
' host, and provides a way for the user to respond to queries via four pushbuttons.

Symbol  S_in   =  6        ' Serial data input pin
Symbol  S_out  =  7        ' Serial data output pin
Symbol  E      =  5        ' Enable pin, 1 = enabled
Symbol  RS     =  4        ' Register select pin, 0 = instruction
Symbol  keys   =  b0       ' Variable holding # of key pressed.
Symbol  char   =  b3       ' Character sent to LCD.
```

```
Symbol  Sw_0   =   pin0               ' User input switches
Symbol  Sw_1   =   pin1               ' multiplexed w/LCD data lines.
Symbol  Sw_2   =   pin2
Symbol  Sw_3   =   pin3

' Set up the Stamp's I/O lines and initialize the LCD.
begin:  let pins = 0                  ' Clear the output lines
        let dirs = %01111111          ' One input, 7 outputs.
        pause 200                     ' Wait 200 ms for LCD to reset.

' Initialize the LCD in accordance with Hitachi's instructions for 4-bit interface.
i_LCD:  let pins = %00000011          ' Set to 8-bit operation.
        pulsout E,1                   ' Send data three times
        pause 10                      ' to initialize LCD.
        pulsout E,1
        pause 10
        pulsout E,1
        pause 10
        let pins = %00000010          ' Set to 4-bit operation.
        pulsout E,1                   ' Send above data three times.
        pulsout E,1
        pulsout E,1
        let char = 14                 ' Set up LCD in accordance with
        gosub wr_LCD                  ' Hitachi instruction manual.
        let char = 6                  ' Turn on cursor and enable
        gosub wr_LCD                  ' left-to-right printing.
        let char = 1                  ' Clear the display.
        gosub wr_LCD
        high    RS                    ' Prepare to send characters.

' Main program loop: receive data, check for backspace, and display data on LCD.
main:   serin S_in,N2400,char         ' Main terminal loop.
        goto bksp
out:    gosub wr_LCD
        goto main

' Write the ASCII character in b3 to LCD.
wr_LCD: let pins = pins & %00010000
        let b2 = char/16              ' Put high nibble of b3 into b2.
        let pins = pins | b2          ' OR the contents of b2 into pins.
        pulsout E,1                   ' Blip enable pin.
        let b2 = char & %00001111     ' Put low nibble of b3 into b2.
        let pins = pins & %00010000   ' Clear 4-bit data bus.
        let pins = pins | b2          ' OR the contents of b2 into pins.
        pulsout E,1                   ' Blip enable.
        return

' Backspace, rub out character by printing a blank.
```

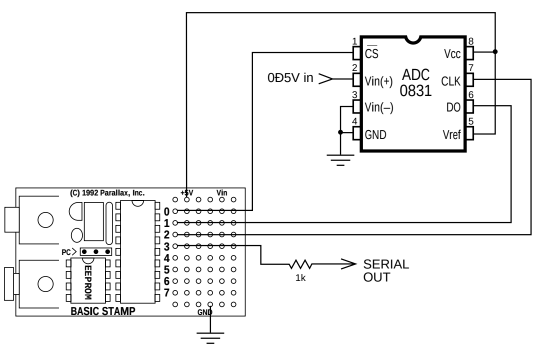
```
bksp:   if char > 13 then out           ' Not a bksp or cr? Output character.
        if char = 3 then clear          ' Ctl-C clears LCD screen.
        if char = 13 then cret          ' Carriage return.
        if char <> 8 then main          ' Reject other non-printables.
        gosub back
        let char = 32                   ' Send a blank to display
        gosub wr_LCD
        gosub back                      ' Back up to counter LCD's auto-
                                        ' increment.
        goto main                       ' Get ready for another transmission.

back:   low RS                          ' Change to instruction register.
        let char = 16                   ' Move cursor left.
        gosub wr_LCD                    ' Write instruction to LCD.
        high RS                         ' Put RS back in character mode.
        return

clear:  low RS                          ' Change to instruction register.
        let b3 = 1                      ' Clear the display.
        gosub wr_LCD                    ' Write instruction to LCD.
        high RS                         ' Put RS back in character mode.
        goto main

' If a carriage return is received, wait for switch input from the user. The host
' program (on the other computer) should cooperate by waiting for a reply before
' sending more data.
cret:   let dirs = %01110000            ' Change LCD data lines to input.
loop:   let keys = 0
        if Sw_0 = 1 then xmit           ' Add one for each skipped key.
        let keys = keys + 1
        if Sw_1 = 1 then xmit
        let keys = keys + 1
        if Sw_2 = 1 then xmit
        let keys = keys + 1
        if Sw_3 = 1 then xmit
        goto loop

xmit:   serout S_out,N2400,(#keys,10,13)
        let dirs = %01111111            ' Restore I/O pins to original state.
        goto main
```

Introduction. This application note presents the hardware and software required to interface an 8-bit serial analog-to-digital converter to the Parallax BASIC Stamp.

Background. The BASIC Stamp's instruction pot performs a limited sort of analog-to-digital conversion. It lets you interface nearly any kind of resistive sensor to the Stamp with a minimum of difficulty. However, many applications call for a true voltage-mode analog-to-digital converter (ADC). One that's particularly suited to interfacing with the Stamp is the National Semiconductor ADC0831, available from Digi-Key, among others.

Interfacing the '831 requires only three input / output lines, and of these, two can be multiplexed with other functions (or additional '831's). Only the chip-select (CS) pin requires a dedicated line. The ADC's range of input voltages is controlled by the VREF and VIN(–) pins. VREF sets the voltage at which the ADC will return a full-scale output of 255, while VIN(–) sets the voltage that will return 0.

In the example application, VIN(–) is at ground and VREF is at +5; however, these values can be as close together as 1 volt without harming the device's accuracy or linearity. You may use diode voltage references or trim pots to set these values.



Schematic to accompany program AD_CONV.BAS.

How it works. The sample program reads the voltage at the '831's input pin every 2 seconds and reports it via a 2400-baud serial connection. The subroutine conv handles the details of getting data out of the ADC. It enables the ADC by pulling the CS line low, then pulses the clock (CLK) line to signal the beginning of a conversion. The program then enters a loop in which it pulses CLK, gets the bit on pin AD, adds it to the received byte, and shifts the bits of the received byte to the left. Since BASIC traditionally doesn't include bit-shift operations, the program multiplies the byte by 2 to perform the shift.

When all bits have been shifted into the byte, the program turns off the ADC by returning CS high. The subroutine returns with the conversion result in the variable data. The whole process takes about 20 milliseconds.

Modifications. You can add more '831's to the circuit as follows: Connect each additional ADC to the same clock and data lines, but assign it a separate CS pin. Modify the conv subroutine to take the appropriate CS pin low when it needs to acquire data from a particular ADC. That's it.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' PROGRAM: ad_conv.bas
' BASIC Stamp program that uses the National ADC0831 to acquire analog data and
' output it via RS-232.

Symbol  CS      =   0
Symbol  AD      =   pin1
Symbol  CLK     =   2
Symbol  S_out   =   3
Symbol  data    =   b0
Symbol  i       =   b2

setup:  let pins = 255                     ' Pins high (deselect ADC).
        let dirs = %11111101               ' S_out, CLK, CS outputs; AD
                                           ' input.

loop:   gosub conv                         ' Get the data.
        serout S_out,N2400,(#b0,13,10)     ' Send data followed by a return
```

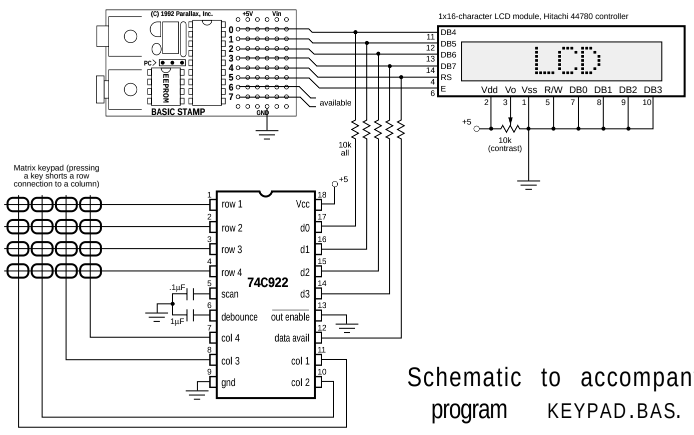
```
                                        ' and linefeed.
        pause 2000                      ' Wait 2 seconds
        goto loop                       ' Do it forever.

conv:   low CLK                         ' Put clock line in starting state.
        low CS                          ' Select ADC.
        pulsout CLK, 1                  ' 10 us clock pulse.
        let data = 0                    ' Clear data.
        for i = 1 to 8                  ' Eight data bits.
        let data = data * 2             ' Perform shift left.
        pulsout CLK, 1                  ' 10 us clock pulse.
        let data = data + AD            ' Put bit in LSB of data.
        next                            ' Do it again.
        high CS                         ' Deselect ADC when done.
        return
```

Introduction. This application note presents a program in PBASIC that enables the BASIC Stamp to read a keypad and display keypresses on a liquid-crystal display.

Background. Many controller applications require a keypad to allow the user to enter numbers and commands. The usual way to interface a keypad to a controller is to connect input/output (I/O) bits to row and column connections on the keypad. The keypad is wired in a matrix arrangement so that when a key is pressed one row is shorted to one column. It's relatively easy to write a routine to scan the keypad, detect keypresses, and determine which key was pressed.

The trouble is that a 16-key pad requires a minimum of eight bits (four rows and four columns) to implement this approach. For the BASIC Stamp, with a total of only eight I/O lines, this may not be feasible, even with clever multiplexing arrangements. And although the programming to scan a keypad is relatively simple, it can cut into the Stamp's 255 bytes of program memory.

An alternative that conserves both I/O bits and program space is to use the 74C922 keypad decoder chip. This device accepts input from a 16-key pad, performs all of the required scanning and debouncing, and



Schematic to accompany program KEYPAD.BAS.

outputs a "data available" bit and 4 output bits representing the number of the key pressed from 0 to 15. A companion device, the 74C923, has the same features, but reads a 20-key pad and outputs 5 data bits.

Application. The circuit shown in the figure interfaces a keypad and liquid-crystal display (LCD) module to the BASIC Stamp, leaving two I/O lines free for other purposes, such as bidirectional serial communication. As programmed, this application accepts keystrokes from 16 keys and displays them in hexadecimal format on the LCD.

When the user presses a button on the keypad, the corresponding hex character appears on the display. When the user has filled the display with 16 characters, the program clears the screen.

The circuit makes good use of the electrical properties of the Stamp, the LCD module, and the 74C922. When the Stamp is addressing the LCD, the 10k resistors prevent keypad activity from registering. The Stamp can easily drive its output lines high or low regardless of the status of these lines. When the Stamp is not addressing the LCD, its lines are configured as inputs, and the LCD's lines are in a high-impedance state (tri-stated). The Stamp can then receive input from the keypad without interference.

The program uses the button instruction to read the data-available line of the 74C922. The debounce feature of button is unnecessary in this application because the 74C922 debounces its inputs in hardware; however, button provides a professional touch by enabling delayed auto-repeat for the keys.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' PROGRAM: Keypad.bas
' The Stamp accepts input from a 16-key matrix keypad with the help of
' a 74C922 keypad decoder chip.
Symbol  E       =   5                   ' Enable pin, 1 = enabled
Symbol  RS      =   4                   ' Register select pin, 0 = instruction
```

```
Symbol  char    =   b1                      ' Character sent to LCD.
Symbol  buttn   =   b3                      ' Workspace for button command.
Symbol  lngth   =   b5                      ' Length of text appearing on LCD.
Symbol  temp    =   b7                      ' Temporary holder for input character.

' Set up the Stamp's I/O lines and initialize the LCD.
begin:  let pins = 0                        ' Clear the output lines
        let dirs = %01111111                ' One input, 7 outputs.
        pause 200                           ' Wait 200 ms for LCD to reset.
        let buttn = 0
        let lngth = 0
        gosub i_LCD
        gosub clear

keyin:  let dirs = %01100000                ' Set up I/O directions.
loop:   button 4,1,50,10,buttn,0,nokey      ' Check pin 4 (data available) for
                                            ' keypress.
        lngth = lngth + 1                   ' Key pressed: increment position
counter.
        let temp = pins & %00001111         ' Strip extra bits to leave only key data.
        if temp > 9 then hihex              ' Convert 10 thru 15 into A thru F (hex).
        let temp = temp + 48                ' Add offset for ASCII 0.
LCD:    let dirs = %01111111                ' Get ready to output to LCD.
        if lngth > 16 then c_LCD            ' Screen full? Clear it.
cont:   let char = temp                     ' Write character to LCD.
        gosub wr_LCD
nokey:  pause 10                            ' Short delay for nice auto-repeat
                                            ' speed.
        goto keyin                          ' Get ready for next key.

hihex:  let temp = temp + 55                ' Convert numbers 10 to 15 into A - F.
        goto LCD
c_LCD:  let lngth = 1                       ' If 16 characters are showing on LCD,
        gosub clear                         ' clear the screen and print at left edge.
        goto cont

' Initialize the LCD in accordance with Hitachi's instructions
' for 4-bit interface.
i_LCD:  let pins = %00000011                ' Set to 8-bit operation.
        pulsout E,1                         ' Send above data three times
        pause 10                            ' to initialize LCD.
        pulsout E,1
        pulsout E,1
        let pins = %00000010                ' Set to 4-bit operation.
        pulsout E,1                         ' Send above data three times.
        pulsout E,1
        pulsout E,1
        let char = 12                       ' Set up LCD in accordance w/
```

```
        gosub wr_LCD                    ' Hitachi instruction manual.
        let char = 6                    ' Turn off cursor, enable
        gosub wr_LCD                    ' left-to-right printing.
        high RS                         ' Prepare to send characters.
        return

' Write the ASCII character in b3 to the LCD.
wr_LCD: let pins = pins & %00010000
        let b2 = char/16                ' Put high nibble of b3 into b2.
        let pins = pins | b2            ' OR the contents of b2 into pins.
        pulsout E,1                     ' Blip enable pin.
        let b2 = char & %00001111       ' Put low nibble of b3 into b2.
        let pins = pins & %00010000     ' Clear 4-bit data bus.
        let pins = pins | b2            ' OR the contents of b2 into pins.
        pulsout E,1                     ' Blip enable.
        return

' Clear the LCD screen.
clear:  low RS                          ' Change to instruction register.
        let char = 1                    ' Clear display.
        gosub wr_LCD                    ' Write instruction to LCD.
        high RS                         ' Put RS back in character mode.
        return
```

Introduction. This application note presents a program in PBASIC that enables the BASIC Stamp to control pulse-width proportional servos and measure the pulse width of other servo drivers.

Background. Servos of the sort used in radio-controlled airplanes are finding new applications in home and industrial automation, movie and theme-park special effects, and test equipment. They simplify the job of moving objects in the real world by eliminating much of the mechanical design. For a given signal input, you get a predictable amount of motion as an output.

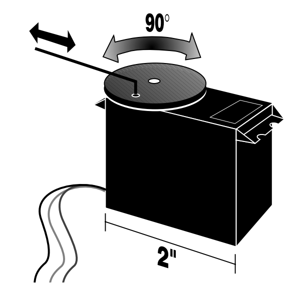


Figure 1. A typical servo.

Figure 1 shows a typical servo. The three wires are +5 volts, ground, and signal. The output shaft accepts a wide variety of prefabricated disks and levers. It is driven by a geared-down motor and rotates through 90 to 180 degrees. Most servos can rotate 90 degrees in less than a half second. Torque, a measure of the servo's ability to overcome mechanical resistance (or lift weight, pull springs, push levers, etc.), ranges from 20 to more than 100 inch-ounces.

To make a servo move, connect it to a 5-volt power supply capable of delivering an ampere or more of peak current, and supply a positioning

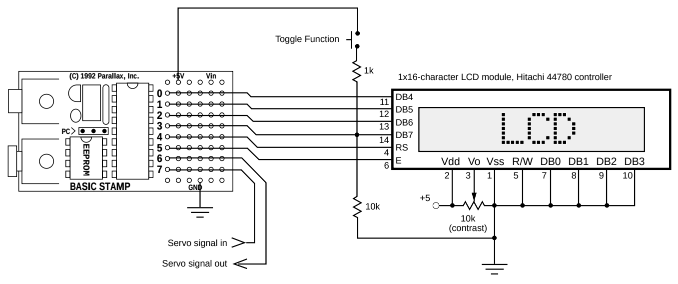


Figure 2. Schematic to accompany program SERVO.BAS.

signal. The signal is generally a 5-volt, positive-going pulse between 1 and 2 milliseconds (ms) long, repeated about 50 times per second. The width of the pulse determines the position of the servo. Since servos' travel can vary, there isn't a definite correspondence between a given pulse width and a particular servo angle, but most servos will move to the center of their travel when receiving 1.5-ms pulses.

Servos are closed-loop devices. This means that they are constantly comparing their commanded position (proportional to the pulse width) to their actual position (proportional to the resistance of a potentiometer mechanically linked to the shaft). If there is more than a small difference between the two, the servo's electronics will turn on the motor to eliminate the error. In addition to moving in response to changing input signals, this active error correction means that servos will resist mechanical forces that try to move them away from a commanded position. When the servo is unpowered or not receiving positioning pulses, you can easily turn the output shaft by hand. When the servo is powered and receiving signals, it won't budge from its position.

Application. Driving servos with the BASIC Stamp is simplicity itself. The instruction pulsout pin, time generates a pulse in 10-microsecond (µs) units, so the following code fragment would command a servo to its centered position and hold it there:

```
servo:   pulsout 0,150
         pause 20
         goto servo
```

The 20-ms pause ensures that the program sends the pulse at the standard 50 pulse-per-second rate.

The program listing is a diagnostic tool for working with servos. It has two modes, pulse measurement and pulse generation. Given an input servo signal, such as from a radio-control transmitter/receiver, it displays the pulse width on a liquid-crystal display (LCD). A display of "Pulse Width: 150" indicates a 1.5-ms pulse. Push the button to toggle functions, and the circuit supplies a signal that cycles between 1 and 2 ms. Both the pulse input and output functions are limited to a resolution of 10µs. For most servos, this equates to a resolution of better than 1 degree of rotation.

The program is straightforward Stamp BASIC, but it does take advantage of a couple of the language's handy features. The first of these is the EEPROM directive. EEPROM address,data allows you to stuff tables of data or text strings into EEPROM memory. This takes no additional program time, and only uses the amount of storage required for the data. After the symbols, the first thing that the listing does is tuck a couple of text strings into the bottom of the EEPROM. When the program later needs to display status messages, it loads the text strings from EEPROM.

The other feature of the Stamp's BASIC that the program exploits is the ability to use compound expressions in a let assignment. The routine BCD (for binary-coded decimal) converts one byte of data into three ASCII characters representing values from 0 (represented as "000") to 255.

To do this, BCD performs a series of divisions on the byte and on the remainders of divisions. For example, when it has established how many hundreds are in the byte value, it adds 48, the ASCII offset for zero. Take a look at the listing. The division (/) and remainder (/ /) calculations happen before 48 is added. Unlike larger BASICs which have a precedence of operators (e.g., multiplication is always before addition), the Stamp does its math from left to right. You cannot use parentheses to alter the order, either.

If you're unsure of the outcome of a calculation , use the debug directive to look at a trial run, like so:

```
let BCDin = 200
let huns = BCDin/100+48
debug huns
```

When you download the program to the Stamp, a window will appear on your computer screen showing the value assigned to the variable huns (50). If you change the second line to let huns = 48+BCDin / 100, you'll get a very different result (2).

By the way, you don't have to uselet, but it will earn you Brownie points with serious computer-science types. Most languages other than BASIC make a clear distinction between equals as in huns = BCDin / 100+48 and if BCDin = 100 then...

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http:/ / www.parallaxinc.com.

```
' PROGRAM: Servo.bas
' The Stamp works as a servo test bench. It provides a cycling servo signal
' for testing, and measures the pulse width of external servo signals.

Symbol  E       =   5                     ' Enable pin, 1 = enabled
Symbol  RS      =   4                     ' Register select pin, 0 = instruction
Symbol  char    =   b0                    ' Character sent to LCD.
Symbol  huns    =   b3                    ' BCD hundreds
Symbol  tens    =   b6                    ' BCD tens
Symbol  ones    =   b7                    ' BCD ones
Symbol  BCDin   =   b8                    ' Input to BCD conversion/display
routine.
Symbol  buttn   =   b9                    ' Button workspace
Symbol  i       =   b10                   ' Index counter

' Load text strings into EEPROM at address 0. These will be used to display
' status messages on the LCD screen.
EEPROM 0,("Cycling... Pulse Width: ")

' Set up the Stamp's I/O lines and initialize the  LCD.
begin:  let pins = 0                      ' Clear the output lines
        let dirs = %01111111              ' One input, 7 outputs.
        pause 200                         ' Wait 200 ms for LCD to reset.

' Initialize the LCD in accordance with Hitachi's instructions
' for 4-bit interface.
i_LCD:  let pins = %00000011              ' Set to 8-bit operation.
        pulsout E,1                       ' Send above data three times
        pause 10                          ' to initialize LCD.
        pulsout E,1
        pulsout E,1
        let pins = %00000010              ' Set to 4-bit operation.
        pulsout E,1                       ' Send above data three times.
        pulsout E,1
        pulsout E,1
        let char = 12                     ' Set up LCD in accordance w/
```

```
        gosub wr_LCD                    ' Hitachi instruction manual.
        let char = 6                    ' Turn off cursor, enable
        gosub wr_LCD                    ' left-to-right printing.
        high RS                         ' Prepare to send characters.

' Measure the width of input pulses and display on the LCD.
mPulse: output 3
        gosub clear                     ' Clear the display.
        for i = 11 to 23                ' Read "Pulse Width:" label
          read i, char
          gosub wr_LCD                  ' Print to display
        next
        pulsin 7, 1, BCDin              ' Get pulse width in 10 us units.
        gosub BCD                       ' Convert to BCD and display.
        pause 500
        input 3                         ' Check button; cycle if down.
        button 3,1,255,10,buttn,1,cycle
        goto mPulse                     ' Otherwise, continue measuring.

' Write the ASCII character in b3 to LCD.
wr_LCD: let pins = pins & %00010000
        let b2 = char/16                ' Put high nibble of b3 into b2.
        let pins = pins | b2            ' OR the contents of b2 into pins.
        pulsout E,1                     ' Blip enable pin.
        let b2 = char & %00001111       ' Put low nibble of b3 into b2.
        let pins = pins & %00010000     ' Clear 4-bit data bus.
        let pins = pins | b2            ' OR the contents of b2 into pins.
        pulsout E,1                     ' Blip enable.
        return

clear:  low RS                          ' Change to instruction register.
        let char = 1                    ' Clear display.
        gosub wr_LCD                    ' Write instruction to LCD.
        high RS                         ' Put RS back in character mode.
        return

' Convert a byte into three ASCII digits and display them on the LCD.
' ASCII 48 is zero, so the routine adds 48 to each digit for display on the LCD.
BCD:    let huns= BCDin/100+48          ' How many hundreds?
        let tens= BCDin//100            ' Remainder of #/100 = tens+ones.
        let ones= tens//10+48           ' Remainder of (tens+ones)/10 = ones.
        let tens= tens/10+48            ' How many tens?
        let char= huns                  ' Display three calculated digits.
        gosub wr_LCD
        let char = tens
        gosub wr_LCD
        let char = ones
        gosub wr_LCD
        return
```

1

```
' Cycle the servo back and forth between 0 and 90 degrees. Servo moves slowly ' in
one direction (because of 20-ms delay between changes in pulse width) and quickly
' in the other. Helps diagnose stuck servos, dirty feedback pots, etc.
cycle:   output 3
         gosub clear
         for i = 0 to 9                       ' Get "Cycling..." string and
           read i, char                       ' display it on LCD.
           gosub wr_LCD
         next i
reseti:  let i = 100                          ' 1 ms pulse width.
cyloop:  pulsout 6,i                          ' Send servo pulse.
         pause 20                             ' Wait 1/50th second.
         let i = i + 2                        ' Move servo.
         if i > 200 then reseti               ' Swing servo back to start position.
         input 3                              ' Check the button; change function if
                                              ' down.
         button 3,1,255,10,buttn,1,mPulse
         goto cyloop                          ' Otherwise, keep cycling.
```

Introduction. This application note explores several applications for the BASIC Stamp's unique pulsin command, which measures the duration of incoming positive or negative pulses in 10-microsecond units.

Background. The BASIC Stamp's pulsin command measures the width of a pulse, or the interval between two pulses. Left at that, it might seem to have a limited range of obscure uses. However, pulsin is the key to many kinds of real-world interfacing using simple, reliable sensors. Some possibilities include:

tachometer
speed trap
physics demonstrator
capacitance checker
duty cycle meter
log input analog-to-digital converter

Pulsin works like a stopwatch that keeps time in units of 10 microseconds (µs). To use it, you must specify which pin to monitor, when to trigger on (which implies when to trigger off), and where to put the resulting 16-bit time measurement. The syntax is as follows:

pulsin *pin, trigger condition, variable*

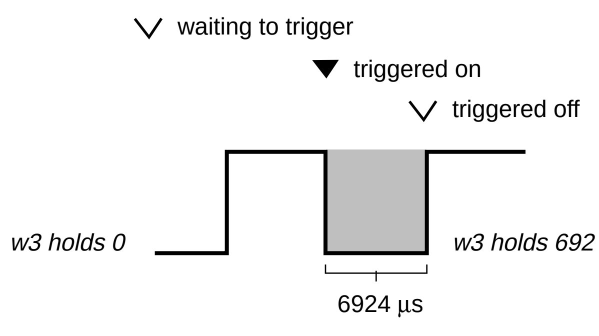


Figure 1. Timing diagram for `pulsin 7,0,w3`.

Pin is a BASIC Stamp input/output pin (0 to 7). Trigger condition is a variable or constant (0 or 1) that specifies the direction of the transition that will start the pulsin timer. If trigger is 0, pulsin will start measuring when a high-to-low transition occurs, because 0 is the edge's destination. Variable can be either a byte or word variable to hold the timing measurement. In most cases, a word variable is called for, because pulsin produces 16-bit results.

Figure 1 shows how pulsin works. The waveform represents an input at pin 7 that varies between ground and +5 volts (V).

A smart feature of pulsin is its ability to recognize a no-pulse or out-of-range condition. If the specified transition doesn't occur within 0.65535 seconds (s), or if the pulse to be measured is longer than 0.65535 s, pulsin will give up and return a 0 in the variable. This prevents the program from hanging up when there's no input or out-of-range input.

Let's look at some sample applications for pulsin, starting with one inspired by the digital readout on an exercise bicycle: pulsin as a tachometer.

Tachometer. The most obvious way to measure the speed of a wheel or shaft in revolutions per minute (rpm) is to count the number of

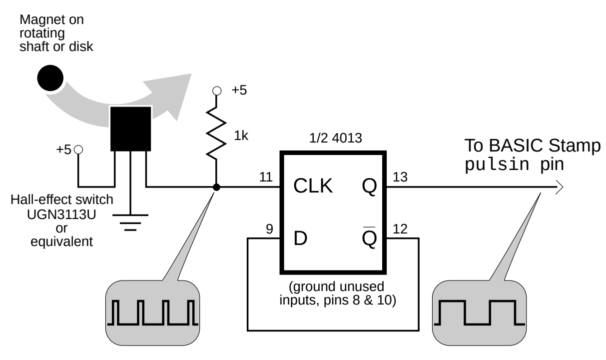


Figure 2. Schematic to accompany listing 1, TACH.BAS.

revolutions that occur during 1 minute. The trouble is, the user probably wouldn't want to wait a whole minute for the answer.

For a continuously updated display, we can use pulsin to measure the time the wheel takes to make one complete revolution. By dividing this time into 60 seconds, we get a quick estimate of the rpm. Listing 1 is a tachometer program that works just this way. Figure 2 is the circuit that provides input pulses for the program. A pencil-eraser-sized magnet attached to the wheel causes a Hall-effect switch to generate a pulse every rotation.

We could use the Hall switch output directly, by measuring the interval between positive pulses, but we would be measuring the period of rotation minus the pulses. That would cause small errors that would be most significant at high speeds. The flip-flop, wired to toggle with each pulse, eliminates the error by converting the pulses into a train of square waves. Measuring either the high or low interval will give you the period of rotation.

Note that listing 1 splits the job of dividing the period into 60 seconds into two parts. This is because 60 seconds expressed in 10-µs units is 6 million, which exceeds the range of the Stamp's 16-bit calculations. You will see this trick, and others that work around the limits of 16-bit math, throughout the listings.

Using the flip-flop's set/reset inputs, this circuit and program could easily be modified to create a variety of speed-trap instruments. A steel ball rolling down a track would encounter two pairs of contacts to set and reset the flip-flop. Pulsin would measure the interval and compute the speed for a physics demonstration (acceleration). More challenging setups would be required to time baseballs, remote-control cars or aircraft, bullets, or model rockets.

The circuit could also serve as a rudimentary frequency meter. Just divide the period into 1 second instead of 1 minute.

Duty cycle meter. Many electronic devices vary the power they deliver to a load by changing the duty cycle of a waveform; the proportion of time that the load is switched fully on to the time it is fully off. This approach, found in light dimmers, power supplies, motor controls and amplifiers, is efficient and relatively easy to implement with digital components. Listing 2 measures the duty cycle of a repetitive pulse train by computing the ratio of two pulsin readings and presenting them as a percentage. A reading approaching 100 percent means that the input is mostly on or high. The output of figure 2's flip-flop is 50 percent. The output of the Hall switch in figure 2 was less than 10 percent when the device was monitoring a benchtop drill press.

Capacitor checker. The simple circuit in figure 3 charges a capacitor, and then discharges it across a resistance when the button is pushed. This produces a brief pulse for pulsin to measure. Since the time constant of the pulse is determined by resistance (R) times capacitance (C), and R is fixed at 10k, the width of the pulse tells us C. With the resistance values listed, the circuit operates over a range of .001 to 2.2 µF. You may substitute other resistors for other ranges of capacitance; just

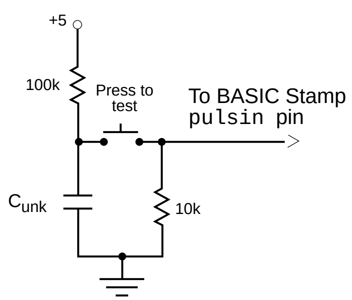


Figure 3. Schematic for listing 3, CAP.BAS.

be sure that the charging resistor (100k in this case) is about 10 times the value of the discharge resistor. This ensures that the voltage at the junction of the two resistors when the switch is held down is a definite low (0) input to the Stamp.

Log-input analog-to-digital converter (ADC). Many sensors have convenient linear outputs. If you know that an input of 10 units (degrees, pounds, percent humidity, or whatever) produces an output of 1 volt, then 20 units will produce 2 volts. Others, such as thermistors

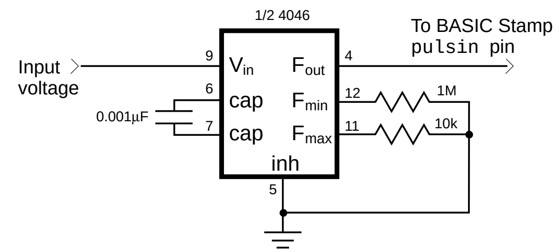


Figure 4. Schematic for listing 4, VCO.BAS.

and audio-taper potentiometers, produce logarithmic outputs. A Radio Shack thermistor (271-110) has a resistance of 18k at 10° C and 12k at 20°C. Not linear, and not even the worst cases!

While it's possible to straighten out a log curve in software, it's often

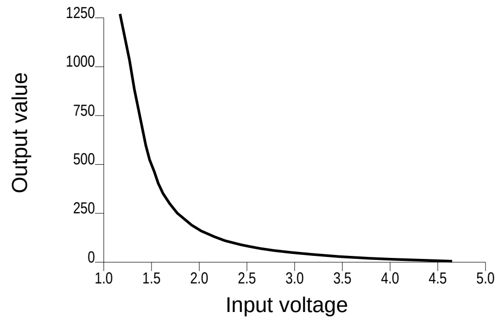


Figure 5. Log response curve of the VCO.

easier to deal with it in hardware. That's where figure 4 comes in. The voltage-controlled oscillator of the 4046 phase-locked loop chip, when wired as shown, has a log response curve. If you play this curve against a log input, you can effectively straighten the curve. Figure 5 is a plot of the output of the circuit as measured by the pulsin program in listing 4. It shows the characteristic log curve.

The plot points out another advantage of using a voltage-controlled oscillator as an ADC; namely, increased resolution. Most inexpensive ADCs provide eight bits of resolution (0 to 255), while the VCO provides the equivalent of 10 bits (0 to 1024+). Admittedly, a true ADC would provide much better accuracy, but you can't touch one for anywhere near the 4046's sub-$1 price.

The 4046 isn't the only game in town, either. Devices that can convert analog values, such as voltage or resistance, to frequency or pulse width include timers (such as the 555) and true voltage-to-frequency converters (such as the 9400). For sensors that convert some physical property such as humidity or proximity into a variable capacitance or inductance, pulsin is a natural candidate for sampling their output via an oscillator or timer.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

A Note about the Program Listings

All of the listings output results as serial data. To receive it, connect Stamp pin 0 to your PC's serial input, and Stamp ground to signal ground. On 9-pin connectors, pin 2 is serial in and pin 5 is signal ground; on 25-pin connectors, pin 3 is serial in and pin 7 is signal ground. Set terminal software for 8 data bits, no parity, 1 stop bit.

```
' Listing 1: TACH.BAS
' The BASIC Stamp serves as a tachometer. It accepts pulse input through pin 7,
' and outputs rpm measurements at 2400 baud through pin 0.
        input 7
        output 0
Tach:   pulsin 7,1,w2 ' Read positive-going pulses on pin 7.
        let w2 = w2/100                 ' Dividing w2/100 into 60,000 is the
                                        ' same as dividing
        let w2 = 60000/w2               ' w2 into 6,000,000 (60 seconds in 10
                                        ' us units).
```

```
' Transmit data followed by carriage return and linefeed.
          serout 0,N2400,(#w2," rpm",10,13)
          pause 1000                         ' Wait 1 second between readings
          goto Tach
```

```
' Listing 2: DUTY.BAS
' The BASIC Stamp calculates the duty cycle of a repetitive pulse train.
' Pulses in on pin 7; data out via 2400-baud serial on pin 0.
          input 7
          output 0
Duty:     pulsin 7,1,w2                      ' Take positive pulse sample.
          if w2 > 6553 then Error            ' Avoid overflow when w2 is multiplied
by 10.
          pulsin 7,0,w3                      ' Take negative pulse sample.
          let w3 = w2+w3
          let w3 = w3/10                     ' Distribute multiplication by 10 into two
          let w2 = w2*10                     ' parts to avoid an overflow.
          let w2 = w2/w3                     ' Calculate percentage.
          serout 0,N2400,(#w2," percent",10,13)
          pause 1000                         ' Update once a second.
          goto Duty

' Handle overflows by skipping calculations and telling the user.
Error:    serout 0,N2400,("Out of range",10,13)
          pause 1000
          goto Duty
```

```
' Listing 3: CAP.BAS
' The BASIC Stamp estimates the value of a capacitor by the time required for it to
' discharge through a known resistance.
          input 7
          output 0
Cap:      pulsin 7,1,w1
          if w1 = 0 then Cap                 ' If no pulse, try again.
          if w1 > 6553 then Err              ' Avoid overflows.
          let w1 = w1*10
          let w1 = w1/14                     ' Apply calibration value.
          if w1 > 999 then uF                ' Use uF for larger caps.
          serout 0,N2400,(#w1," nF",10,13)
          goto Cap

uF:       let b4 = w1/1000                   ' Value left of decimal point.
          let b6 = w1//1000                  ' Value right of decimal point.
          serout 0,N2400,(#b4,".",#b6," uF",10,13)
          goto Cap
```

1

```
Err:    serout 0,N2400,("out of range",10,13)
        goto Cap
```

```
' Listing 4: VCO.BAS
' The BASIC Stamp uses input from the VCO of a 4046 phase-locked loop as a
logarithmic
' A-to-D converter. Input on pin 7; 2400-baud serial output on pin 0.
        input 7
        output 0
VCO:    pulsin 7,1,w2 ' Put the width of pulse on pin 7 into w2.
        let w2 = w2-45                  ' Allow a near-zero minimum value
                                        ' without underflow.
        serout 0,N2400,(#w2,10,13)
        pause 1000                      ' Wait 1 second between measure-
                                        ' ments.
        goto VCO
```

Introduction. This application note demonstrates simple hardware and software techniques for driving and controlling common four-coil stepper motors.

Background. Stepper motors translate digital switching sequences into motion. They are used in printers, automated machine tools, disk drives, and a variety of other applications requiring precise motions under computer control.

Unlike ordinary dc motors, which spin freely when power is applied, steppers require that their power source be continuously pulsed in specific patterns. These patterns, or step sequences, determine the speed and direction of a stepper's motion. For each pulse or step input, the stepper motor rotates a fixed angular increment; typically 1.8 or 7.5 degrees.

The fixed stepping angle gives steppers their precision. As long as the motor's maximum limits of speed or torque are not exceeded, the controlling program knows a stepper's precise position at any given time.

Steppers are driven by the interaction (attraction and repulsion) of magnetic fields. The driving magnetic field "rotates" as strategically placed coils are switched on and off. This pushes and pulls at permanent magnets arranged around the edge of a rotor that drives the output

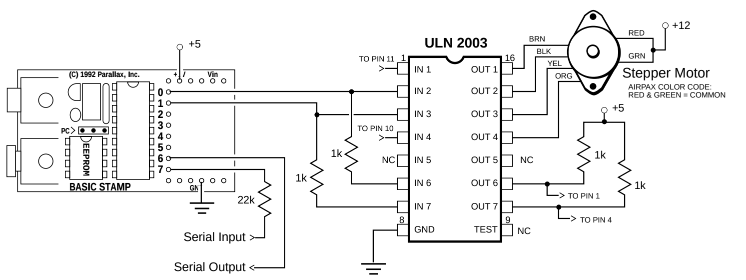


Figure 1. Schematic for the serial stepper controller.

shaft. When the on-off pattern of the magnetic fields is in the proper sequence, the stepper turns (when it's not, the stepper sits and quivers).

The most common stepper is the four-coil unipolar variety. These are called unipolar because they require only that their coils be driven on and off. Bipolar steppers require that the polarity of power to the coils be reversed.

The normal stepping sequence for four-coil unipolar steppers appears in figure 2. There are other, special-purpose stepping sequences, such as half-step and wave drive, and ways to drive steppers with multi-phase analog waveforms, but this application concentrates on the normal sequence. After all, it's the sequence for which all of the manufacturer's specifications for torque, step angle, and speed apply.

	Step Sequence				
	1	2	3	4	1
coil 1	1	1	0	0	1
coil 2	0	0	1	1	0
coil 3	1	0	0	1	1
coil 4	0	1	1	0	0

Figure 2. Normal stepping sequence.

If you run the stepping sequence in figure 2 forward, the stepper rotates clockwise; run it backward, and the stepper rotates counterclockwise. The motor's speed depends on how fast the controller runs through the step sequence. At any time the controller can stop in mid sequence. If it leaves power to any pair of energized coils on, the motor is locked in place by their magnetic fields. This points out another stepper motor benefit: built-in brakes.

Many microprocessor stepper drivers use four output bits to generate the stepping sequence. Each bit drives a power transistor that switches on the appropriate stepper coil. The stepping sequence is stored in a lookup table and read out to the bits as required.

This design takes a slightly different approach. First, it uses only two output bits, exploiting the fact that the states of coils 1 and 4 are always the inverse of coils 2 and 3. Look at figure 2 again. Whenever coil 2 gets a 1, coil 1 gets a 0, and the same holds for coils 3 and 4. In Stamp designs, output bits are too precious to waste as simple inverters, so we give that job to two sections of the ULN2003 inverter / driver.

The second difference between this and other stepper driver designs is that it calculates the stepping sequence, rather than reading it out of a table. While it's very easy to create tables with the Stamp, the calculations required to create the two-bit sequence required are very simple. And reversing the motor is easier, since it requires only a single additional program step. See the listing.

How it works. The stepper controller accepts commands from a terminal or PC via a 2400-baud serial connection. When power is first applied to the Stamp, it sends a prompt to be displayed on the terminal screen. The user types a string representing the direction (+ for forward, – for backward), number of steps, and step delay (in milliseconds), like this:

```
step>+500 20
```

As soon as the user presses enter, return, or any non-numerical character at the end of the line, the Stamp starts the motor running. When the stepping sequence is over, the Stamp sends a new step> prompt to the terminal. The sample command above would take about 10 seconds (500 x 20 milliseconds). Commands entered before the prompt reappears are ignored.

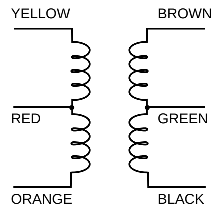


Figure 3. Color code for Airpax steppers.

On the hardware side, the application accepts any stepper that draws 500 mA or less per coil. The schematic shows the color code for an Airpax-brand stepper, but there is no standardization among different brands. If you use another stepper, use figure 3 and an ohmmeter to translate the color code. Connect the stepper and give it a try. If it vibrates instead of turning, you have one or more coils connected incorrectly. Patience and a little experimentation will prevail.

Program listing: As with the other application notes, this program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program STEP.BAS
' The Stamp accepts simply formatted commands and drives a four-coil stepper.
Commands
' are formatted as follows: +500 20<return> means rotate forward 500 steps with 20
' milliseconds between steps. To run the stepper backward, substitute - for +.

Symbol    Directn = b0
Symbol    Steps = w1
Symbol    i = w2
Symbol    Delay = b6
Symbol    Dir_cmd = b7

          dirs = %01000011 : pins = %00000001 ' Initialize output.
          b1 = %00000001 : Directn = "+"
          goto Prompt                          ' Display prompt.

' Accept a command string consisting of direction (+/-), a 16-bit number
' of steps, and an 8-bit delay (milliseconds) between steps. If longer
' step delays are required, just command 1 step at a time with long
' delays between commands.

Cmd:      serin 7,N2400,Dir_cmd,#Steps,#Delay  ' Get orders from terminal.
          if Dir_cmd = Directn then Stepit     ' Same direction? Begin.
          b1 = b1^%00000011
' Else reverse (invert b1).

Stepit:   for i = 1 to Steps
' Number of steps.
          pins = pins^b1
' XOR output with b1, then invert b1
          b1 = b1^%00000011
' to calculate the stepping sequence.
          pause Delay                          ' Wait commanded delay between
                                               ' steps.
          next
          Directn = Dir_cmd
' Direction = new direction.

Prompt:   serout 6,N2400,(10,13,"step> ")      ' Show prompt, send return
          goto Cmd                             ' and linefeed to terminal.
```

Introduction. This application note shows how to measure temperature using an inexpensive thermistor and the BASIC Stamp's pot command. It also discusses a technique for correcting nonlinear data.

Background. Radio Shack offers an inexpensive and relatively precise thermistor—a component whose resistance varies with temperature. The BASIC Stamp has the built-in ability to measure resistance with the pot command and an external capacitor. Put them together, and your Stamp can measure the temperature, right? Not without a little math.

The thermistor's resistance decreases as the temperature increases, but this response is not linear. There is a table on the back of the thermistor package that lists the resistance at various temperatures in degrees celsius (°C). For the sake of brevity, we won't reproduce that table here, but the lefthand graph of figure 1 shows the general shape of the thermistor response curve in terms of the more familiar Fahrenheit scale (°F).

The pot command throws us a curve of its own, as shown in figure 1 (right). Though not as pronounced as the thermistor curve, it must be figured into our temperature calculations in order for the results to be usable.

One possibility for correcting the combined curves of the thermistor and pot command would be to create a lookup table in the Stamp's EEPROM. The table would have to be quite large to cover a reasonable temperature range at 1° precision. An alternative would be to create a smaller table at 10° precision, and figure where a particular reading

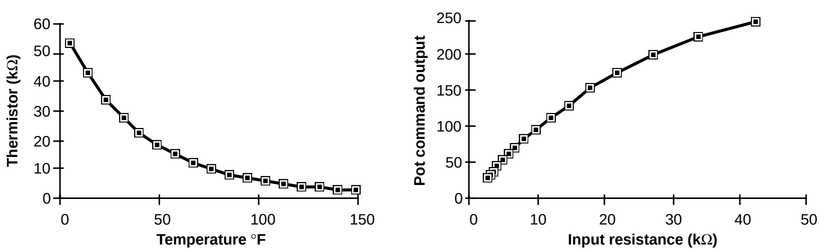


Figure 1. Response curves of the thermistor and pot command.

might lie within its 10° range. This is interpolation, and it can work quite well. It would still use quite a bit of the Stamp's limited EEPROM space, though.

Another approach, the one used in the listing, is to use a power-series polynomial to model the relationship between the `pot` reading and temperature. This is easier than it sounds, and can be applied to many nonlinear relationships.

Step 1: Prepare a table. The first step is to create a table of a dozen or so inputs and outputs. The inputs are resistances and outputs are temperatures in °F. Resistance values in this case are numbers returned by the `pot` function. To equate `pot` values with temperatures, we connected a 50k pot and a 0.01 µF capacitor to the Stamp and performed the calibration described in the Stamp manual. After obtaining a scale factor, we pressed the space bar to lock it in.

Now we could watch the pot value change as the potentiometer was adjusted. We disconnected the potentiometer from the Stamp and hooked it to an ohmmeter. After setting the potentiometer to 33.89k (corresponding to a thermistor at 23 °F or –5 °C), we reconnected it to the Stamp, and wrote down the resulting reading. We did this for each of the calibration values on the back of the thermistor package, up to 149 °F (65 °C).

Step 2: Determine the coefficients. The equation that can approximate our nonlinear temperature curve is:

$$\text{Temperature} = C0 + C1 \bullet (\text{Pot Val}) + C2 \bullet (\text{Pot Val})^2 + C3 \bullet (\text{Pot Val})^3$$

where C0, C1, C2, and C3 are coefficients supplied by analytical software, and each $Cn \bullet (\text{Pot Val})^n$ is called a term. The equation above has three terms, so it is called a third-order equation. Each additional term increases the range over which the equation's results are accurate. You can increase or decrease the number of terms as necessary, but each additional coefficient requires that Pot Val be raised to a higher power. This can make programming messy, so it pays to limit the number of terms to the fewest that will do the job.

The software that determines the coefficients is called GAUSFIT.EXE and is available from the Parallax ftp site. To use it, create a plain text file called GF.DAT. In this file, which should be saved to the same subdirectory as GAUSFIT, list the inputs and outputs in the form in,out<return>. If there are values that require particular precision, they may be listed more than once. We wanted near-room-temperature values to be right on, so we listed 112,68 (pot value at 68 °F) several times.

To run the program, type GAUSFIT n where n is the number of terms desired. The program will compute coefficients and present you with a table showing how the computed data fits your samples. The fit will be good in the middle, and poorer at the edges. If the edges are unacceptable, you can increase the number of terms. If they are OK, try rerunning the program with fewer terms. We were able to get away with just two terms by allowing accuracy to suffer outside a range of 50 °F to 90 °F.

Step 3: Factor the coefficients. The coefficients that GAUSFIT produces are not directly useful in a BASIC Stamp program. Our coefficients were: C0 = 162.9763, C1 = –1.117476, and C2 = 0.002365991. We plugged the values into a spreadsheet and computed temperatures from pot values and then started playing with the coefficients. We found that the following coefficients worked almost as well as the originals: C0 = 162, C1 = –1.12, and C2 = 0.0024.

The problem that remained was how to use these values in a Stamp program. The Stamp deals in only positive integers from 0 to 65,535. The trick is to express the numbers to the right of the decimal point as fractions. For example, the decimal number 0.75 can be expressed as 3 / 4. So to multiply a number by 0.75 with the BASIC Stamp, first multiply the number by 3, then divide the result by 4. For less familiar decimal values, it may take some trial and error to find suitable fractions. We found that the 0.12 portion of C1 was equal to 255 / 2125, and that C2 (0.0024) = 3 / 1250.

Step 4: Plan the order of execution. Just substituting the fractions for the decimal portions of the formula still won't work. The problem is that portions of terms, such as 3 • Pot Val2 / 1250, can exceed the 65,535 limit. If Pot Val were 244, then $3 \cdot 244^2$ would equal 178,608; too high.

The solution is to factor the coefficients and rearrange them into smaller problems that can be solved within the limit. For example (using PV to stand for Pot Val):

$$\frac{PV*PV*3}{1250} = \frac{PV*PV*3}{5*5*5*5*2} = \frac{PV}{25} * \frac{PV*3}{50}$$

The program in the listing is an example of just such factoring and rearrangement. Remember to watch out for the lower limit as well. Try to keep intermediate results as high as possible within the Stamp's integer limits. This will reduce the effect of truncation errors (where any value to the right of the decimal point is lost).

Conclusion. The finished program, which reports the temperature to the PC screen via the debug command, is deceptively simple. An informal check of its output found that it tracks within 1 °F of a mercury / glass bulb thermometer in the range of 60 °F to 90 °F. Additional range could be obtained at the expense of a third-order equation; however, current performance is more than adequate for use in a household thermostat or other noncritical application. Cost and complexity are far less than that of a linear sensor, precision voltage reference, and analog-to-digital converter.

If you adapt this application for your own use, component tolerances will probably produce different results. However, you can calibrate the program very easily. Connect the thermistor and a stable, close-tolerance 0.1-µF capacitor to the Stamp as shown in figure 2. Run the program and note the value that appears in the debug window. Compare it to a known accurate thermometer located close to the thermistor. If the thermometer says 75 and the Stamp 78, reduce the value of C0 by 3. If the thermometer says 80 and the Stamp 75, increase the value of C0 by 5. This works because the relationship between the thermistor resistance and the temperature is the same, only the value of the capacitor is different. Adjusting C0 corrects this offset.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

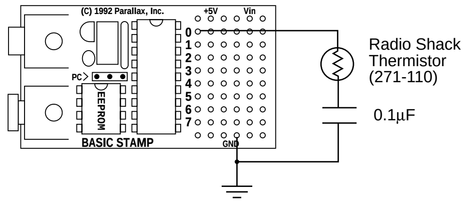


Figure 2. Schematic to accompany THERM.BAS.

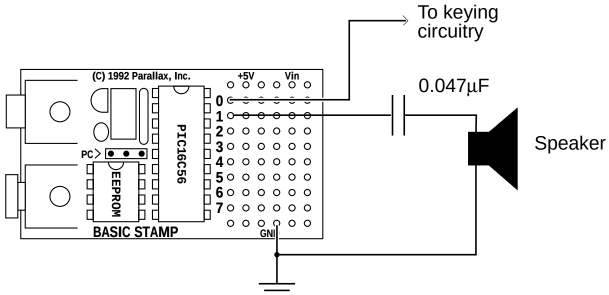

```
' Program THERM.BAS
' This program reads a thermistor with the BASIC
' pot command, computes the temperature using a
' power-series polynomial equation, and reports
' the result to a host PC via the Stamp cable
' using the debug command.

' Symbol constants represent factored portions of
' the coefficients C0, C1, and C2. "Top" and "btm"
' refer to the values' positions in the fractions;
' on top as a multiplier or on the bottom as a
' divisor.
Symbol co0    = 162
Symbol co1top = 255
Symbol co1btm = 2125
Symbol co2bt1 = 25
Symbol co2top = 3
Symbol co2btm = 50

' Program loop.
Check_temp:
        pot 0,46,w0                     ' 46 is the scale factor.

' Remember that Stamp math is computed left to
' right--no parentheses, no precedence of
' operators.
        let w1 = w0*w0/co2bt1*co2top/co2btm
        let w0 = w0*co1top/co1btm+w0
        let w0 = co0+w1-w0
        debug w0
        pause 1000                      ' Wait 1 second for next
goto Check_temp                         ' temperature reading.
```

Introduction. This application note presents a technique for using the BASIC Stamp to send short messages in Morse code. It demonstrates the Stamp's built-in `lookup` and `sound` commands.

Background. Morse code is probably the oldest serial communication protocol still in use. Despite its age, Morse has some virtues that make it a viable means of communication. Morse offers inherent compression; the letter E is transmitted in one-thirteenth the time required to send the letter Q. Morse requires very little transmitting power and bandwidth compared to other transmitting methods. And Morse may be sent and received by either human operators or automated equipment.

Although Morse has fallen from favor as a means for sending large volumes of text, it is still the legal and often preferred way to identify automated repeater stations and beacons. The BASIC Stamp, with its ease of programming and minuscule power consumption, is ideal for this purpose.

The characters of the Morse code are represented by sequences of long and short beeps known as dots and dashes (or dits and dahs). There are one to six beeps or elements in the characters of the standard Morse code. The first step in writing a program to send Morse is to devise a compact way to represent sequences of elements, and an efficient way to play them back.



Schematic to accompany program MORSE.BAS.

The table on the next page shows the encoding scheme used in this program. A single byte represents a Morse character. The highest five bits of the byte represent the actual dots(0s) and dashes (1s), while the lower three bits represent the number of elements in the character. For example, the letter F is dot dot dash dot, so it is encoded 0010x100, where x is a don't-care bit. Since Morse characters can contain up to six elements, we have to handle the exceptions. Fortunately, we have some excess capacity in the number-of-elements portion of the byte, which can represent numbers up to seven. So we assign a six-element character ending in a dot the number six, while a six-element character ending in a dash gets the number seven.

The program listing shows how these bytes can be played back to produce Morse code. The table of symbols at the beginning of the program contain the timing data for the dots and dashes themselves. If you want to change the program's sending speed, just enter new values for `dit_length`, `dah_length`, etc. Make sure to keep the timing

Morse Characters and their Encoded Equivalents

Char	Morse	Binary	Decimal	Char	Morse	Binary	Decimal
A	¥Đ	01000010	66	S	¥¥¥	00000011	3
B	Đ¥¥¥	10000100	132	T	Đ	10000001	129
C	Đ¥Đ¥	10100100	164	U	¥¥Đ	00100011	35
D	Đ¥¥	10000011	131	V	¥¥¥Đ	00010100	20
E	¥	00000001	1	W	¥ĐĐ	01100011	99
F	¥¥Đ¥	00100100	36	X	Đ¥¥Đ	10010100	148
G	ĐĐ¥	11000011	195	Y	Đ¥ĐĐ	10110100	180
H	¥¥¥¥	00000100	4	Z	ĐĐ¥¥	11000100	196
I	¥¥	00000010	2	0	ĐĐĐĐĐ	11111101	253
J	¥ĐĐĐ	01110100	116	1	¥ĐĐĐĐ	01111101	125
K	Đ¥Đ	10100011	163	2	¥¥ĐĐĐ	00111101	61
L	¥Đ¥¥	01000100	68	3	¥¥¥ĐĐ	00011101	29
M	ĐĐ	11000010	194	4	¥¥¥¥Đ	00001101	13
N	Đ¥	10000010	130	5	¥¥¥¥¥	00000101	5
O	ĐĐĐ	11100011	227	6	Đ¥¥¥¥	10000101	133
P	¥ĐĐ¥	01100100	100	7	ĐĐ¥¥¥	11000101	197
Q	ĐĐ¥Đ	11010100	212	8	ĐĐĐ¥¥	11100101	229
R	¥Đ¥	01000011	67	9	ĐĐĐĐ¥	11110101	245

relationships roughly the same; a dash should be about three times as long as a dot.

The program uses the BASIC Stamp's `lookup` function to play sequences of Morse characters. `Lookup` is a particularly modern feature of Stamp BASIC in that it is an object-oriented data structure. It not only contains the data, it also "knows how" to retrieve it.

Modifications. The program could readily be modified to transmit messages whenever the Stamp detects particular conditions, such as "BATTERY LOW." With some additional programming and analog-to-digital hardware, it could serve as a low-rate telemetry unit readable by either automated or manual means.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program MORSE.BAS
' This program sends a short message in Morse code every
' minute. Between transmissions, the Stamp goes to sleep
' to conserve battery power.
Symbol  Tone = 100
Symbol  Quiet = 0
Symbol  Dit_length = 7                  ' Change these constants to
Symbol  Dah_length = 21                 ' change speed. Maintain ratios
Symbol  Wrd_length = 42                 ' 3:1 (dah:dit) and 7:1 (wrd:dit).
Symbol  Character = b0
Symbol  Index1 = b6
Symbol  Index2 = b2
Symbol  Elements = b4

Identify:
output  0: output 1
for Index1 = 0 to 7
' Send the word "PARALLAX" in Morse:
        lookup Index1,(100,66,67,66,68,68,66,148),Character
        gosub Morse
next
sleep 60
goto Identify

Morse:
```

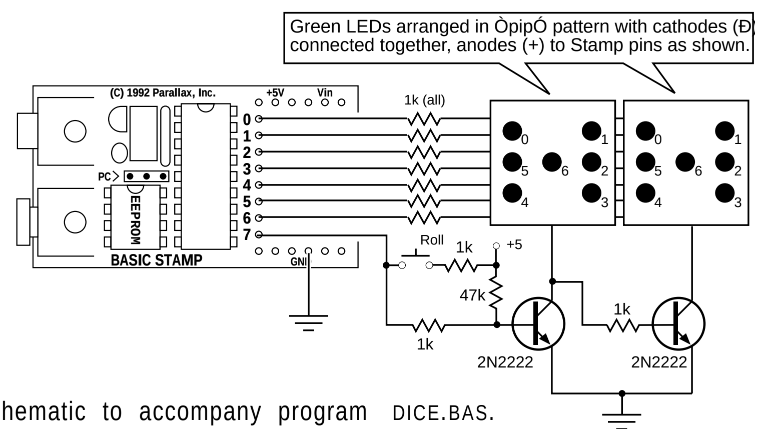
```
let Elements = Character & %00000111
if Elements = 7 then Adjust1
if Elements = 6 then Adjust2
Bang_Key:
for Index2 = 1 to Elements
        if Character >= 128 then Dah
        goto Dit
  Reenter:
        let Character = Character * 2
next
gosub char_sp
return
Adjust1:
Elements = 6
goto Bang_Key

Adjust2:
Character = Character & %11111011
goto Bang_Key
end

Dit:
high 0
sound 1,(Tone,Dit_length)
low 0
sound 1,(Quiet,Dit_length)
goto Reenter

Dah:
high 0
sound 1,(Tone,Dah_length)
low 0
sound 1,(Quiet,Dit_length)
goto Reenter

Char_sp:
sound 1,(Quiet,Dah_length)
return

Word_sp:
sound 1,(Quiet,Wrd_length)
return
```

Introduction. This application note describes an electronic dice game based on the BASIC Stamp. It shows how to connect LED displays to the Stamp, and how to multiplex inputs and outputs on a single Stamp pin.

Background. Much of BASIC's success as a programming language is probably the result of its widespread use to program games. After all, games are just simulations that happen to be fun.

How it works. The circuit for the dice game uses Stamp pins 0 through 6 to source current to the anodes of two sets of seven LEDs. Pin 7 and the switching transistors determine which set of LEDs is grounded. Whenever the lefthand LEDs are on, the right are off, and vice versa. To light up the LEDs, the Stamp puts die1's pattern on pins 0-6, and enables die1 by making pin 7 high. After a few milliseconds, it puts die2's pattern on pins 0-6 and takes pin 7 low to enable die2.

In addition to switching between the dice, pin 7 also serves as an input for the press-to-roll pushbutton. The program changes the pin to an input and checks its state. If the switch is up, a low appears on pin 7 because the base-emitter junction of the transistor pulls it down to about 0.7 volts. If the switch is pressed, a high appears on pin 7. The 1k resistor puts a high on pin 7 when it is an input, but pin 7 is still able to pull the base of the transistor low when it is an output. As a result, holding the switch down doesn't affect the Stamp's ability to drive the display.



Schematic to accompany program DICE.BAS.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program DICE.BAS
' An electonic dice game that uses two sets of seven LEDs
' to represent the pips on a pair of dice.

Symbol   die1 = b0                      ' Store number (1-6) for first die.
Symbol   die2 = b1                      ' Store number (1-6) for ssecond die.
Symbol   shake = w3                     ' Random word variable
Symbol   pippat = b2                    ' Pattern of "pips" (dots) on dice.
Symbol   Select = 7                     ' Pin number of select transistors.

high Select
let dirs = 255                          ' All pins initially outputs.
let die1 = 1                            ' Set lucky starting value for dice (7).
let die2 = 4                            ' (Face value of dice = die1+1, die2+1.)

Repeat:                                 ' Main program loop.
let pippat = die1
gosub Display                           ' Display die 1 pattern.
let pippat = die2                       ' Now die 2.
gosub Display
input Select                            ' Change pin 7 to input.
if pin7 = 1 then Roll                   ' Switch closed? Roll the dice.
let w3 = w3+1                           ' Else stir w3.
Reenter:                                ' Return from Roll subroutine.
output Select                           ' Restore pin 7 to output.
goto Repeat

Display:                                ' Look up pip pattern.
lookup pippat,(64,18,82,27,91,63),pippat
let pins = pins&%10000000
toggle Select                           ' Invert Select.
let pins = pins|pippat                  ' OR pattern into pins.
pause 4                                 ' Leave on 4 milliseconds.
return

Roll:
random shake                            ' Get random number.
let die1 = b6&%00000111                 ' Use lower 3 bits of each byte.
let die2 = b7&%00000111
if die1 > 5 then Roll                   ' Throw back numbers over 5 (dice>6).
if die2 > 5 then Roll
goto Reenter                            ' Back to the main loop.
```

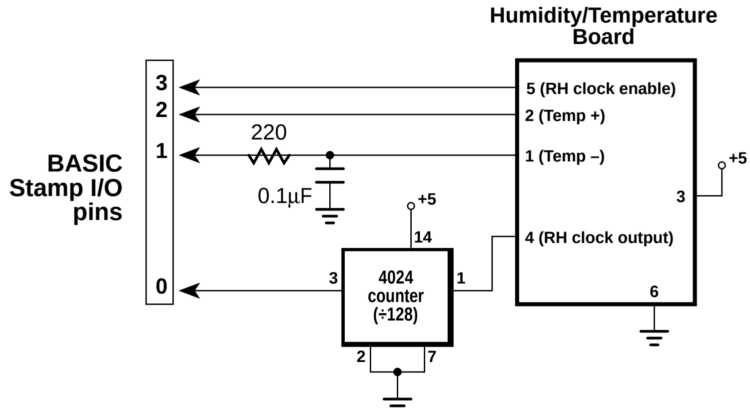
Introduction. This application note shows how to interface an inexpensive humidity / temperature sensor kit to the Stamp.

Background. When it's hot, high humidity makes it seem hotter. When it's cold, low humidity makes it seem colder. In areas where electronic components are handled, low humidity increases the risk of electrostatic discharge (ESD) and damage. The relationship between temperature and humidity is a good indication of the efficiency of heavy-duty air-conditioning equipment that uses evaporative cooling.

Despite the value of knowing temperature and humidity, it can be hard to find suitable humidity sensors. This application solves that problem by borrowing a sensor kit manufactured for computerized home weather stations.

The kit, available from the source listed at the end of this application note for $25, consists of fewer than a dozen components and a small (0.5" x 2.75") printed circuit board. Assembly entails soldering the components to the board. When it's done, you have two sensors: a temperature-dependent current source and a humidity-dependent oscillator.

Once the sensor board is complete, connect it to the Stamp using the circuit shown in the figure and download the software in the listing. The



Schematic to accompany program HUMID.BAS.

debug window will appear on your PC screen showing values representing humidity and temperature. To get a feel for the board's sensitivity, try this: Breathe on the sensor board and watch the debug values change. The humidity value should increase dramatically, while the temperature number (which decreases as the temperature goes up) will fall a few counts.

How it works. The largest portion of the program is devoted to measuring the temperature, so we'll start there. The temperature sensor is an LM334Z constant-current source. Current through the device varies at the rate of 0.1µA per 1° C change in temperature. The program in the listing passes current from pin 2 of the Stamp through the sensor to a capacitor for a short period of time, starting with 5000 µs. It then checks the capacitor's state of charge through pin 1. If the capacitor is not charged enough for pin 1 to see a logical 1, the Stamp discharges the capacitor and tries again, with a slightly wider pulse of 5010 µs.

It stays in a loop, charging, checking, discharging, and increasing the charging pulse until the capacitor shows as a 1 on pin 1's input. Since the rate of charge is proportional to current, and the current is proportional to temperature, the width of the pulse that charges the capacitor is a relative indication of temperature.

Sensing humidity is easier, thanks to the design of the kit's hardware. The humidity sensor is a capacitor whose value changes with relative humidity (RH). At a relative humidity of 43 percent and a temperature of 77° F, the sensor has a value of 122 pF ± 15 percent. Its value changes at a rate of 0.4 pF ± 0.05 pF for each 1-percent change in RH.

The sensor controls the period of a 555 timer wired as a clock oscillator. The clock period varies from 225 µs at an arid 10-percent RH to 295 µs at a muggy 90-percent RH. Since we're measuring this change with the Stamp's pulsin command, which has a resolution of 10 µs, we need to exaggerate those changes in period in order to get a usable change in output value. That's the purpose of the 4024 counter.

We normally think of a counter as a frequency divider, but by definition it's also a period multiplier. By dividing the clock output by 128, we create a square wave with a period 128 times as long. Now humidity is represented by a period ranging from 28.8 to 37.8 milliseconds. Since `pulsin` measures only half of the waveform, the time that it's high, RH values range from 14.4 to 18.9 milliseconds. At 10-µs resolution, `pulsin` expresses these values as numbers ranging from 1440 to 1890. (Actually, thanks to stray capacitance, the numbers returned by the circuit will tend to be higher than this.)

In order to prevent clock pulses from interfering with temperature measurements, the RH clock is disabled when not in use. If you really need the extra pin, you can tie pin 5 of the sensor board high, leaving the clock on continuously. You may need to average several temperature measurements to eliminate the resulting jitter, however.

Since the accuracy of both of the measurement techniques is highly dependent on the individual components and circuit layout used, we're going to sidestep the sticky issue of calibration and conversion to units. A recent article in Popular Electronics (January 1994 issue, page 62, "Build a Relative-Humidity Gauge") tells how to calibrate RH sensors using salt solutions. Our previous application note (Stamp #7, "Sensing Temperature with a Thermistor") covers methods for converting raw data into units, even if the data are nonlinear.

Program listing and parts source. These programs may be downloaded from our ftp site at ftp.parallaxinc.com, or through our web site at http://www.parallaxinc.com. The sensor kit (#WEA-TH-KIT) is available for $25 plus shipping and handling from Fascinating Electronics, PO Box 126, Beaverton, OR 97075-0126; phone, 1-800-683-5487.

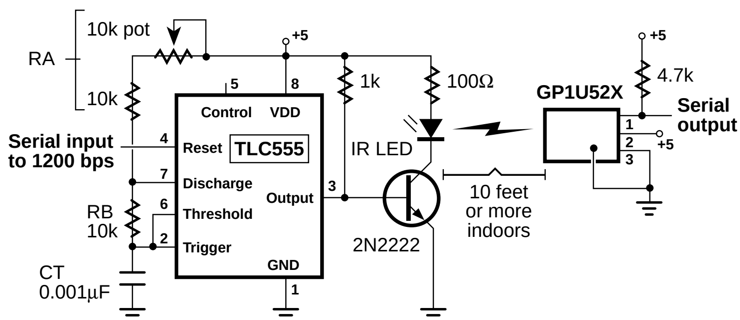
```
' Program HUMID.BAS
' The Stamp interfaces to an inexpensive temperature/humidity
' sensor kit.

Symbol   temp = w4                    ' Temperature
Symbol   RH = w5                      ' Humidity

' The main program loop reads the sensors and displays
' the data on the PC screen until the user presses a key.

Loop:
input 0:input 2: output 3
```

```
low 2: low 3
let temp = 500                          ' Start temp at a reasonable value.

ReadTemp:
        output 1: low 1
        pause 1                         ' Discharge the capacitor.
        input 1                         ' Get ready for input.
        pulsout 2,temp                  ' Charge cap thru temp sensor.
        if pin1 = 1 then ReadRH         ' Charged: we're done.
        let temp = temp + 1 ' Else try again
        goto ReadTemp                   ' with wider pulse.

ReadRH:
        high 3                          ' Turn on the 555 timer
        pause 500                       ' and let it stabilize.
        pulsin 0,1,RH                   ' Read the pulse width.
        low 3                           ' Kill the timer.
        debug temp:debug RH             ' Display the results.
        goto Loop                       ' Do it all again.
```

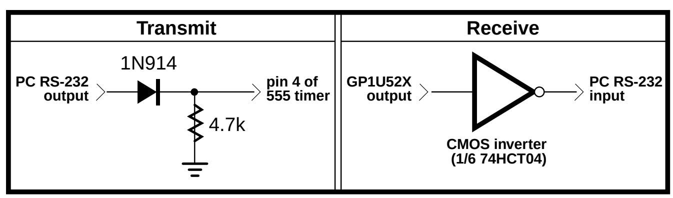
Introduction. This application note shows how to build a simple and inexpensive infrared communication interface for the BASIC Stamp.

Background. Today's hottest products all seem to have one thing in common; wireless communication. Personal organizers beam data into desktop computers and wireless remotes allow us to channel surf from our couches. Not wanting the BASIC Stamp to be left behind, we devised a simple infrared data link. With a few inexpensive parts from your neighborhood electronics store you can communicate at 1200 baud over distances greater than 10 feet indoors. The circuit can be modified for greater range by the use of a higher performance LED.

How it works. As the name implies, infrared (IR) remote controls transmit instructions over a beam of IR light. To avoid interference from other household sources of infrared, primarily incandescent lights, the beam is modulated with a 40-kHz carrier. Legend has it that 40 kHz was selected because the previous generation of ultrasonic remotes worked



PC Interfaces



Schematic to accompany program IR.BAS.

at this frequency. Adapting their circuits was just a matter of swapping an LED for the ultrasonic speaker.

The popularity of IR remotes has inspired several component manufacturers to introduce readymade IR receiver modules. They contain the necessary IR detector, amplifier, filter, demodulator, and output stages required to convert a 40-kHz IR signal into 5-volt logic levels. One such module is the GP1U52X, available from your local Radio Shack store as part no. 276-137. As the schematic shows, this part is all that's required for the receiving section of our application.

For the transmitting end, all we need is a switchable source of 40-kHz modulation to drive an IR LED. That's the purpose of the timer circuit in the schematic. Putting a 1 on the 555's reset pin turns the 40-kHz modulation on; a 0 turns it off. You may have to fiddle with the values of RA, RB, and CT. The formula is Frequency $= 1.44 / ((RA+2*RB)*CT)$. With RB at 10k, the pot in the RA leg of the circuit should be set to about 6k for 40-kHz operation. However, capacitor tolerances being what they are, you may have to adjust this pot for optimum operation.

To transmit from a Stamp, connect one of the I/O pins directly to pin 4 of the '555 timer. If you use pin 0, your program should contain code something like this:

```
low 0                           ' Turn off pin 0's output latch.
output 0                        ' Change pin 0 to output.
...                             ' other instructions
serout 0,N1200,("X")            ' Send the letter "X"
```

To receive with another Stamp, connect an I/O pin to pin 1 of the GP1U52X. If the I/O pin is pin 0, the code might read:

```
input 0                         ' Change pin 0 to input.
...                             ' other instructions
serin 0,T1200,b2                ' Receive data in variable b2.
```

To receive with a PC, you'll need to verify that the PC is capable of receiving 5-volt RS-232. If you have successfully sent RS-232 from your Stamp to the PC, then it's compatible. As shown in the schematic, you'll need to add a CMOS inverter to the output of the GP1U52X. Don't use a TTL inverter; its output does not have the required voltage swing. To transmit from a PC, you'll need to add a diode and resistor ahead of the '555 timer as shown in the schematic. These protect the timer from the negative voltage swings of the PC's real RS-232 output.

Modifications. I'm sure you're already planning to run the IR link at 2400 baud, the Stamp's maximum serial speed. Go ahead, but be warned that there's a slight detection delay in the GP1U52X that causes the start bit of the first byte of a string to be shortened a bit. Since the serial receiver bases its timing on the leading edge of the start bit, the first byte will frequently be garbled.

If you want more range or easier alignment between transmitter and receiver, consider using more or better LEDs. Some manufacturers' data sheets offer instructions for using peak current, duty cycle, thermal characteristics, and other factors to calculate optimum LED power right up to the edge of burnout. However, in casual tests around the workshop, we found that a garden-variety LED driven as shown could reliably communicate with a receiver more than 10 feet away. A simple reflector or lens arrangement might be as beneficial as an exotic LED for improving on this performance.

If you find that your IR receiver occasionally produces "garbage characters" when the transmitter is off, try grounding the metal case of the GP1U52X. It is somewhat sensitive to stray signals. If you build the transmitter and receiver on the same prototyping board for testing, you are almost certain to have this problem. Bypass all power connections with 0.1-µF capacitors and use a single-point ground. And be encouraged by the fact that the circuit works much better in its intended application, with the transmitter and receiver several feet apart.

Program listing. There's no program listing this time; however, you may download programs for other application notes from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

Introduction. This application note presents a circuit that allows the BASIC Stamp to measure distances from 1 to 12 feet using inexpensive ultrasonic transducers and commonly available parts.

Background. When the November 1980 issue of *Byte* magazine presented Steve Ciarcia's article *Home in on the Range! An Ultrasonic Ranging System*, computer hobbyists were fascinated. The project, based on Polaroid's SX-70 sonar sensor, allowed you to make real-world distance measurements with your computer. We've always wanted to build that project, but were put off by the high cost of the Polaroid sensor ($150 in 1980, about $80 today).

1

If you're willing to give up some of the more advanced features of the

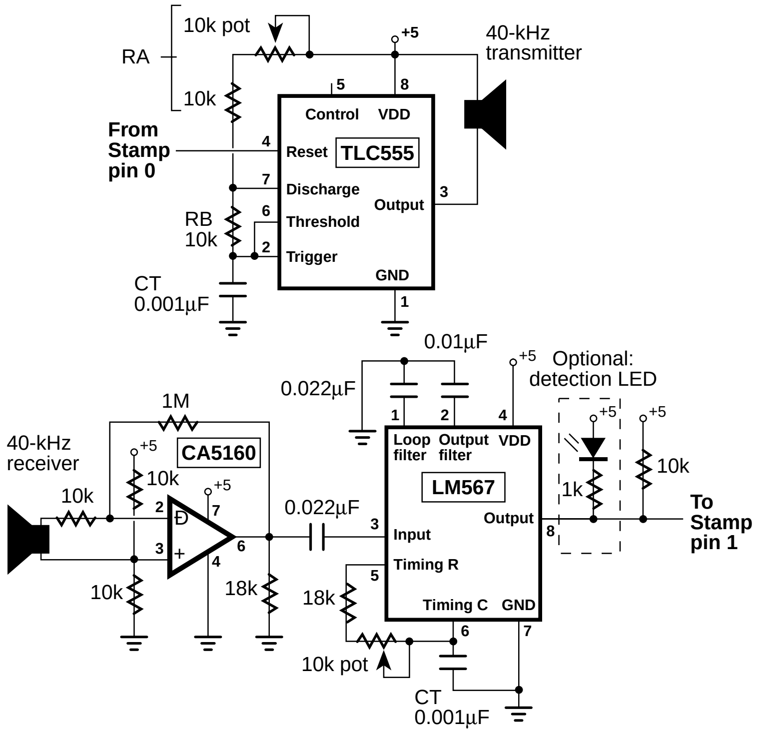


Figure 1. Schematic to accompany program SONAR.BAS.

Polaroid sensor (35-foot range, multi-frequency chirps to avoid false returns, digitally controlled gain) you can build your own experimental sonar unit for less than $10. Figure 1 shows how.

Basically, our cheap sonar consists of two sections; an ultrasonic transmitter based on a TLC555 timer wired as an oscillator, and a receiver using a CMOS op-amp and an NE567 tone decoder. The Stamp controls these two units to send and receive 40-kHz ultrasonic pulses. By measuring the elapsed time between sending a pulse and receiving its echo, the Stamp can determine the distance to the nearest reflective surface. Pairs of ultrasonic transducers like the ones used in this project are available from the sources listed at the end of this application note for $2 to $3.50.

Construction. Although the circuits are fairly self-explanatory, a few hints will make construction go more smoothly. First, the transmitter and receiver should be positioned about 1 inch apart, pointing in the same direction. For reasons we'll explain below, the can housing the transmitter should be wrapped in a thin layer of sound-deadening material. We used self-adhesive felt from the hardware store. Cloth tape or thin foam would probably work as well. Don't try to enclose the transducers or block the receiver from hearing the transmitter directly; we count on this to start the Stamp's timing period. More on this later. For best performance, the oscillation frequency of the TLC555 and the NE567 should be identical and as close to 40 kHz as possible. There are two ways to achieve this. One way is to adjust the circuits with a frequency counter. For the '555, temporarily connect pin 4 to +5 volts and measure the frequency at pin 3. For the '567, connect the counter to pin 5.

If you don't have a counter, you'll have to use ±5-percent capacitors for the units marked CT in the '555 and '567 circuits. Next, you'll need to adjust the pots so that the timing resistance is as close as possible to the following values. For the '555: Frequency = 1.44 / ((RA + 2∗RB)∗ CT), which works out to $40x10^3 = 1.44 / ((16x10^3 + 20x10^3) \times 0.001x10^{-6})$.

Measure the actual resistance of the 10k resistors labeled RA and RB in the figure and adjust the 10k pot in the RA leg so that the total of the equation RA + 2∗RB is 36k. Once the resistances are right on, the frequency of oscillation will depend entirely on CT. With 5-percent tolerance, this puts you in the ballpark; 38.1 to 42.1 kHz.

For the ’567 the math comes out like so: Frequency = 1/(1.1*R*CT); $40x10^3 = 1 / (1.1 \times 22.73x10^3 \times 0.001x10^{-6})$

Adjust the total resistance of the 18k resistor and the pot to 22.73k. Again, the actual frequency of the ’567 will depend on CT. With 5-percent tolerance, we get the same range of possible frequencies as for the ’555; 38.1 to 42.1 kHz.

Once you get close, you can fine-tune the circuits. Connect the LED and resistor shown in the figure to the ’567. Temporarily connect pin 4 of the ’555 to +5 volts. When you apply power to the circuits, the LED should light. If it doesn’t, gradually adjust the pot on the ’555 circuit until it does. When you’re done, make sure to reconnect pin 4 of the ’555 to Stamp pin 0. Load and run the program in the listing. For a test run, point the transducers at the ceiling; a cluttered room can cause a lot of false echoes. From a typical tabletop to the ceiling, the Stamp should return `echo_time` values in the range of 600 to 900. If it returns mostly 0s, try adjusting the RA pot very, very slightly.

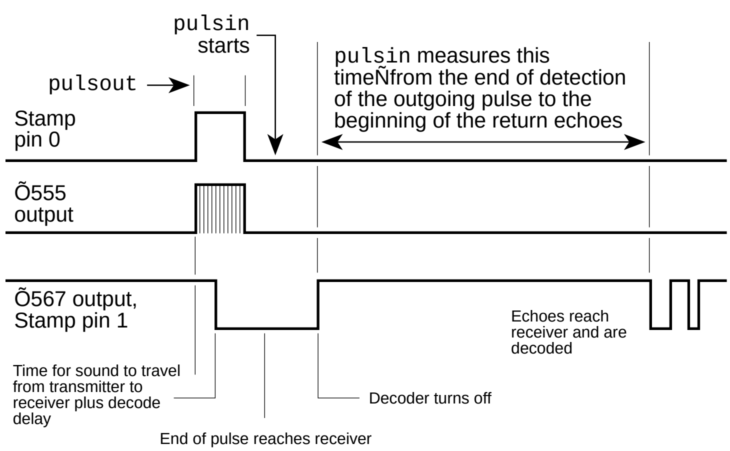


Figure 2. Timing diagram of the sonar-ranging process.

How it works. In figure 1, the TLC555 timer is connected as a oscillator; officially an *astable multivibrator*. When its reset pin is high, the circuit sends a 40-kHz signal to the ultrasonic transmitter, which is really just a specialized sort of speaker. When reset is low, the ’555 is silenced.

In the receiving section, the ultrasonic receiver—a high-frequency microphone—feeds the CA5160 op amp, which amplifies its signal 100 times. This signal goes to an NE567 tone decoder, which looks for a close match between the frequency of an incoming signal and that of its internal oscillator. When it finds one, it pulls its output pin low.

Figure 2 illustrates the sonar ranging process. The Stamp activates the ’555 to send a brief 40-kHz pulse out through the ultrasonic transmitter. Since the receiver is an inch away, it hears this initial pulse loud and clear, starting about 74 µs after the pulse begins (the time required for sound to travel 1 inch at 1130 feet per second). After the ’567 has heard enough of this pulse to recognize it as a valid 40-kHz signal, it pulls its output low.

After `pulsout` finishes, the transmitter continues to ring for a short time. The purpose of the felt or cloth wrapping on the transmitter is to damp out this ringing as soon as possible. Meanwhile, the Stamp has issued the `pulsin` command and is waiting for the ’567 output to go high to begin its timing period. Thanks to the time required for the end of the pulse to reach the receiver, and the pulse-stretching tendency of the ’567 output filter, the Stamp has plenty of time to catch the rising edge of the ’567 output.

That’s why we have to damp the ringing of the transmitter. If the transmitter were allowed to ring undamped, it would extend the interval between the end of `pulsout` and the beginning of `pulsin`, reducing the minimum range of the sonar. Also, if the ringing were allowed to gradually fade away, the output of the ’567 might chatter between low and high a few times before settling high. This would fool `pulsin` into a false, low reading.

On the other hand, if we prevented the receiver from hearing the transmitter at all, `pulsin` would not get a positive edge to trigger on. It would time out and return a reading of 0.

Once pulsin finds the positive edge that marks the end of the NE567's detection of the outgoing pulse, it waits. Pulsin records this waiting time in increments of 10 µs until the output of the '567 goes low again, marking the arrival of the first return echo. Using debug, the program displays this delay on your PC screen.

To convert this value to distance, first remember that the time pulsin measures is the round-trip distance from the sonar to the wall or other object, and that there's an offset time peculiar to your homemade sonar unit. To calibrate your sonar, carefully measure the distance in inches between the transmitter/receiver and the nearest wall or the ceiling. Multiply that number by two for the roundtrip, then by 7.375 (at 1130 feet/second sound travels 1 inch in 73.746 µs; 7.375 is the number of 10-µs pulsin units per inch). Now take a Stamp sonar reading of the distance. Subtract your sonar reading from the calculated reading. That's the offset.

Once you have the offset, add that value to pulsin's output before dividing by 7.375 to get the round-trip distance in inches. By the way, to do the division with the Stamp's integer math, multiply the value plus offset by 10, then divide by 74. The difference between this and dividing by 7.375 will be about an inch at the sonar's maximum range. The result will be the round-trip distance. To get the one-way distance, divide by two.

Modifications. The possibilities for modifications are endless. For those who align the project without a frequency counter, the most beneficial modification would be to borrow a counter and precisely align the oscillator and tone decoder.

Or eliminate the need for frequency alignment by designing a transmitter oscillator controlled by a crystal, or by the resonance of the ultrasonic transducer itself.

Try increasing the range with reflectors or megaphone-shaped baffles on the transmitter and/or receiver.

Soup up the receiver's amplifier section. The Polaroid sonar unit uses variable gain that increases with the time since the pulse was transmitted to compensate for faint echoes at long distances.

Make the transmitter louder. Most ultrasonic transmitters can withstand inputs of 20 or more volts peak-to-peak; ours uses only 5.

Tinker with the tone decoder, especially the loop and output filter capacitors. These are critical to reliable detection and ranging. We arrived at the values used in the circuit by calculating reasonable starting points, and then substituting like mad. There's probably still some room for improvement.

Many ultrasonic transducers can work as both a speaker and microphone. Devise a way to multiplex the transmit and receive functions to a single transducer. This would simplify the use of a reflector or baffle.

Parts sources. Suitable ultrasonic transducers are available from All Electronics, 1-800-826-5432. Part no. UST-23 includes both transmitter and receiver. Price was $2 at the time of this writing. Marlin P. Jones and Associates, 1-800-652-6733, stock #4726-UT. Price was $3.95 at the time of this writing. Hosfelt Electronics, 1-800-524-6464, carries a slightly more sensitive pair of transducers as part no. 13-334. Price was $3.50 at the time of this writing.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: SONAR.BAS
' The Stamp runs a sonar transceiver to measure distances
' up to 12 feet.

Symbol  echo_time = w2              ' Variable to hold delay time

setup:  let pins = 0                ' All pins low
        output 0                    ' Controls sonar xmitter
        input 1                     ' Listens to sonar receiver

ping:   pulsout 0,50                ' Send a 0.5-ms ping
        pulsin 1,1,echo_time        ' Listen for return
        debug echo_time             ' Display time measurement
        pause 500                   ' Wait 1/2 second
        goto ping                   ' Do it again.
```

Introduction. This application note shows how to use the 93LC66 EEPROM to provide 512 bytes of nonvolatile storage. It provides a tool kit of subroutines for reading and writing the EEPROM.

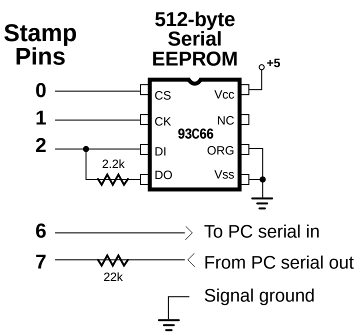
Background. Many designs take advantage of the Stamp's ability to store data in its EEPROM program memory. The trouble is that the more data, the smaller the space left for code. If only we could expand the Stamp's EEPROM!

This application note will show you how to do the next best thing; add a separate EEPROM that your data can have all to itself.

The Microchip 93C66 and 93LC66 electrically erasable PROMs (EEPROMs) are 512-byte versions of the 93LC56 used as the Stamp's program memory. (Before you ask: No, dropping a '66 in place of the Stamp's '56 will not double your program memory!) Serial EEPROMs communicate with a processor via a three- or four-wire bus using a simple synchronous (clocked) communication protocol at rates of up to 2 million bits per second (Mbps).

Data stored in the EEPROM will be retained for 10 years or more, according to the manufacturer. The factor that determines the EEPROM's longevity in a particular application is the number of erase / write cycles. Depending on factors such as temperature and supply voltage, the EEPROM is good for 10,000 to 1 million erase / write cycles. For a thorough discussion of EEPROM endurance, see the Microchip Embedded Control Handbook, publication number DS00092B, November 1993.

How it works. The circuit in the figure specifies a 93LC66 EEPROM, but a 93C66 will work as well. You can also subsitute the 256-byte '56, provided you restrict the highest address to 255. The difference between the C and LC models is that the LC has a wider Vcc range (2.5–5.5 V,



Schematic to accompany EEPROM.BAS.

versus 4–5.5 V), lower current consumption (3 mA versus 4 mA), and can be somewhat slower in completing internal erase / write operations, presumably at lower supply voltages. In general, the LC type is less expensive, and a better match for the operating characteristics of the Stamp.

The schematic shows the data in and data out (DI, DO) lines of the EEPROM connected together to a single Stamp I/O pin. The 2.2k resistor prevents the Stamp and DO from fighting over the bus during a read operation. During a read, the Stamp sends an opcode and an address to the EEPROM. As soon as it has received the address, the EEPROM activates DO and puts a 0 on it. If the last bit of the address is a 1, the Stamp could end up sourcing current to ground through the EEPROM. The resistor limits the current to a reasonable level.

The program listing is a collection of subroutines for reading and writing the EEPROM. All of these rely on `Shout`, a routine that shifts bits out to the EEPROM. To perform an EEPROM operation, the software loads the number of clock cycles into `clocks` and the data to be output into `ShifReg`. It then calls `Shout`, which does the rest.

The demonstration program calls for you to connect the Stamp to your PC serial port, type in up to 512 characters of text, and hit return when you're done. Please type this sample text rather than downloading a file to the Stamp. The Stamp will miss characters of a rapidly downloaded file, though it's more than fast enough to keep up with typing. As you type in your message, the Stamp will record each character to EEPROM.

When you're finished typing, the Stamp will repeat your text back to the PC serial port. In fact, it will read all 512 bytes of the EEPROM contents back to the PC.

If you don't have the EEPROM data handy (Microchip Data Book, DS00018D, 1991), you should know about a couple of subtleties. First, when the EEPROM powers up, it is write protected. You must call `Eenable` before trying to write or erase it. It's a good idea to call `Edisbl` (disable writes) as soon as possible after you're done. Otherwise, a power glitch could alter the contents of your EEPROM.

The second subtle point is that National Semiconductor makes a series of EEPROMs with the same part numbers as the Microchip parts discussed here. However, the National parts use a communication protocol that's sufficiently different to prevent them from working with these routines. Make sure to ask for Microchip parts, or be prepared to rewrite portions of the code.

Modifications. If you're using PBASIC interpreter chips as part of a finished product, you may be contemplating buying a programmer to duplicate EEPROMs for production. If you'd prefer to avoid the expense, why not build a Stamp-based EEPROM copier? Just remember to include a 2-millisecond delay or read the busy flag between sequential writes to an EEPROM. This is required to allow the internal programming process to finish. These topics are covered in more detail in the EEPROM documentation.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: EEPROM.BAS
' This program demonstrates subroutines for storing data in a
' Microchip 93LC66 serial EEPROM. This program will not work
' with the National Semiconductor part with the same number.
' Its serial protocol is substantially different.

Symbol  CS       = 0          ' Chip-select line to pin 0.
Symbol  CLK      = 1          ' Clock line to pin 1.
Symbol  DATA     = pin2       ' Destination of Shout; input to Shin
Symbol  DATA_N   = 2          ' Pin # of DATA for "input" & "output"
Symbol  ReadEE   = $C00       ' EEPROM opcode for read.
Symbol  Enable   = $980       ' EEPROM opcode to enable writes.
Symbol  Disable  = $800       ' EEPROM opcode to disable writes.
Symbol  WriteEE  = $A00       ' EEPROM opcode for write.
Symbol  GetMSB   = $800       ' Divisor for getting msb of 12-bit no.
Symbol  ShifReg  = w1         ' Use w1 to shift out 12-bit sequences.
Symbol  EEaddr   = w2         ' 9-bit address for reads & writes.
Symbol  EEdata   = b6         ' Data for writes; data from reads.
Symbol  i        = b7         ' Index counter for EEPROM routines.
Symbol  clocks   = b10        ' Number of bits to shift with Shout.

        output DATA_N         ' EEPROM combined data connection.
        output CLK            ' EEPROM clock.
```

```
        output CS                   ' EEPROM chip select.

' Demonstration program to exercise EEPROM subroutines:
' Accepts serial input at 2400 baud through pin 7. Type a
' message up to 512 characters long. The Stamp will store
' each character in the EEPROM. When you reach 512 characters
' or press return, the Stamp will read the message back from
' the EEPROM and transmit it serially through pin 6
' at 2400 baud.

        output 6                    ' For serial output.
        input  7                    ' For serial input.
        gosub Eenabl                ' Remove EEPROM write protection.
        let EEaddr=0                ' Start at 1st (0th) address.
CharIn: serin 7,N2400,EEdata        ' Get character.
        if EEdata<32 then Done      ' If it's return, done.
        gosub Ewrite                ' Otherwise, write to EEPROM.
        let EEaddr=EEaddr+1         ' Increment addr for next write.
        if EEaddr=512 then Done     ' Memory full? Done.
        goto CharIn

Done:   gosub Edisbl                ' Protect EEPROM.
        for w4 = 0 to 511           ' Show all 512 bytes.
        let EEaddr = w4             ' Point to EEPROM address.
        gosub Eread                 ' Retrieve the data.
        serout 6,N2400,(EEdata)     ' Send it out serial port.
        next                        ' Next character.
        End                         ' Demo over.

' Write the data in EEdata to the address EEaddr.
Ewrite: let ShifReg=WriteEE         ' Get the write opcode.
        let ShifReg=ShifReg|EEaddr  ' OR in the address bits.
        let clocks = 12             ' Send 12 bits to EEPROM.
        high CS                     ' Chip select on.
        gosub Shout                 ' Send the opcode/address.
        let ShifReg = EEdata*16     ' Move bit 7 to bit 11.
        let clocks = 8              ' Eight data bits.
        gosub Shout                 ' Send the data.
        low CS                      ' Deselect the EEPROM.
        return

' Read data from EEPROM address EEaddr into EEdata.
Eread:  let ShifReg=ReadEE          ' Get the read opcode.
        let ShifReg=ShifReg|EEaddr  ' OR in the address bits.
        let clocks=12               ' Send 12 bits to EEPROM.
        high CS                     ' Chip select on.
        gosub Shout                 ' Send the opcode/address.
        gosub Shin                  ' Receive the byte.
        low CS                      ' Deselect the EEPROM.
```

```
        return

' Enable writes to the EEPROM. Upon power-up the EEPROM is
' write-protected, so this routine must be called before
' first writing to the EEPROM.
Eenabl: let ShifReg=Enable          ' Get the write-enable opcode.
        high CS                     ' Chip select on.
        let clocks = 12             ' Send 12 bits to EEPROM.
        gosub Shout                 ' Send the opcode.
        low CS                      ' Deselect the EEPROM.
        return

' Disable writes to the EEPROM.
Edisbl: let ShifReg=Disable         ' Get the write-disable opcode.
        high CS                     ' Chip select on.
        let clocks = 12             ' Send 12 bits to EEPROM.
        gosub Shout                 ' Send the opcode
        low CS                      ' Deselect the EEPROM
        return

' Shift data into EEdata.
Shin:   input DATA_N                ' Change the data line to input.
        let EEdata=0                ' Clear data byte.
        for i = 1 to 8              ' Prepare to get 8 bits.
        let EEdata=EEdata*2         ' Shift EEdata to the left.
        high CLK                    ' Data valid on rising edge.
        let EEdata=EEdata+DATA      ' Move data to lsb of variable.
        low CLK                     ' End of clock pulse.
        next i                      ' Get another bit.
        output DATA_N               ' Restore data line to output.
        return

' Shift data out of ShifReg.
Shout:  for i = 1 to clocks         ' Number of bits to shift out.
        let DATA=ShifReg/GetMSB     ' Get bit 12 of ShifReg.
        pulsout CLK,10              ' Output a brief clock pulse.
        let ShifReg=ShifReg*2       ' Shift register to the left.
        next i                      ' Send another bit.
        return
```

Introduction. This application note shows how to connect multiple Stamps together in a simple network. It explains the use of the serout open-drain and open-source baudmodes.

Background. Many Parallax customers are interested in connecting multiple Stamps together to form a network. Their applications include intelligent home control, security sytems, small-scale robotics, and distributed sensing arrangements. For these applications, the Stamp has built-in serial networking capabilities requiring a minimum of external components. Better yet, participation in a network requires only a couple of lines of Stamp code and one additional I/O line at most.

How it works. The first question that comes to mind is: “Why not just connect multiple Stamps to one serial port and make them talk one at a time? That would be a good enough network for most jobs.” That’s true, for the most part, but the Stamp’s normal serial outputs would destroy each other. Figure 1 shows why.

In output mode, the Stamp’s I/O pins act like switches connected to the power-supply rails. When the Stamp outputs a 1, it’s turning on the switch connected to the +5-volt rail while turning off the one going to ground. To output a 0, it does the reverse. If you connect multiple Stamp outputs together, you set up the situation in figure 1b: a direct short to ground through a pair of Stamp output switches. This would damage the Stamp’s PBASIC interpreter chip.

Now, before you run off to design a system of logic gates or diodes to fix this, listen up: The Stamp can be configured to use only one of the two switches for serial output. This eliminates the possibility of a short circuit and opens up the possibility of network hookups. See figure 2.

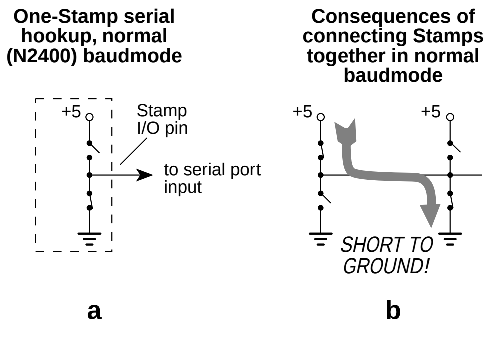


Figure 1

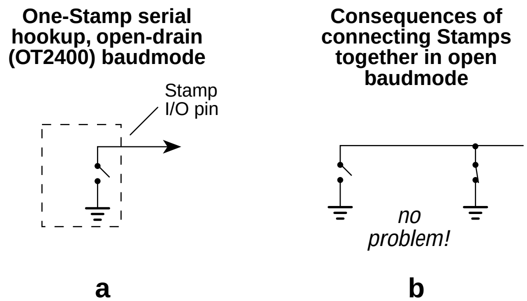


Figure 2

To use this technique, your program should begin by setting the serial pin to input in order to turn off the output switches. Then, when it's time for the Stamp to put some data onto the network using **serout**, the baudmode argument should begin with **OT**, as in **OT2400**. This is known as an open-drain configuration, in honor of the portion of the PBASIC interpreter's output MOSFET switch left "open" at the pin connection.

When connected Stamp pins are in different states there's no problem, because no current flows. No data flows, either, because the pins are incapable of outputting a logical 1 (+5 volts). That's easily remedied by adding a pullup resistor, however, as shown in figure 3.

The inverter / line driver shown in figure 3 can either be a CMOS type like one-sixth of a 74HCT04 or an actual RS-232 line driver, such as a MAX-232. If the Stamps will be talking to each other instead of reporting to a host computer, you can eliminate the line driver entirely.

The Stamp also supports an open baudmode that switches to +5 only instead of ground. This is the open-source configuration, selected by an argument beginning with **ON**, such as **ON2400**. To make this work, you must reverse the polarity of everything shown in figure 3. The resistor would go to ground. A non-inverting buffer (or additional inverter) would be used to straighten out the signal polarity.

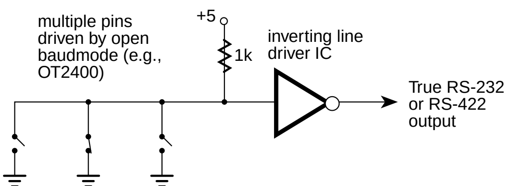


Figure 3

Now that we have a way to safely connect multiple Stamp serial pins to a single line, how do we ensure that only one Stamp talks at once? The possibilities seem endless, and depend primarily on the nature of the data to be sent through the net. For example, each Stamp could alternate between talking and listening on the net. You could use a system of qualifiers that each Stamp would have to receive via **serin** before it could transmits onto the net. That way, one Stamp would send its data, then turn the net over to the next. That is the approach used in the demonstration programs.

Of course, if you have I/O pins available on each of the Stamps in the net, you could just have each Stamp wait for a particular logic level to tell it to transmit. Another approach would be to have one Stamp trigger its neighbor. As I said, the possibilities go on and on. If you get stuck for ideas, just look at a diagram of a local-area network (LAN). LAN designers have invented all kinds of schemes, called "network topologies," for determining who talks when. They've dreamed up good names, too, like *token rings*, *stars*, *hubs*, etc.

The example we present is a variation on the token-ring idea. Three Stamps named Moe, Larry, and Curly will share a single serial line. When they are first powered up, Moe will transmit a message concluding with "Larry." Larry, recognizing his name, will transmit a message concluding with "Curly." Curly will transmit a message, concluding with "Moe." Moe will start the process all over again. Even though the Stamps are communicating among themselves, we'll still use an inverter/driver in order to monitor the process with a PC running

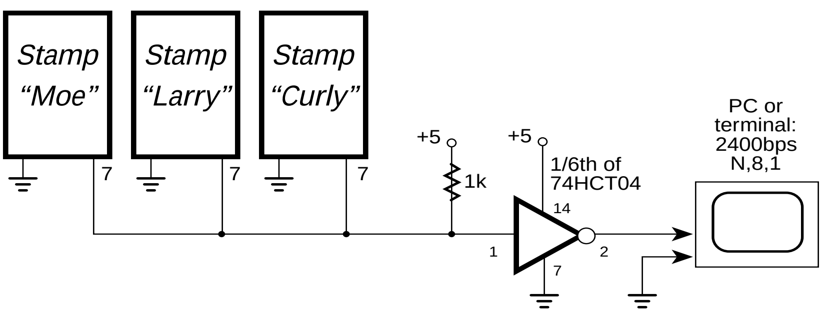


Figure 4. Serial network of Stamps using open-drain output.

terminal software. Figure 4 shows the circuit; the program listing shows the code used in the Stamps.

For your application, you'd simply substitute a real message (based on data gathered by the Stamps) for the sample messages. Make sure that your data messages cannot contain the names of the other Stamps, or you'll create chaos. A safe bet is to restrict data to numbers, and names to text. Make sure that the individual Stamps can gather data quickly enough to be ready when their names are called. If they're not ready, they may miss their cues. This can cause the entire net to hang up. Likewise, simple failure of one of the Stamps will hang the net. For critical applications, you might want to consider making one of the Stamps a supervisor whose job it is to handle these emergencies.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
'  Program:  Moe
' Stamp participant in a simple ring-type network. This Stamp has the job of
' starting the network up by passing an initial message before receiving a cue.
' Thereafter, Moe only transmits when cued by Curly, the last Stamp on the net.

input 7                                 ' Set pin 7 to input.
pause 1000                              ' Give others time to wake up.
serout 7,OT2400,(10,13,"Three   ")      ' Say the line.
serout 7,OT2400,("Larry",10,13)         ' Cue next.

' Now enter the main program loop.
Loop:
     serin 7,T2400,("Moe",10,13)        ' Wait for cue.
     serout 7,OT2400,(10,13,"Three   ") ' Say the line.
     serout 7,OT2400,("Larry",10,13)    ' Cue next.
goto Loop
```

```
'  Program:  Larry
' Stamp participant in a simple ring-type network. Only transmits when cued
' by Moe, the first Stamp on the net.

input 7                                 ' Set pin 7 to input.

' Main program loop:
```

```
Loop:
    serin 7,T2400,("Larry",10,13)          ' Wait for cue.
    serout 7,OT2400,("Blind   ")           ' Say your line.
    serout 7,OT2400,("Curly",10,13)        ' Cue next
goto Loop


'  Program:  Curly
' Stamp participant in a simple ring-type network. Only transmits when cued
' by Larry, the middle Stamp in the net.

input 7                                    ' Set pin 7 to input.

' Main program loop:
Loop:
    serin 7,T2400,("Curly",10,13)          ' Wait for cue.
    serout 7,OT2400,("Mice    ")           ' Say your line.
    serout 7,OT2400,("Moe",10,13)          ' Cue next
goto Loop
```

Introduction. This application note explains how to convert digital values to analog voltages using the BASIC Stamp command `pwm`.

Background. There's probably some misunderstanding about the pulse-width modulation (`pwm`) command. Most Stamp users know that it generates a waveform whose duty cycle (ratio of on time to off time) can be varied from 0 to 100 percent by varying the `duty` input from 0 to 255. But experience with other devices probably leads them to expect the output to look like figure 1. This is the sort of variable duty cycle output you get from most timer and counter circuits.

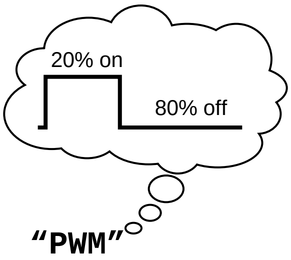


Figure 1. What users think pwm looks like.

The Stamp uses a different, more efficient algorithm to generate pwm. Its output is just as useful for generating analog voltages, but when displayed on an oscilloscope, it can look like a mess; see figure 2.

The proportion of on time to off time is the same, but instead of being separated into neat chunks, Stamp pwm is distributed over a large number of pulses of varying width.

Without getting too far into the details, the reason is this: The Stamp generates pwm by adding the duty cycle into an internal variable that we'll call the "accumulator." It doesn't care what the accumulator contains, only whether or not it overflows (generates a carry-the-one operation). If it does, the pwm pin goes high; otherwise, low.

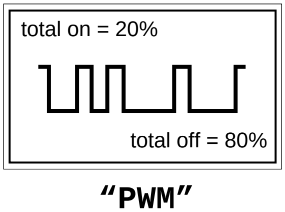


Figure 2. What pwm really looks like.

The Stamp does this addition quite a few times. The larger the duty cycle is, the more often carries occur, and the higher the proportion of highs to lows. However, the carries occur with an irregular rhythm, so the output waveform, while perfect duty-cycle pwm, looks like fruit salad on the 'scope.

Using pwm. The primary application for pwm is to generate a voltage from 0 to 5 volts proportional to the duty cycle. An even simpler use is to control the brightness of an LED. See figure 3.

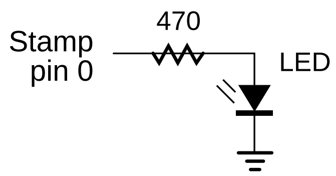


Figure 3. Controlling the brightness of an LED with pwm.

If, as shown in the figure, the LED is connected to pin 0, the following fragment of a Stamp program will gradually raise the brightness of the LED from off to fully on:

```
low 0                       ' LED completely off.
for b2 = 0 to 255           ' Loop from off to on.
    pwm 0, b2,1             ' Output one burst of pwm.
next
high 0                      ' Leave LED on.
```

Although the Stamp is sending a stream of 1s and 0s to the LED, it appears to be steadily on at varying levels of brightness. That's because your eyes integrate (smooth) the rapid flickering, just as they do the frames of a movie or television picture.

If you look at the pwm writeup in the Stamp manual, you'll see that in most applications you need a resistor and capacitor to integrate the output to a smoothly varying voltage. What the manual doesn't show is the effect that connected circuits can have on a simple resistor/ capacitor (RC) integrator.

The fact is that if you try to draw too much current from the RC circuit, your program will have to output many cycles of pwm, and do so quite often in order to maintain the charge on the capacitor. Otherwise, the voltage level set by pwm will begin to droop.

Figure 4 shows one way to overcome this. The CA5160E operational amplifier (op amp) has an extremely high input impedance, so it draws very little current from the capacitor. Since its gain is set to 1 by the accompanying components, the voltage at its output is the same as the voltage at its input, with one big exception: The current drawn from the

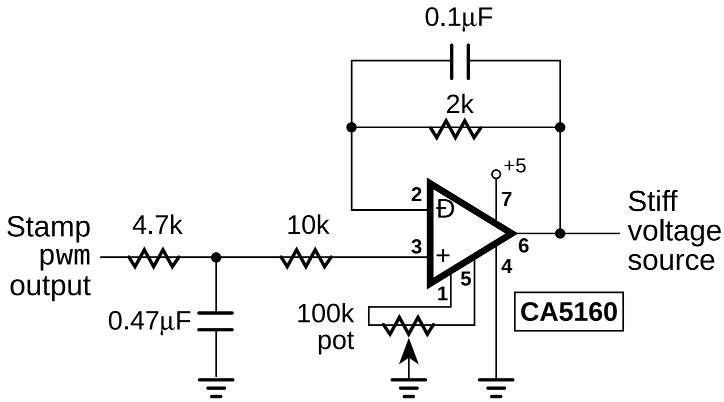


Figure 4. Example op-amp buffer circuit.

output of the op amp does not affect the charge on the capacitor in the RC integrator.

According to the op amp's specs, you can draw up to 12 mA from its output. Other op amps may offer higher current outputs, but make sure to check all the specifications. The CA5160 was used here because it is happy operating from a 5-volt, single-ended supply. Supply current is typically 50 µA (ignoring current drawn from the output). Other op amps may require split supplies of ±15 volts or more.

To drive the op-amp circuit properly, the pin used for pwm output must actually be defined as an input. This ensures that once pwm establishes a voltage level on the capacitor it disconnects itself from the circuit. The code we used to set the circuit to approximately 2.5 volts is:

```
input 0             ' Make pin 0 an input.
pwm 0, 127,1        ' Output one burst of pwm.
```

In our tests, one burst of pwm was sufficient to charge the capacitor to the desired voltage. Once set, the voltage at the op amp's output (driving a 1k resistor load) remained steady for more than 15 minutes. It actually drifted slowly upward, probably due to slight current leakage from the Stamp I/O pin. In a real application, you should try to reestablish the voltage level more often than once every 15 minutes.

A few final notes about the circuit. The 100k pot allows you to fine-tune the op amp's output offset. Connect the circuit with an accurate voltmeter at the output. Program the Stamp to kick out a burst of PWM. The voltage appearing at the op amp output should be (duty/255) times the supply voltage (5 volts from the Stamp's regulated supply). So if the duty is 127, the output voltage should be $(127/255) * 5 = 2.49$ volts. Adjust the pot until the actual voltage agrees with your calculation.

You may find that your op amp won't track the input voltage all the way to +5 volts. One solution is to simply ignore this limitation, and just work within the range you do get. Another is to connect the + supply pin of the op amp (pin 7) to unregulated +9 volts from the battery. As the battery dies, you'll eventually have the same problem again, but you will get rail-to-rail performance for most of the battery's life.

Program listing. There's no program listing this time; however, you may download programs for other application notes our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

Introduction. This application note explains how to use the BASIC Stamp directive bsave and the program BSLOAD.EXE to enable customers to update Stamp programs without access to the source code. It also shows a method by which the Stamp can reload its own program memory from data received over RS-232.

Background. Try this: Phone Microsoft and tell them you own Excel™ or another product of theirs, and you'd like a copy of the source code. Be generous; tell them you are willing to pay for the disks and the shipping charges.

You'll probably find out how people working at a big corporation react to pranks. You'll also learn a lot of new ways to gently say "no."

If you want to keep your Stamp source code private, but still allow customers to download alternative functions, change EEPROM data, or update firmware, you need to know about bsave.

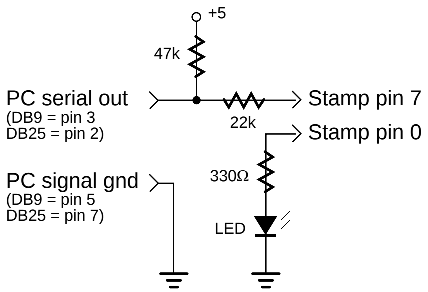
Using bsave. When you run a Stamp program using the latest versions of STAMP.EXE, the software looks for the directive bsave on a line by itself anywhere in the source-code listing. If bsave is present, the software saves a 256-byte file called CODE.OBJ to the current directory. That file contains a copy of the binary data written to the Stamp's EEPROM. You can rename and distribute that file, along with a program called BSLOAD.EXE that's available from the Parallax bulletin-board system.

If you renamed your code file UPDATE.OBJ (it's smart to retain the extension .OBJ because that is the default recognized by BSLOAD) you could distribute it, the BSLOAD software, and a Stamp cable to your customer. Instruct the customer to connect the cable from a PC to the Stamp-based product, connect power, and type BSLOAD UPDATE. A status message appears on the screen to indicate the success of the download.

This technique eliminates the need to distribute your source files and STAMP.EXE in order to update Stamp firmware.

Self-replacing programs. This is going to sound like do-it-yourself brain surgery, but it's possible to write Stamp programs that replace themselves in EEPROM program memory. This means you can download a new program to the Stamp via a serial link.

Program listings 1 and 2 are examples of self-replacing programs. The trick lies in the fact that both contain identical startup code. This code, with the assistance of the serial hookup depicted in the figure, determines whether or not a serial output is connected to the Stamp at startup. If no serial connection is present, the Stamp goes about its business—in the cases of listings 1 and 2, flashing an LED in two different ways. If a serial connection is present at startup, the Stamp receives 256 bytes of data and uses them to replace the entire contents of its EEPROM.



This means that the program overwrites itself. It doesn't crash, however, because the replacement program contains the same code in the same place; at the very beginning of the program.

Listing 3 is a QBASIC program that performs the serial downloading. You may copy and modify this program to fit your own requirements. When you write your own version, be sure to note that QBASIC must open the .OBJ file as binary data. Otherwise, chances are good that a control-Z character (ASCII 26) somewhere in the .OBJ file would cause QBASIC to end the download.

Here's how to make this demonstration work: Construct the circuit shown in the figure, but do not connect your PC's serial port to the Stamp yet. Load and run the Stamp program THROB.BAS. Because the file contains `bsave`, the Stamp software will write its binary image to the file CODE.OBJ. Make a mental note of the DOS path to this file; you'll need it for the downloading step. Next load and run BLINK.BAS. Since it does not contain `bsave`, this will not generate an object file.

Now, quit the Stamp software and disconnect the Stamp from its battery or power supply. Remember, the Stamp only looks for the serial connection at startup, otherwise, it goes into its normal loop.

Boot QBASIC or QuickBASIC and load the program REPROG.BAS. Before you run the program, type your path name into the command `OPEN "D:\CODE.OBJ" FOR BINARY AS #1`. Connect the PC's serial output as indicated in the figure and apply power to the Stamp. Now run the program.

As the download proceeds, the program will display the current byte number on the screen of your PC, and the Stamp will blink its LED in time to the arriving data. A large `FOR/NEXT` delay has been added to the downloading loop to prevent it from outrunning the EEPROM programming process.

When the download is over, the Stamp will begin running THROB.BAS. If you like, you can create an object file of BLINK.BAS and follow the procedures above to replace THROB. Or you can write your own program, include the downloading code, and replace either program with your program.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Listing 1: Blink.BAS
' This program can replace itself with a new program
' downloaded via a serial connection. It is part of a
' demonstration described in Stamp application note 16.
if pin7 = 1 then Loop                   ' No serial hookup so skip.
for b2 = 255 to 0 step -1               ' Download 256 bytes
        serin 7,N2400,b4                ' Get a byte.
        write b2,b4                     ' Write to EEPROM.
        toggle 0 ' Flash LED.
next

Loop:   ' Main program loop:
        toggle 0 ' blink LED.
        pause 50
goto Loop
```

```
' Listing 2: Throb.BAS
' This program can replace itself with a new program
' downloaded via a serial connection. It is part of a
' demonstration described in Stamp application note 16.
if pin7 = 1 then Loop                   ' No serial hookup so skip.
for b2 = 255 to 0 step -1               ' Download 256 bytes
        serin 7,N2400,b4                ' Get a byte.
        write b2,b4                     ' Write to EEPROM.
        toggle 0 ' Flash LED.
next

Loop:                                   ' Main program loop:
        for b2 = 0 to 255 step 5        ' make LED "throb"
        pwm 0,b2,1                      ' by varying its brightness
        next                            ' using pwm.
        for b2 = 255 to 0 step -3
        pwm 0,b2,1
        next
goto Loop
```

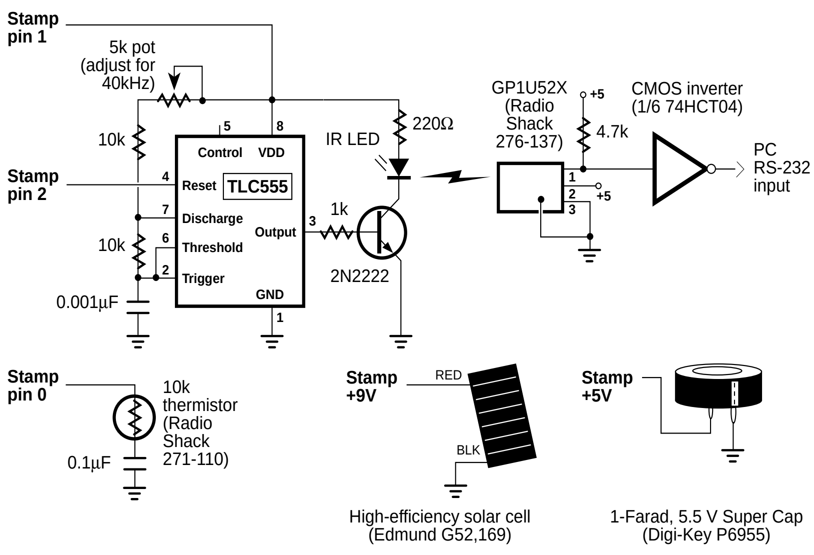
```
' Listing 3: REPROG.BAS (NOT a Stamp program)
' This is a QBASIC program that will download a Stamp
' object file via an RS-232 serial hookup. Be sure to
' enter the correct path to your CODE.OBJ file in the
' OPEN command below.
DEFINT A-Z:CLS
DIM code(255) AS INTEGER
' Load the contents of the CODE.OBJ into a variable.
' Replace "D:\CODE.OBJ" with your file's path.
OPEN "D:\CODE.OBJ" FOR BINARY AS #1
FOR i = 0 TO 255
        code(i) = ASC(INPUT$(1, 1))
NEXT i
CLOSE #1
' Send the code bytes out the serial port.
OPEN "COM1:2400,N,8,1,CD0,CS0,DS0,OP0" FOR RANDOM AS #1
FOR i = 0 TO 255
        CLS: PRINT "Sending: "; i
        PRINT #1, CHR$(code(i));
        FOR j = 1 TO 20000: NEXT j  ' Large delay.
NEXT i
CLOSE #1
END
```

Introduction. This application note shows how to operate the Stamp 24 hours a day from the power provided by a 1.5" x 2.5" solar battery. The example application takes outdoor temperature measurements every 12 seconds, then relays them to a computer indoors via an infrared link.

Background. A standard 9-volt battery can power the Stamp for a long time with the use of the **sleep** and **nap** commands. But eventually the battery *will* die, if only from old age.

Although it's usually no problem to just replace the battery, there are applications that require long periods of unattended operation. Imagine a mountaintop weather station, forest wildlife counter, or floating sensor buoy, drifting in the currents at sea. Now imagine the cost of mounting an expedition to replace the Stamp's battery. Whew!

There are also less exotic places in which independence from batteries would be a good idea. How about pollution-measuring instruments at the top of a pole, or an electronic bicycle speedometer?



Schematic to accompany program SOLAR.BAS

Solar batteries can solve these problems, but only during the daytime. At night, the Stamp would have to run off an alternative power source, such as a rechargeable battery. However, rechargeables are notoriously fussy about proper care and feeding, which might become more of a job than the Stamp's primary mission.

In keeping with the minimalist philosophy of the Stamp itself, we decided to try the simplest conceivable combination of round-the-clock power; a solar battery and a really big capacitor.

How it works. For a trial application, we borrowed from two previous application notes. We took the thermistor temperature measurement scheme of note #7 and wedded it to the infrared communication setup of note #11. That way, we could show that the Stamp and some fairly current-hungry peripherals could both share our 24-hour power source. See the schematic.

For our test of the project, the Stamp, 40-kHz transmitter, and super capacitor were mounted outdoors in a small cardboard box taped to a window on the shady side of a building. The box helped protect the circuit from the elements, and provided a dark background for the IR LED. The solar battery was mounted outside the box, angled upward. On the indoor side of the window, a breadboard holding the IR receiver, CMOS inverter and power supply was pointed at the IR LED on the other side of the glass.

The project works like this: Every 12 seconds the Stamp takes a temperature reading by executing a **pot** command on pin 0, the pin to which the thermistor is connected. It converts the resulting byte of data into the current temperature using the power-series technique described in app note #7. Then the Stamp applies power to the '555 transmitter circuit. The Stamp sends a byte of data at 1200 baud to the pin 4 of the '555, causing it to transmit the data as an on/off-keyed 40-kHz infrared signal.

The infrared remote-control receiver (GP1U52X) converts the modulated light beam back into bits. A CMOS inverter reverses the polarity of the bits and provides sufficient voltage swing for reception through a PC serial port. The PC receives the data, adds a time tag, and records it to a file on the hard drive.

When the serial transmission is done, the PIC turns off the '555 and goes to sleep for another 12 seconds.

From the standpoint of the project's solar power source, there isn't much to explain. The specified solar battery produces up to 10 volts at 9 mA in direct sunlight, or 8 volts and 0.075 mA in typical indoor lighting. We split the difference and mounted the battery outdoors on the shady side of a building. At noon in this location we got 10 volts at about 1 mA.

Before installing the 1-Farad super capacitor, we charged it to about 4 volts by leaving it connected to a 5-volt power supply through a 4.7k resistor for several hours. This limited the amount of charging current that the capacitor would demand from the Stamp's voltage regulator when first connected. Once the capacitor was installed, the solar battery kept it charged.

We ran the project 'round the clock for several days, periodically reviewing the time-tagged data files for breaks or erratic data that would indicate a power failure. None occurred. The lowest voltage across the super cap, which occurred after about 10 hours of darkness, was 3.65 volts, just enough to keep the Stamp going. Less than an hour after sunrise the cap would charge back up to 5 volts.

The solar battery has plenty of excess capacity for this type of application. An interesting challenge would be to find ways to exploit this. For example, in a telemetry application, the Stamp might store data over night, then transmit it during daylight when power would be abundant.

Parts sources. The solar battery is available from Edmund Scientific, 609-573-6250. The super cap is available from Digi-Key, 800-344-4539. Many of the other components used in the circuit are available from Radio Shack electronics stores.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: SOLAR.BAS
' Program to demonstrate that the Stamp can operate 24 hours a day
' from a solar battery and 1-Farad memory-backup capacitor (super
' cap). Every 12 seconds the Stamp wakes up, takes a temperature
' reading from a thermistor, converts it to degrees F and
' transmits it (as a single byte of data) over a 1200-bps
' infrared link.

' Coefficients for the thermistor conversion/linearization routine.
' For more information, see Stamp app note #7.
Symbol co0      = 171               ' Adjusted to match capacitor.
Symbol co1top   = 255
Symbol co1btm   = 2125
Symbol co2bt1   = 25
Symbol co2top   = 3
Symbol co2btm   = 50

' Change pins 1 and 2 to outputs and take them low. Pin 1 controls
' power to the '555 timer/40-kHz transmitter. Pin 2 is serial output
' to the 40-kHz transmitter.
low 1:low 2

' Main program loop.
Loop:
' Take a thermistor measurement using pot.
        pot 0,46,w0
' Linearize it and convert to degrees F with the equation from
' Stamp application note #6.
        let w1 = w0*w0/co2bt1*co2top/co2btm
        let w0 = w0*co1top/co1btm+w0
        let w0 = co0+w1-w0
' Now turn on the '555 timer and give it a little time to get ready.
        high 1
        pause 100
' Transmit the data.
        serout 2,N1200,(b0)
' Turn off the '555.
        low 1
' Go back to sleep.
        sleep 10
goto Loop
```

```
' Program DATA_LOG.BAS
' This is a QBASIC program to display and record the data
' from the Stamp program SOLAR.BAS. To quit this program,
' either press control-break, or press any key and wait
' for the next Stamp transmission.

DEFINT A-Z
OPEN "com1:1200,N,8,1,CD0,CS0,DS0,OP0" FOR INPUT AS #1
OPEN "c:\data.log" FOR OUTPUT AS #2
CLS
Again:
        temp$ = INPUT$(1, 1)
        PRINT ASC(temp$); CHR$(9); TIME$
        PRINT #2, ASC(temp$); CHR$(9); TIME$
IF INKEY$ = "" THEN GOTO Again
CLOSE
END
```

Introduction. This application note shows how to read multiple switches through a single input/output (I/O) pin by using the *pot* command.

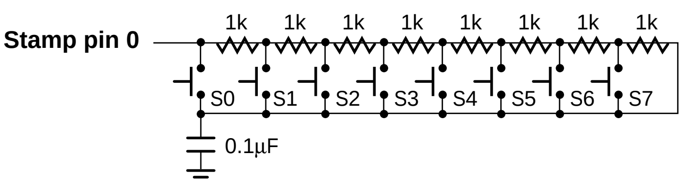
Background. If your BASIC Stamp application needs to check the status of more than a few switches, you have probably considered using external hardware to do the job. The trouble is that most hardware solutions still use more than one I/O pin, and often require considerable program overhead.

Now, consider the pot command. It reads a resistance and returns a proportional number. What if you wired your switches to vary the resistance measured by *pot*? With an appropriate lookup routine, you'd be able to determine which switch was pressed.

That's exactly the method we're going to demonstrate here.

How it works. As the figure shows, we wired up eight switches and eight 1k resistors in a sort of pushbutton-pot arrangement. When no switch is pressed, the circuit's resistance is the sum of all of the resistors in series; 8k. If you press the switch closest to the pot pin (S0), the network is shorted out, so the resistance is 0. Press S1, and the resistance is 1k. And so on.

To see this effect in action, follow these steps: Wire up the circuit in the figure, connect the Stamp to your PC, run STAMP.EXE, and press ALT-P (calibrate pot). Select the appropriate I/O pin; in this case pin 0. The PC screen will display a dialog box showing a suggested value for the pot scale factor—the number that ensures a full-scale response for the connected combination of the resistor(s) and capacitor.



Schematic to accompany program MANY_SW.BAS

Press the space bar to lock in the scale factor. Now the screen displays the actual value returned by the pot command. Press the switches and watch the value change. Write down the scale factor and the numbers returned by pressing S0 through S7. As you do so, you'll notice that the numbers vary somewhat. They tend to be steadier in the lower resistance ranges, and jumpier at higher resistances. Write down the highest number returned for each switch.

Armed with this calibration data, you can write PBASIC code to determine which switch was pressed just by looking at the pot value. The program listing shows an example. We took the numbers recorded in the step above, added a fixed amount to each, and put them in a lookup table. To identify a switch by its resistance value, the program starts searching at the lowest resistance, represented by switch 0. The program asks, "is this resistance less than or equal to the lookup entry for switch 0?" If it is, then switch 0 was pressed; if not, the program increments the switch number and repeats the question until it determines which switch was pressed.

In creating the lookup table, we added 10 to the maximum value for each of the switches. This serves as a safety margin to prevent errors in case the capacitance and resistance values wander a bit with temperature.

This scheme has some drawbacks, mostly related to the way pot works. Pot makes resistance readings by charging up the capacitor, then gradually discharging it through the series-connected pot or resistor. By measuring the time required to discharge the cap, pot can provide a pretty accurate estimate of the relative resistance. This process takes several milliseconds to complete.

If one of the switches is pressed during the pot timing cycle, the rate at which the capacitor discharges will change. The pot measurement will be wrong, and the switch number returned by the program will be wrong. To guard against this, the program ignores the first several readings after an initial switch closure. This isn't completely foolproof, but it makes misidentified switches a relatively rare event.

Another potential drawback is that the program cannot detect more than one switch closure at a time. If two switches are closed at the same time, the program will correctly identify the lower of the two switches. For example, if switches 2 and 5 are both closed, the program will recognize switch 2. You can understand this by analyzing the circuit. Switch 2 effectively shorts out all of the resistor/switch network beyond itself. Additional closed switches have no effect.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: MANY_SW.BAS (Read switches with POT command)

' This program illustrates a method for reading eight switches using
' one I/O pin by using the POT command. The switches are wired as
' shown in the accompanying application note to cut out portions of
' a network of series-connected 1k resistors. The POT command reads
' the resulting resistance value. The subroutine ID_sw compares the
' value to a table of previously determined values to determine
' which switch was pushed.

Clear:                          ' Clear counter that determines how many
let b0 = 0                      ' readings are taken before switch is ID'ed.

Again:
     pot 0,148,b2               ' Take the resistance reading.
     if b2 >= 231 then Clear    ' Higher than 230 means no switch pushed.
     goto ID_sw                 ' Value in range: identify the switch.
Display:
     debug b3                   ' Show the switch number on PC screen.
goto Clear                      ' Repeat.


' ID_sw starts with the lowest switch-value entry in the table (the 0th
' entry) and compares the POT value to it. If the POT value is less than
' or equal, then that's the switch that was pushed. If it's not
' lower, the routine checks the next switch-value entry.

' There's nothing magical about the switch values in the table below. They
' were obtained by pressing the switches and recording their POT
' values, then adding an arbitrary amount--in this case 10. The idea
' was to select numbers that would always be higher than the highest
' POT value returned when the corresponding switch was pressed, but
' lower than the lowest value returned by the next switch. This keeps
```

```
' the comparison/search required to identify the switch as simple as
' possible.

ID_sw:
        if b0 > 8 then skip             ' Take 8 readings before trying to
        b0 = b0+1                       ' identify the switch.
        goto Again
skip:
        for b3 = 0 to 7                 ' Compare table entries to the current reading.
                lookup b3,(10,45,80,114,146,175,205,230),b4
                if b2 <= b4 then done   ' Match? Then done.
        next
done:   goto Display                    ' Switch identified; display its number.
```

1

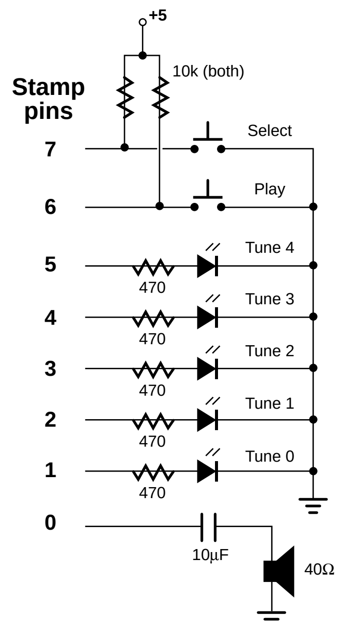
Introduction. This application note explains the *button* command and presents an example program that uses *button* in its immediate and delay / autorepeat modes.

Background. The idea is simple enough—a single command allows your PBASIC programs to read and debounce a switch. However, *button*'s myriad features and its lack of an equivalent in other BASIC dialects have led to considerable misunderstanding among Stamp users. An explanation is in order.

First of all, *button* is intended to be used inside a loop. The idea is that the program goes about its normal business, periodically checking the state of the button. If conditions set up by the button command are met, then the program goes to the address included in the button command.

Second, we should define a slippery term that's important to understanding what button does. That term is "debounce." When you press a switch, the contacts smack into each other with the action of a microscopic earthquake. For several milliseconds they bounce and shudder and grind against one another before finally settling into solid contact. This bouncing shows up as several milliseconds of rapid on / off switching that can be detected by a relatively fast device like the Stamp.

In order to keep switch bounce from seeming like several deliberate switch presses, the button command ignores these very rapid changes in the switch state. So, when we talk about switch "debouncing" in the discussions that follow, we mean button's effort to clean up the switch output.



Schematic to accompany program listings 1 and 2.

Now, let's take a look at the parameters of button in detail. The syntax, as described in the instruction manual, is this:

BUTTON pin,downstate,delay,rate,bytevariable,targetstate,address

Pin is a variable or constant in the range of 0 to 7 that specifies which pin the button is connected to. Remember to use the number of the pin and not its pin name (e.g., Pin3 or Pins.3). The pin name will return the state of the specified pin (0 or 1), which is probably not what you want.

Downstate is a variable or constant that specifies what state the button will be in (0 or 1) when it is pressed.

Delay is used with button's autorepeat capability. If you hold down the A key on your PC keyboard, there's a small pause before the PC goes into machine-gun mode and starts rapidly filling the screen with AAAAAAA... With button, *delay* sets the length of this pause as a variable or constant number of loops (1 to 254) through the button command. So, if you set delay to 100, your Stamp program must loop through the button command 100 times after the initial press before autorepeat will begin. How long will this take? It depends on your program. If the delay is too short for your taste, insert a short pause in the loop that contains the button command.

You can also use the delay setting to change the way button works. A delay of 0 turns off debounce and autorepeat. A delay of 255 turns on debounce, but turns off autorepeat.

Rate is a variable or constant that specifies how fast the autorepeat will occur. Like delay, it is also specified in terms of the number of loops through the button command.

Bytevariable is button's workspace—a variable in which button stores the current state of the delay or rate counters. Make sure to give each button command you use a different workspace variable, or your buttons will interact in bizarre and undesirable ways. Also make sure that byte variables used by button commands are cleared to 0 before they are first used. After that, button will take care of them.

Targetstate is a variable or constant (0 or 1) that specifies whether the program should take action when the button is pressed (1), or when it's not pressed (0). Why the heck would you want to go to some address when the button isn't pressed? In some cases, it's simpler to skip over part of your program unless the button is pushed. This reverse logic can be a little hard to get used to, but it can help reduce the "spaghetti code" of multiple *goto*s for which BASIC is so frequently condemned.

Address is the program label that you want to go to when all of the conditions set by the button command are met.

To illustrate how all of these parameters make button work, we've designed a sample application called BTN_JUKE.BAS. It's a five-selection jukebox that uses one button to select which tune to play by scrolling through five LEDs, and a second button to trigger the currently selected tune.

How it works. The circuit in the figure should be pretty self-explanatory, but note that the switches are wired so that the Stamp pins see highs (+5 volts) when the switches are open and lows (0 volts) when they're pressed.

Now look at listing 1. The program begins by defining the variable *Select*, which will hold the number of the currently selected tune. It then sets up the pins' I/O directions. It clears both of the byte variables that will be used in the button commands (*b0* and *b1*) at one time by clearing the word variable to which they belong (*w0*). As a final setup step, it turns on the LED corresponding to a selection of 0.

The program then enters its main loop containing the button commands. The first is:

button 7,0,0,0,b0,0,no_play

This command translates to: "Read the button on pin 7. When it is pressed, there will be a logical 0 on the pin. Don't debounce or autorepeat (delay = 0). With autorepeat turned off, rate doesn't matter, so set it to 0. Use *b0* as your byte workspace. When the button is not pressed (0), go to *no_play*."

So as long as the button is not pressed, the button command will skip over the code that plays the selected tune. When the button is pressed, the tune will play.

This button command doesn't require debounce or autorepeat, because the tunes are relatively long. By the time a tune is finished playing, the user has probably already released the button. If he hasn't, the tune will simply play again without delay.

The second button command is:

button 6,0,200,60,b1,1,Pick

This translates to: "Read the button on pin 6. When it is pressed, there will be a logical 0 on the pin. Debounce the switch and delay 200 cycles through this command before starting autorepeat. Once autorepeat begins, delay 60 cycles through button between repeats. Use b1 as a workspace. When the button is pressed (1) go to the label *Pick*."

From the user's standpoint, this means that a single press of the select button lights the next LED in the sequence. Holding down the button makes the LEDs scan rapidly. Releasing the switch causes the currently lit LED to remain on.

It's hard to describe what an important difference debounce and autorepeat make in the ease and quality of a user interface. The best way is to offer a comparison. Listing 2 is the same jukebox program as listing 1, but without the button command to debounce the switches. It uses the same circuit as listing 1, so you can alternately download the two programs for an instant comparison.

When you run NO_BTN.BAS, you'll find no difference in the operation of the play button. Remember that button's debounce and autorepeat features were turned off in the original program anyway. If you need to economize on variables, you can substitute a simple *if/then* for button in cases that don't use these features.

The select button is a different story. It becomes almost impossible to select the LED you want. To make the comparison fair, we even added a brief pause to the *Pick* routine as a sort of debouncing. It helps, but not enough to make the button action feel solid and predictable. This is the kind of case that requires *button*.

Program listing. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

Listing 1: BTN_JUKE.BAS (Demonstration of the Button command)

```
' The Stamp serves as a tiny jukebox, allowing you to pick from one of
' five musical (?) selections created with the sound command. The point
' of the program is to demonstrate the proper way to use the button
' command. The juke has two buttons--one that lets you pick the tune
' by "scrolling" through five LEDs, and the other that plays the tune
' you selected. The selection button uses the debounce and autorepeat
' features of button, while the play button is set up for immediate
' response without delay or autorepeat.

SYMBOL Select = b2            ' Variable to hold tune selection, 0-4.

let dirs = %00111111          ' Pins 6 & 7 are inputs for buttons.
let w0 = 0                    ' Initialize all variables to zero
let w1 = 0                    ' (includes clearing the button variables b0,b1)
let pins = %00000010          ' Turn on the first selection LED.

' The main program loop. Main scans the two buttons and branches to
' no_play or Pick, depending on which button was pressed. Note the two
' different ways the button command is used. In the first case,
' button skips over the branch instruction that jumps to the
' appropriate tune routine _unless_ the button is pushed.
' The tunes are fairly long, so no debounce is needed, and
' autorepeat isn't appropriate (the next trip through main will
' play the tune again, anyway). The second button command, which
' scrolls through the selection LEDs, uses both debounce and auto-
' repeat. Switch bounce could cause the display to seem to skip
' over selections, and autorepeat is a nice, professional touch
' for rapidly scrolling through the display.

Main:
  button 7,0,0,0,b0,0,no_play      ' Don't play tune unless button is pushed.
  branch Select,(Tune0,Tune1,Tune2,Tune3,Tune4)
no_play:
  button 6,0,200,60,b1,1,Pick      ' When button is pushed, change selection.
goto Main
```

```
' Pick increments the variable Selection, while limiting it to a maximum
' value of 4. If Selection exceeds 4, the code resets it to 0.

Pick:
  let Select = Select + 1          ' Increment selection.
  if Select < 5 then skip          ' If Select = 5, then Select = 0.
  let Select = 0                   ' Skip this line if Select is < 3.
skip:
  lookup Select,(2,4,8,16,32),pins             ' Light appropriate LED.
goto Main                                      ' Return to main program loop.

' The tunes. Not necessarily music.

Tune0: sound 0,(100,10,110,100): goto main

Tune1: sound 0,(98,40,110,10,100,40): goto main

Tune2: sound 0,(100,10,80,100): goto main

Tune3: sound 0,(100,10,110,50,98,10): goto main

Tune4: sound 0,(98,40,100,10,110,40): goto main
```

' Listing 2: NO_BTN.BAS (Demonstration of poor debouncing)

```
' This program is identical to BTN_JUKE.BAS, except that it does not
' use button commands to read the state of the switches. Contrasting
' the operation of this program to BTN_JUKE will give you a good idea
' of the benefits of button.

' The Stamp serves as a tiny jukebox, allowing you to pick from one of
' five musical (?) selections created with the sound command. The point
' of the program is to demonstrate the proper way to use the button
' command. The juke has two buttons--one that lets you pick the tune
' by "scrolling" through five LEDs, and the other that plays the tune
' you selected.


SYMBOL Select = b2               ' Variable to hold tune selection, 0-4.

let dirs = %00111111             ' Pins 6 & 7 are inputs for buttons.
let b2 = 0                       ' Clear the selection.
let pins = %00000010             ' Turn on the first selection LED.

' The main program loop. Main scans the two buttons and takes the
' appropriate action. If the play button on pin 7 is not pressed,
' the program skips over the code that plays a tune. If the select
```

```
' button is pressed, the program goes to the routine Pick, which
' increments the current tune selection and LED indicator.

Main:
  if pin7 = 1 then no_play          ' Don't play tune unless pin 7 button is pushed.
  branch Select,(Tune0,Tune1,Tune2,Tune3,Tune4)
no_play:
  if pin6 = 0 then Pick             ' When pin 6 button is pushed, change tune.
goto Main

' Pick increments the variable Selection, while limiting it to a maximum
' value of 4. Note that it begins with a pause of 0.15 seconds. This
' prevents the code from executing so fast that the LEDs become a blur.
' However, it's no substitute for the button command. You'll find that
' it is hard to select the particular LED you want.

Pick:
  pause 150                         ' Attempt to debounce by delaying .15 sec.
  let Select = Select + 1           ' Increment selection.
  if Select < 5 then skip           ' If Select = 5, then Select = 0.
  let Select = 0                    ' Skip this line if Select is < 3.
skip:
  lookup Select,(2,4,8,16,32),pins              ' Light appropriate LED.
goto Main                                       ' Return to main program loop.

' The tunes. Not necessarily music.

Tune0: sound 0,(100,10,110,100): goto main

Tune1: sound 0,(98,40,110,10,100,40): goto main

Tune2: sound 0,(100,10,80,100): goto main

Tune3: sound 0,(100,10,110,50,98,10): goto main

Tune4: sound 0,(98,40,100,10,110,40): goto main
```

1

Introduction. This application note describes an inexpensive and accurate timebase for Stamp applications.

Background. The Stamp has remarkable timing functions for dealing with microseconds and milliseconds, but it stumbles a little when it comes to minutes, hours, and days.

The reason for this is twofold: First, the Stamp's ceramic resonator timebase is accurate to about ±1 percent, so the longer the timing interval, the larger the error. A clock that was off by 1 percent would gain or lose almost 15 minutes a day.

Second, Stamp instructions take varying amounts of time. For example, the *Pot* command reads resistance by measuring the length of time required to discharge a capacitor. The higher the resistance, the longer *Pot* takes. The math operators also take varying amounts of time depending on the values supplied to them.

The result is that even the most carefully constructed long-term timing programs end up being less accurate than a cheap clock.

An obvious cure for this might be to interface a real-time clock to the Stamp. Available units have all kinds of neat features, including calendars with leap-year compensation, alarms, etc. The trouble here is that once you write a program to handle their synchronous serial interfaces, acquire the time from the user, set the clock, read the time and convert

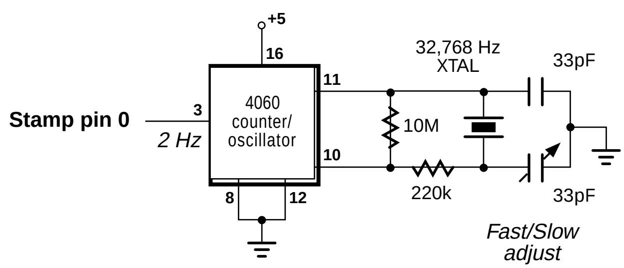


Figure 1. Schematic to accompany TIC_TOC.BAS

it to a usable form, you have pretty much filled the Stamp's EEPROM. A compromise approach is to provide the Stamp with a very accurate source of timing pulses, and let your program decide how to use them. The circuit and example program presented here do just that. For this demonstration, the Stamp counts the passing seconds and displays them using *debug*.

How it works. The circuit in figure 1 shows how to construct a crystal-controlled, 2-pulse-per-second timebase from a common digital part, the CD4060B. This part costs less than $1 from mail-order companies like the one listed at the end of this note. The 32,768-Hz crystal is also inexpensive, at just over 50 cents.

The 4060 is a 14-stage binary counter with an onboard oscillator. Although the oscillator can be used with a resistor / capacitor timing circuit, we're going for accuracy; hence the crystal. Why 32,768 Hz and not some other value, like 1 MHz? It just happens that $32{,}768 = 2^{15}$, so it's easy to use a binary counter like the 4060 to divide it down to easy fractions of one second. Since the 4060 is a 14-stage counter, the best it can do is divide by 2^{14}. The program further divides the resulting twice-a-second pulses to produce one count per second.

Take a look at the program listing. It consists of a main loop and a routine to increment the clock. In an actual application, the main loop would contain most of the program instructions. For accurate timing, the instructions within the main loop must take less than 250 milliseconds total. Even with the timing problems we've discussed, that's pretty easy to do.

Let's walk through the program's logic. In the main loop, the program compares the state of *pin0* to *bit0*. If they're equal (both 0 or both 1) it jumps to the *tick* routine.

In *tick*, the program toggles *bit0* by adding 1 to the byte it belongs to, *b0*. This makes sure that *bit0* is no longer equal to the state of *pin0*, so the program won't return to *tick* until *pin0* changes again.

B0 also serves as a counter. If it is less than 4, the program returns to the main loop. When *b0* reaches 4, *tick* clears it, adds 1 to the running total of seconds, displays the number of seconds on the screen, and jumps back to the main loop.

This is pretty elementary programming, but there's one detail that may be bothering you: If we're using a 2-Hz timebase, why count to 4 before incrementing the seconds? The reason is that we're counting transitions—changes in the state of *pin0*—not cycles. Figure 2 shows the difference.

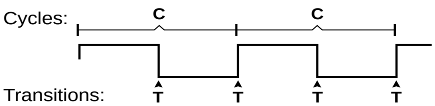


Figure 2.

This stems from our use of *bit0* to track changes in the timing pulses. As soon as *pin0* = *bit0*, we drop into *tick* and toggle the state of *bit0*. This keeps us from visiting *tick* more than once during the same pulse. The next time *pin0* changes—the next transition—*pin0* = *bit0*, and *tick* executes again. A side effect of this approach is that we increment the counter twice per cycle.

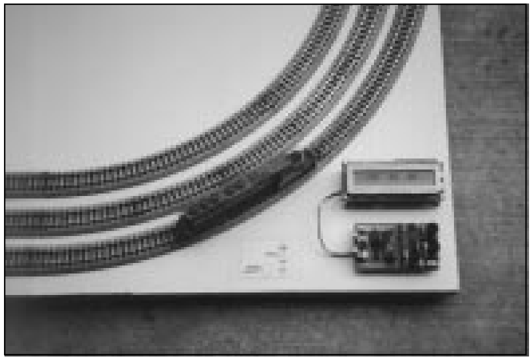
Construction notes. The circuit in figure 1 draws only about 0.5 mA, so you can power it from the Stamp's +5V supply without any problem. The resistor and capacitor values shown are a starting point, but you may have to adjust them somewhat for most reliable oscillator startup and best frequency stability. You may substitute a fixed capacitor for the adjustable one shown, but you'll have to determine the best value for accurate timing. The prototype was right on the money with a 19-pF capacitor, but your mileage may vary due to stray capacitance and parts tolerances.

Parts source. The CD4060B and crystal are available from Digi-Key (800-344-4539) as part numbers CD4060BE-ND and SE3201, respectively.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: TIC_TOC.BAS  (Increment a counter in response to a
' precision 2-Hz external clock.)

' The 2-Hz input is connected to pin0. Bit0 is the lowest bit of b0,
' so each time b0 is incremented (in tick), bit0 gets toggled. This
' ensures that tick gets executed only once per transition of pin0.

Main:
        if pin0 = bit0 then tick
          ' Other program activities--
          ' up to 250 ms worth--
          ' go here.
        goto Main

' Tick maintains a 16-bit counter to accumulate the number of seconds.
' The maximum time interval w1 can hold is 65535 seconds--a bit over
' 18 hours. If you want a minute count instead, change the second
' line of tick to read: "if b0 < 240 then Main". There are 1440 minutes
' in a day, so w1 can hold up to 65535/1440 = 45.5 days worth of to-the-
' minute timing information.

tick:
        let b0 = b0 + 1                 ' Increment b0 counter.
        if b0 < 4 then Main             ' If b0 hasn't reached 4, back to Main.
        let b0 = 0                      ' Else clear b0,
        let w1 = w1 + 1                 '  increment the seconds count,
        debug cls,#w1," sec."           '  and display the seconds.
        goto Main                       ' Do it again.
```

Introduction. This application note describes a simple model train project that we showed at the Embedded Systems Conference in 1994. The project uses a Stamp to control the speeds of three N-scale trains. The speeds are displayed on an LCD display, and can be changed using three buttons: *track select*, *up*, and *down*.



The completed Stamp-controlled train set (buildings and trees were added later).

Background. Several months before the Conference, we decided that we should have an interesting example of the Stamp's capabilities. We determined that it should be something physical, something simple, and something that people would relate to. We looked at various toys, including Legos, Erector Sets, electric race cars, and model trains. They all had their good and bad points, but we finally decided upon model trains. I always liked model trains as a child, and I was the one who had to build it, anyway.

Trains are somewhat simple to control and detect, and many people like them (more than we expected). The only drawback was the amazingly high cost of constructing a complete train set. A complete train set, with three loops of track, three trains, several buildings, and lots of trees, cost about $700! (the trains my parents bought were much less expensive). It didn't seem like that much, because I purchased the track one day, and the engines a week later, and the buildings a week later, etc. But the bookkeeper was keeping track, and indeed the simple train display was getting expensive. But, alas, it was too late to go back.

Having decided upon a train set, I had the harder task of deciding what to do with it. I had some really neat ideas, like having a Stamp in each engine, thus making each train intelligent. With a brain in each train, I would then have infrared “markers” along the track, so the trains would know their position and act accordingly. In fact, perhaps they could even communicate with a master Stamp, which could then modify their path and communicate with other trains. The possibilities were endless, especially since I hadn’t run into reality, yet.

After some humbling thought, I tapered my ideas to a simple two-part goal: to control the speed of three trains, and to detect the position of the trains. I didn’t know exactly how to accomplish these goals, but they seemed possible. I knew that high-current drivers existed, and could be used to run the trains. As for detecting the trains, my thoughts ranged from LED / detector pairs to Hall-effect sensors. The Hall-effect sensors seemed better, since they could be hidden (LEDs would be too obvious).

Preliminary research. Not knowing much about high-current drivers, I called Scott Edwards. He knows something about everything, and he was happy to fax a pinout of the Motorola ULN2803. The Motorola chip is an 18-pin device described as an “octal high-voltage, high-current Darlington transistor array.” Other people refer to it as a “low-side driver,” since it’s used to drive the low (GND) side of a load. Each driver can sink 500 mA, and as you might guess from the word “octal” in the name, the ULN2803 has eight separate drivers, so you can really drive a lot of current with one chip. The chip even has internal clamping diodes to suppress transients that occur when “noisy” devices turn on and off (“noisy” devices include motors, relays, solenoids, etc.). Without diodes to suppress transients, the digital control circuitry (in this case, the Stamp) may go crazy (I think this is caused by fluctuations on the I/O pins and/or power pins). In any case, the ULN2803 makes a previously messy task very clean, simple, and inexpensive (the chips are under $1).

As for Hall-effect sensors, I ordered a selection from Digi-Key and then went to Radio Shack to buy some magnets. If you’re not familiar with them, Hall-effect sensors are 3-pin, transistor-sized devices that sense magnetic fields. They sense the presence of a north or south magnetic field, depending on the individual sensor’s design. Some even act as a mechanical switch: they trigger when a magnetic field is present, and then remain activated until power is removed. Others remain active until they sense another magnetic field of the same or opposite polarity. And all of the ones I found had TTL-level outputs, which was perfect for the Stamp. All in all, if you need to sense a magnetic field, there's probably one for you.

For me, the only question was: will the train's engine generate a strong enough field to trigger the sensor? After all, I wanted to place the sensor under the track, or even under the wooden board on which the train set was built. This would place the sensor 0.25 to 0.75 inches from the underside of the train. Unfortunately, the train didn't produce an adequate field at any distance, no matter how small. So, I purchased a selection of "super strong" magnets at a nearby electronics store. These small magnets were strong enough to keep themselves secured to my hand by placing one in my palm and the other on the back of my hand (fairly impressive, since my hand is at least an inch thick). And they were strong enough to activate the most sensitive Hall-effect sensor through the track *and the wooden board!* This was great, because placing the sensors on the "back" of the train set would be much easier than drilling holes in the board.

Starting construction. Having done a little preliminary research, it was time to start making something. It seemed logical to construct the basic track layout first, and then start integrating the Stamp. So, I constructed a simple layout of three oval tracks. The distance separating each track from the next was about half an inch. I thought this closeness would look attractive when all three trains were running at the same time; I even reversed the polarity of the middle track, just to make the display look especially interesting (all trains going the same direction might get boring).

With the physical layout complete, I turned to speed control. I remembered that the ULN2803 was used on our Stamp Experiment Board, so I used the experiment board for initial testing. Using a handful of micrograbber cables, I quickly connected the on-board Stamp circuit to the ULN2803 and then to the first loop of track. And, of course, nothing worked. I examined the circuit for several hours, and discovered two or three stupid mistakes. The mistakes were truly stupid (like missing ground connections), but one of them reminded me of why the ULN2803 is called a low-side driver: the driver provides a switchable ground, so my circuit must therefore provide a constant "supply" voltage to one side of the tracks (in this case, 12 VDC). With the minor bugs corrected, it worked, or at least somewhat. I hadn't written much code, so the necessary PWM routines weren't in place to vary the train's speed. However, I could toggle a Stamp I/O pin, which drove the ULN2803, which powered the train. A miracle was upon us (at least for me): the BASIC Stamp could make the train start and stop.

A foundation was forming, but there were still basic human-interface questions (how many buttons would control the system?, would there be an LCD display?, etc.). I decided upon the following design:

- Three buttons (track select, up, down)
- LCD display for track speeds

I ordered a selection of push-buttons from Digi-Key and called Scott about his new serial LCD module (it was new at the time). He had designed a 1x16 character LCD which was controlled with one line (plus power and ground). The serial LCD was a godsend, because I was running out of I/O lines on the Stamp. Controlling the track voltages took three lines, and the buttons were going to take three more. This left only two unused I/O lines, which would usually fall short of the six lines required to drive a regular intelligent LCD. But, again, the serial LCD saved the day. With the tracks, buttons, and LCD, I had one I/O line left unused.

The buttons arrived the next day, and I chose the ones that seemed best for the job (large button, small footprint). I soldered the ULN2803 and three buttons onto a BASIC Stamp, and then connected the Stamp to the train set.

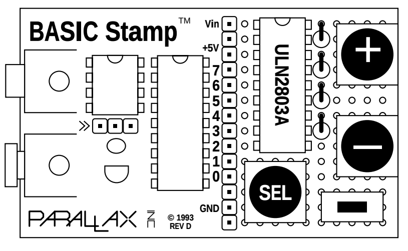
Programming custom PWM. It was time to do some real BASIC programming. Earlier, when Scott sent the ULN2803 data, he also included some routines to make the Stamp perform "custom" pulse-width-modulation (PWM). The Stamp has a built-in PWM command, but it's meant for purposes other than driving the ULN2803. To control the speed of the trains, I would need to write a program that pulsed the voltage to the tracks. Instead of varying the voltage to the tracks, which would require more complex hardware, the Stamp could simply pulse the tracks with a set voltage. Pulse-width-modulation has that name because you are varying, or *modulating*, the width of a pulse. If the pulse is on half the time and off half the time, then you have a duty cycle of 0.5, which would theoretically make the train run at half speed (of course, the engine's performance is probably not linear). Using Scott's example as a guide, I wrote a subroutine that pulsed all three tracks according to the speed set by the user. I still don't fully understand real PWM, but the basic theory of the train routine makes sense:

- A counter (or *accumulator*) is maintained for each track.
- The user sets a speed (0-99) for each track.
- For every pass through the PWM routine, the speed is added to the accumulator. The high bit (bit 7) of the accumulator is then copied to the I/O pin for the appropriate track. If the bit is a '1', then the train will receive power; if the bit is a '0', then power is removed.
- The Stamp executes the PWM routine many times per second, so the train receives a number of 'on' and 'off' states. A higher speed value causes the accumulator to overflow more often, which results in more frequent 'on' states. If power to the tracks is 'on' more often, then the trains move more quickly. If power is 'off' more often, then the trains slow down.

Connecting push-buttons. With the PWM routine working relatively well, it was time to move on to other concerns. The push-buttons and LCD were waiting to be used. The buttons seemed like the obvious thing to work on next.

The BASIC Stamp has a particularly handy instruction called BUTTON, which is used to read push-buttons and perform otherwise tedious functions, such as debounce and auto-repeat. Debounce is necessary to convert one button press into one electrical pulse (many pulses actually occur when the button's contacts are closed); auto-repeat allows the user to hold down the button and have the system act as if he were repeatedly pressing the button (most computer keyboards do this). I had never used the BUTTON instruction before, but it was relatively simple to experiment with and understand.

But, I noticed that the buttons seemed unstable; sometimes the Stamp would act as if I were still pressing a button long after I had stopped. Then I realized that I had forgotten pull-up resistors on the button inputs. In my circuit, when a button was pressed, it connected the associated I/O pin to ground, which read as '0' to the BASIC program. However, when the button was not pressed, the I/O pin would "float," since it wasn't connected to anything. Since the pin was floating, it would randomly read as '0' or '1'. This was solved by adding pull-up resistors to the button inputs; the resistors provide a weak connection to the 5-volt supply, so the inputs read as '1' when their buttons are not pressed. The last step involving the buttons was to adjust the auto-repeat rate until it seemed right (not too fast, not too slow). The repeat rate is controlled by one of the values given in the BUTTON instruction, so it just took a few quick downloads to arrive at the right value.



Completed Stamp with ULN2803 and buttons

Connecting the LCD display. With the buttons working, the next item was the LCD. I connected the LCD to the Stamp and then entered the sample program provided with the LCD. After some minor trouble-shooting, the LCD worked, and worked well! Printing text was almost as easy as using the normal PRINT instruction found in other versions of BASIC. But, since the Stamp has no PRINT instruction, the LCD is controlled with simple SEROUT instructions. For instance, SEROUT 0,N2400,("hello") prints the word "hello" on an LCD module connected to pin 0.

I wanted the LCD to display something fancy, but reality came into play for two reasons: 16 characters isn't that much, especially if you want to display three speeds, and I was quickly running out of program space in the Stamp. So, I decided upon a simple display of the track speeds, as shown below:

```
>00   00   00
```

The pairs of digits represent the speed of the trains, and the arrow indicates which train is currently selected (pressing the up and down buttons affects the speed of the currently selected train). This arrangement was simple to operate, and made good use of available resources.

Streamlining the program. After a day or so, I had a program that was nearly finished; it read the buttons, updated the LCD, and ran the trains. But, as I finished the LCD routine, I noticed that the performance of the trains was getting progressively worse. The trains had run smoothly before, even at slow speeds, but now they were very jerky, even at medium and fast speeds. The problem was that the LCD took a fairly long time to update. Updating the LCD meant sending 22 bytes of data, which took about 0.1 seconds. One-tenth of a second isn't much to us, but it's an eternity to the Stamp, and was quite noticeable in the trains. I spent the evening making the program more efficient, which resulted in more acceptable operation. The two changes that really helped were:

- Updating the LCD only when something changed, which looks better, anyway (less flicker).
- Calling the train PWM routine several times from within the LCD routine.

I was finally nearing the end of the project. I did a few downloading tests, and realized that I only had a few more bytes of program space in the Stamp.

There was one more function I wanted: the trains derailed a few times while running continuously, so I felt that a panic button would be a good idea. The purpose of the button would be to stop the trains in the event of an accident. Without the panic button, the operator would have to set each speed to zero, which would take some time (I imagined trains strewn about the board). The panic button was easy: all I needed to add was a single line in the beginning of the main loop, which would check the panic button and jump to an earlier line that set the speeds to zero (something that the program did upon start-up). This seemed straightforward, but it proved to be more difficult than I thought. The concept was fine, but I was short a few bytes of program space.

A few more bytes. Squeezing a few more bytes out of my program was painfully difficult. Finally, everything did fit, but only after resorting to extreme measures. For instance, if you look at the first few lines of code, you'll see the following:

```
symbol track1_speed=b2
symbol track1_accum=b1

symbol track2_speed=b3
symbol track2_accum=b7

symbol track3_speed=b4
symbol track3_accum=b6

symbol current_track = b5
.
.
.
reset: w1 = 0: w2 = 0
```

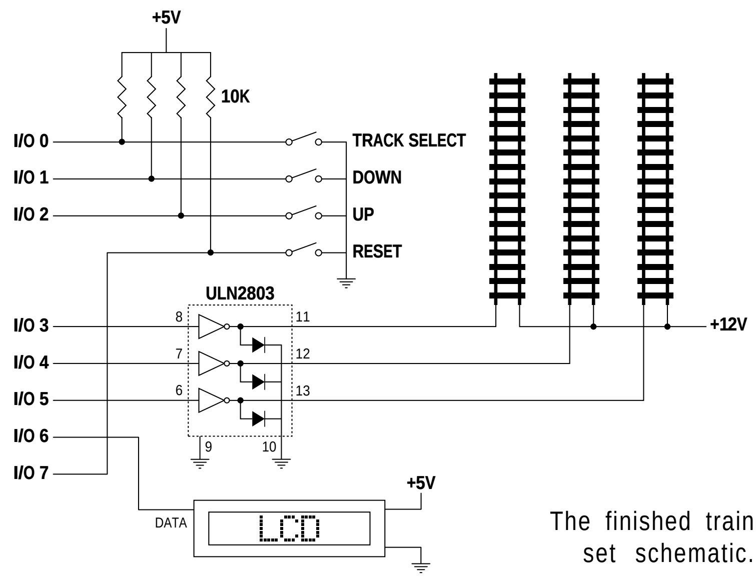
You might wonder why I didn't just use the variables b1-b7 in order, which is how I originally had them. The order shown seems random, but it actually saves program space later. The last line shown resets the track speeds and current track variable. The word variable w1 includes b2 and b3, and the word variable w2 includes b4 and b5. So, by clearing two word variables, the program clears four byte variables, which saves a byte or two of program space.

If you're really wondering about variable allocation, you might also wonder why the program doesn't store anything in b0. This is because b0 has a special role in the train PWM routine:

```
.
.
.
b0 = track1_accum
pin3 = bit7
```

In this piece of code, b0 is loaded with the accumulator for track #1. You may recall that the high bit (bit 7) of the accumulator is used to drive the track. But, how do we isolate the high bit? The easiest way, at least on the Stamp, is to copy the 8-bit accumulator value into b0, and then use the unique bit-addressable quality of b0 to drive the track I/O pin. The statement pin3 = bit7 means *make pin 3 the same state as bit 7 of b0.* The only variable that's bit-addressable is b0, so it should be saved for such cases.

Conclusion. In the end, the train project was fun and educational. It wasn't nearly as elaborate as I originally intended, but it was a good example of what the BASIC Stamp could do. We now offer a larger Stamp, which would have made the programming portion much easier. But, it wouldn't have been nearly as much fun.



The finished train set schematic.

Program listing: As with the other application notes, this program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: TRAIN.BAS
' Uses simple 4-button interface and LCD to control voltages to three N-scale trains.

symbol track1_speed=b2                          'set up variable names
symbol track1_accum=b1

symbol track2_speed=b3
symbol track2_accum=b7

symbol track3_speed=b4
symbol track3_accum=b6

symbol current_track = b5

symbol track_btn = b8
symbol up_btn = b9
symbol down_btn = b10

pause 2000                                      'wait for lcd to wake up

serout 6,n2400,(254,1,254," ")                  'clear lcd

dirs = %00111000                                'make track driver pins
                                                'outputs; all others are
                                                'inputs

reset:      w1 = 0: w2 = 0                      'set track speeds and
                                                'current track # to 0

goto update_lcd                                 'update lcd

main_loop:

            if pin7 = 0 then reset              'reset everything if
                                                'reset button is pressed

            gosub run_trains                    'update track pwm

track:      button 0,0,30,6,track_btn,0,down0   'read track select button

            current_track = current_track + 1   'increment current track #
            if current_track <> 3 then go_lcd
            current_track = 0                   'reset if over 2
go_lcd:     goto update_lcd                     'update lcd

down0:      button 1,0,30,1,down_btn,0,up0      'read down button
```

```
                if current_track <> 0 then down1      'check current track #
                if track1_speed = 0 then up0
                track1_speed = track1_speed - 1       'reduce track 1 speed
                goto update_lcd                       'update lcd

down1:          if current_track <> 1 then down2      'check current track #
                if track2_speed = 0 then up0
                track2_speed = track2_speed - 1       'reduce track 2 speed
                goto update_lcd                       'update lcd

down2:          if track3_speed = 0 then up0
                track3_speed = track3_speed - 1       'reduce track 3 speed
                goto update_lcd                       'update lcd

up0:            button 2,0,30,1,up_btn,0,main_loop    'read up button

                if current_track <> 0 then up1        'check current track #
                if track1_speed = 99 then main_loop
                track1_speed = track1_speed + 1       'increase track 1 speed
                goto update_lcd                       'update lcd

up1:            if current_track <> 1 then up2        'check current track #
                if track2_speed = 99 then main_loop
                track2_speed = track2_speed + 1       'increase track 2 speed
                goto update_lcd                       'update lcd

up2:            if track3_speed = 99 then main_loop
                track3_speed = track3_speed + 1       'increase track 3 speed

update_lcd:

                serout 6,n2400,(254,130,254," ")      'move cursor and print " "
                if track1_speed > 9 then abc          'test for 1 or 2 digits
                serout 6,n2400,("0")                  'print leading zero
abc:            serout 6,n2400,(#track1_speed)        'print track 1 speed

                gosub run_trains                      'update track pwm

                serout 6,n2400,(254,134,254," ")      'move cursor and print " "
                if track2_speed > 9 then abc2         'test for 1 or 2 digits
                serout 6,n2400,("0")                  'print leading zero
abc2:           serout 6,n2400,(#track2_speed)        'print track 2 speed

                gosub run_trains                      'update track pwm

                serout 6,n2400,(254,138,254," ")      'move cursor and print " "
                if track3_speed > 9 then abc3         'test for 1 or 2 digits
                serout 6,n2400,("0")                  'print leading zero
abc3:           serout 6,n2400,(#track3_speed)        'print track 3 speed
```

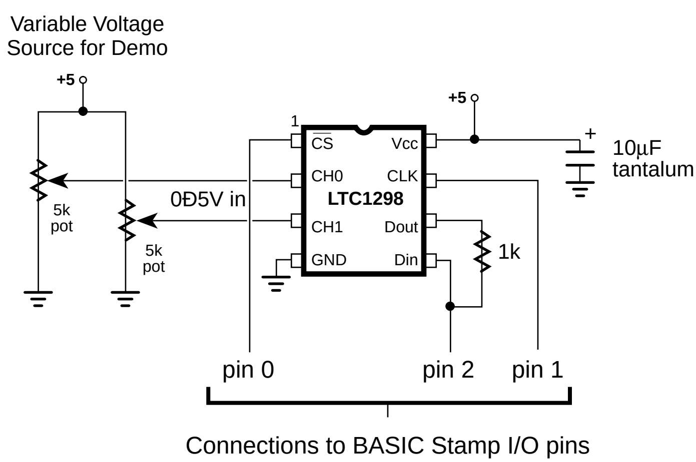
```
            gosub run_trains                    'update track pwm

done:       b0 = current_track * 4 + 130        'print arrow pointing to
            serout 6,n2400,(254,b0,254,">")     'currently selected track

goto main_loop

run_trains:

            'update track 1 pwm
            track1_accum = track1_accum + track1_speed
            b0 = track1_accum
            pin3 = bit7                         'drive track 1
            track1_accum = track1_accum & %01111111

            'update track 2 pwm
            track2_accum = track2_accum + track2_speed
            b0 = track2_accum
            pin4 = bit7                         'drive track 2
            track2_accum = track2_accum & %01111111

            'update track 3 pwm
            track3_accum = track3_accum + track3_speed
            b0 = track3_accum
            pin5 = bit7                         'drive track 3
            track3_accum = track3_accum & %01111111

            return
```

Introduction. This application note shows how to interface the LTC1298 analog-to-digital converter (ADC) to the BASIC Stamp.

Background. Many popular applications for the Stamp include analog measurement, either using the Pot command or an external ADC. These measurements are limited to eight-bit resolution, meaning that a 5-volt full-scale measurement would be broken into units of 5/256 = 19.5 millivolts (mV).

That sounds pretty good until you apply it to a real-world sensor. Take the LM34 and LM35 temperature sensors as an example. They output a voltage proportional to the ambient temperature in degrees Fahrenheit (LM34) or Centigrade (LM35). A 1-degree change in temperature causes a 10-mV change in the sensor's output voltage. So an eight-bit conversion gives lousy 2-degree resolution. By reducing the ADC's range, or amplifying the sensor signal, you can improve resolution, but at the expense of additional components and a less-general design.

The easy way out is to switch to an ADC with 10- or 12-bit resolution. Until recently, that hasn't been a decision to make lightly, since more bits = more bucks. However, the new LTC1298 12-bit ADC is reasonably priced at less than $10, and gives your Stamp projects two channels



Schematic to accompany LTC1298.BAS

of 1.22-mV resolution data. It's packaged in a Stamp-friendly 8-pin DIP, and draws about 250 microamps (µA) of current.

How it works. The figure shows how to connect the LTC1298 to the Stamp, and the listing supplies the necessary driver code. If you have used other synchronous serial devices with the Stamp, such as EEPROMs or other ADCs described in previous application notes, there are no surprises here. We have tied the LTC1298's data input and output together to take advantage of the Stamp's ability to switch data directions on the fly. The resistor limits the current flowing between the Stamp I/O pin and the 1298's data output in case a programming error or other fault causes a "bus conflict." This happens when both pins are in output mode and in opposite states (1 vs. 0). Without the resistor, such a conflict would cause large currents to flow between pins, possibly damaging the Stamp and/or ADC.

If you have used other ADCs, you may have noticed that the LTC1298 has no voltage-reference (Vref) pin. The voltage reference is what an ADC compares its analog input voltage to. When the analog voltage is equal to the reference voltage, the ADC outputs its maximum measurement value; 4095 in this case. Smaller input voltages result in proportionally smaller output values. For example, an input of 1/10th the reference voltage would produce an output value of 409.

The LTC1298's voltage reference is internally connected to the power supply, Vcc, at pin 8. This means that a full-scale reading of 4095 will occur when the input voltage is equal to the power-supply voltage, nominally 5 volts. Notice the weasel word "nominally," meaning "in name only." The actual voltage at the +5-volt rail of the full-size (pre-BS1-IC) Stamp with the LM2936 regulator can be 4.9 to 5.1 volts initially, and can vary by 30 mV.

In some applications you'll need a calibration step to compensate for the supply voltage. Suppose the LTC1298 is looking at 2.00 volts. If the supply is 4.90 volts, the LTC1298 will measure (2.00/4.90) * 4095 = 1671. If the supply is at the other extreme, 5.10 volts, the LTC1298 will measure (2.00/5.10) * 4095 = 1606.

How about that 30-mV deviation in regulator performance, which cannot be calibrated away? If calibration makes it seem as though the LTC1298 is getting a 5.000-volt reference, a 30-mV variation means that the reference would vary 15 mV high or low. Using the 2.00-volt example, the LTC1298 measurements can range from (2.00 / 4.985) * 4095 = 1643 to (2.00 / 5.015) * 4095 = 1633.

The bottom line is that the measurements you make with the LTC1298 will be only as good as the stability of your +5-volt supply.

The reason the manufacturer left off a separate voltage-reference pin was to make room for the chip's second analog input. The LTC1298 can treat its two inputs as either separate ADC channels, or as a single, differential channel. A differential ADC is one that measures the voltage difference between its inputs, rather than the voltage between one input and ground.

A final feature of the LTC1298 is its sample-and-hold capability. At the instant your program requests data, the ADC grabs and stores the input voltage level in an internal capacitor. It measures this stored voltage, not the actual input voltage.

By measuring a snapshot of the input voltage, the LTC1298 avoids the errors that can occur when an ADC tries to measure a changing voltage. Without going into the gory details, most common ADCs are *successive approximation* types. That means that they zero in on a voltage measurement by comparing a guess to the actual voltage, then determining whether the actual is higher or lower. They formulate a new guess and try again. This becomes very difficult if the voltage is constantly changing! ADCs that aren't equipped with sample-and-hold circuitry should not be used to measure noisy or fast-changing voltages. The LTC1298 has no such restriction.

Parts source. The LTC1298 is available from Digi-Key (800-344-4539) for $8.89 in single quantities (LTC1298CN8-ND). Be sure to request a data sheet or the data book (9210B-ND, $9.95) when you order.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: LTC1298.BAS (LTC1298 analog-to-digital converter)
' The LTC1298 is a 12-bit, two-channel ADC. Its high resolution, low
' supply current, low cost, and built-in sample/hold feature make it a
' great companion for the Stamp in sensor and data-logging applications.
' With its 12-bit resolution, the LTC1298 can measure tiny changes in
' input voltage; 1.22 millivolts (5-volt reference/4096).

' ==================================================================
'                 ADC Interface Pins
' ==================================================================

' The 1298 uses a four-pin interface, consisting of chip-select, clock,
' data input, and data output. In this application, we tie the data lines
' together with a 1k resistor and connect the Stamp pin designated DIO
' to the data-in side of the resistor. The resistor limits the current
' flowing between DIO and the 1298's data out in case a programming error
' or other fault causes a "bus conflict." This happens when both pins are
' in output mode and in opposite states (1 vs 0). Without the resistor,
' such a conflict would cause large currents to flow between pins,
' possibly damaging the Stamp and/or ADC.

SYMBOL   CS = 0          ' Chip select; 0 = active.
SYMBOL   CLK = 1         ' Clock to ADC; out on rising, in on falling edge.
SYMBOL   DIO_n = 2       ' Pin _number_ of data input/output.
SYMBOL   DIO_p = pin2    ' Variable_name_ of data input/output.
SYMBOL   ADbits = b1     ' Counter variable for serial bit reception.
SYMBOL   AD = w1         ' 12-bit ADC conversion result.

' ==================================================================
'                 ADC Setup Bits
' ==================================================================

' The 1298 has two modes. As a single-ended ADC, it measures the
' voltage at one of its inputs with respect to ground. As a differential
' ADC, it measures the difference in voltage between the two inputs.
' The sglDif bit determines the mode; 1 = single-ended, 0 = differential.
' When the 1298 is single-ended, the oddSign bit selects the active input
' channel; 0 = channel 0 (pin 2), 1 = channel 1 (pin 3).
' When the 1298 is differential, the oddSign bit selects the polarity
' between the two inputs; 0 = channel 0 is +, 1 = channel 1 is +.
' The msbf bit determines whether clock cycles _after_ the 12 data bits
' have been sent will send 0s (msbf = 1) or a least-significant-bit-first
' copy of the data (msbf = 0). This program doesn't continue clocking after
' the data has been obtained, so this bit doesn't matter.

' You probably won't need to change the basic mode (single/differential)
' or the format of the post-data bits while the program is running, so
' these are assigned as constants. You probably will want to be able to
' change channels, so oddSign (the channel selector) is a bit variable.
```

```
SYMBOL    sglDif = 1        ' Single-ended, two-channel mode.
SYMBOL    msbf = 1          ' Output 0s after data transfer is complete.
SYMBOL    oddSign = bit0    ' Program writes channel # to this bit.


' ===========================================================
'              Demo Program
' ===========================================================

' This program demonstrates the LTC1298 by alternately sampling the two
' input channels and presenting the results on the PC screen using Debug.

high CS                       ' Deactivate the ADC to begin.
Again:                        ' Main loop.
  For oddSign = 0 to 1        ' Toggle between input channels.
    gosub Convert             ' Get data from ADC.
    debug "ch ",#oddSign,":",#AD,cr  ' Show the data on PC screen.
    pause 500                 ' Wait a half second.
  next                        ' Change input channels.
goto Again                    ' Endless loop.

' ===========================================================
'              ADC Subroutine
' ===========================================================

' Here's where the conversion occurs. The Stamp first sends the setup
' bits to the 1298, then clocks in one null bit (a dummy bit that always
' reads 0) followed by the conversion data.

Convert:
  low CLK                     ' Low clock—output on rising edge.
  high DIO_n                  ' Switch DIO to output high (start bit).
  low CS                      ' Activate the 1298.
  pulsout CLK,5               ' Send start bit.
  let DIO_p = sglDif          ' First setup bit.
  pulsout CLK,5               ' Send bit.
  let DIO_p = oddSign         ' Second setup bit.
  pulsout CLK,5               ' Send bit.
  let DIO_p = msbf            ' Final setup bit.
  pulsout CLK,5               ' Send bit.
  input DIO_n                 ' Get ready for input from DIO.
  let AD = 0                  ' Clear old ADC result.
  for ADbits = 1 to 13        ' Get null bit + 12 data bits.
    let AD = AD*2+DIO_p       ' Shift AD left, add new data bit.
    pulsout CLK,5             ' Clock next data bit in.
  next                        ' Get next data bit.
  high CS                     ' Turn off the ADC
return                        ' Return to program.
```

Introduction. This application note shows how to interface the DS1620 Digital Thermometer to the BASIC Stamp.

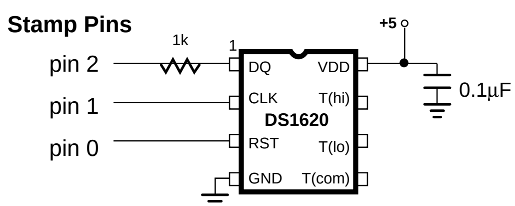
Background. In application note #7, we demonstrated a method for converting the non-linear resistance of a thermistor to temperature readings. Although satisfyingly cheap and crafty, the application requires careful calibration and industrial-strength math.

Now we're going to present the opposite approach: throw money ($7) at the problem and get precise, no-calibration temperature data.

How it works. The Dallas Semiconductor DS1620 digital thermometer / thermostat chip, shown in the figure, measures temperature in units of 0.5 degrees Centigrade from –55° to +125° C. It is calibrated at the factory for exceptional accuracy: +0.5° C from 0 to +70° C.

(In the familiar Fahrenheit scale, those °C temperatures are: range, –67° to +257° F; resolution, 0.9° F; accuracy, +0.9° F from 32° to 158° F.)

The chip outputs temperature data as a 9-bit number conveyed over a three-wire serial interface. The DS1620 can be set to operate continuously, taking one temperature measurement per second, or intermit-



DQÑData input/output
CLKÑClock for shifting data in/out (active-low conversion start in thermostat/ 1-shot mode)
RSTÑReset; high activates chip, low disables it
GNDÑGround connection
VDDÑSupply voltage; +4.5 to 5.5 Vdc
T(hi)ÑIn thermostat mode, outputs a 1 when temp is above high setpoint
T(lo)ÑIn thermostat mode, outputs a 1 when temp is below low setpoint
T(com)ÑIn thermostat mode, outputs a 1 when temp exceeds high setpoint and remains high until temp drops below low setpoint

Schematic to accompany DS1620.BAS

tently, conserving power by measuring only when told to.

The DS1620 can also operate as a standalone thermostat. A temporary connection to a Stamp establishes the mode of operation and high / low-temperature setpoints. Thereafter, the chip independently controls three outputs: T(high), which goes active at temperatures above the high-temperature setpoint; T(low), active at temperatures below the low setpoint; and T(com), which goes active at temperatures above the high setpoint, and stays active until the temperature drops below the low setpoint.

We'll concentrate on applications using the DS1620 as a Stamp peripheral, as shown in the listing.

Using the DS1620 requires sending a command (what Dallas Semi calls a *protocol*) to the chip, then listening for a response (if applicable). The code under "DS1620 I / O Subroutines" in the listing shows how this is done. In a typical temperature-measurement application, the program will set the DS1620 to thermometer mode, configure it for continuous conversions, and tell it to start. Thereafter, all the program must do is request a temperature reading, then shift it in, as shown in the listing's *Again* loop.

The DS1620 delivers temperature data in a nine-bit, two's complement format, shown in the table. Each unit represents 0.5° C, so a reading of 50 translates to +25° C. Negative values are expressed as two's complement numbers. In two's complement, values with a 1 in their leftmost bit position are negative. The leftmost bit is often called the *sign* bit, since a 1 means – and a 0 means +.

To convert a negative two's complement value to a positive number, you must invert it and add 1. If you want to display this value, remember to put a minus sign in front of it.

Rather than mess with two's complement negative numbers, the program converts DS1620 data to an absolute scale called *DSabs*, with a range of 0 to 360 units of 0.5° C each. The Stamp can perform calculations in this all-positive system, then readily convert the results for display in °C or °F, as shown in the listing.

Once you have configured the DS1620, you don't have to reconfigure it unless you want to change a setting. The DS1620 stores its configuration in EEPROM (electrically erasable, programmable read-only memory), which retains data even with the power off. In memory-tight Stamp applications, you might want to run the full program once for configuration, then strip out the configuration stuff to make more room for your final application.

If you want to use the DS1620 in its role as a standalone thermostat, the Stamp can help here, too. The listing includes protocols for putting the DS1620 into thermostat (*NoCPU*) mode, and for reading and writing the temperature setpoints. You could write a Stamp program to accept temperature data serially, convert it to nine-bit, two's complement format, then write it to the DS1620 configuration register.

Be aware of the DS1620's drive limitations in thermostat mode; it sources just 1 mA and sinks 4 mA. This isn't nearly enough to drive a relay—it's just enough to light an LED. You'll want to buffer this output with a Darlington transistor or MOSFET switch in serious applications.

Parts sources. The DS1620 is available from Jameco (800-831-4242) for $6.95 in single quantity as part number 114382 (8-pin DIP). Be sure to

Nine-Bit Format for DS1620 Temperature Data

Temperature		DS1620 Data		
°F	*°C*	*Binary*	*Hex*	*Decimal*
+257	+125	0 11111010	00FA	250
+77	+25	0 00110010	0032	50
+32.9	+0.5	0 00000001	0001	1
+32	0	0 00000000	0000	0
+31.1	-0.5	1 11111111	01FF	511
-13	-25	1 11001110	01CE	462
-67	-55	1 10010010	0192	402

Example conversion of a negative temperature:
-25°C = 1 11001110 in binary. The 1 in the leftmost bit indicates that this is a negative number. Invert the lower eight bits and addÊ1: **1**001110 -> 00110001 +1 = 00110010 = 50. Units are 0.5°C, soÊdivide by 2. Converted result is -25°C.

request a data sheet when you order. Dallas Semiconductor offers data and samples of the DS1620 at reasonable cost. Call them at 214-450-0448.

Program listing. The program DS1620.BAS is available from the Parallax bulletin board system. You can reach the BBS at (916) 624-7101. You may also obtain this and other Stamp programs via Internet: ftp.parallaxinc.com.

```
' Program: DS1620.BAS
' This program interfaces the DS1620 Digital Thermometer to the
' BASIC Stamp. Input and output subroutines can be combined to
' set the '1620 for thermometer or thermostat operation, read
' or write nonvolatile temperature setpoints and configuration
' data.

' ===================== Define Pins and Variables ================
SYMBOL  DQp = pin2        ' Data I/O pin.
SYMBOL  DQn = 2           ' Data I/O pin _number_.
SYMBOL  CLKn = 1          ' Clock pin number.
SYMBOL  RSTn = 0          ' Reset pin number.
SYMBOL  DSout = w0        ' Use bit-addressable byte for DS1620 output.
SYMBOL  DSin = w0         ' "   "   "        word "   "     input.
SYMBOL  clocks = b2       ' Counter for clock pulses.

' ===================== Define DS1620 Constants ===================
' >>> Constants for configuring the DS1620
SYMBOL  Rconfig = $AC     ' Protocol for 'Read Configuration.'
SYMBOL  Wconfig = $0C     ' Protocol for 'Write Configuration.'
SYMBOL  CPU = %10         ' Config bit: serial thermometer mode.
SYMBOL  NoCPU = %00       ' Config bit: standalone thermostat mode.
SYMBOL  OneShot = %01     ' Config bit: one conversion per start request.
SYMBOL  Cont = %00        ' Config bit: continuous conversions after start.
' >>> Constants for serial thermometer applications.
SYMBOL  StartC = $EE      ' Protocol for 'Start Conversion.'
SYMBOL  StopC = $22       ' Protocol for 'Stop Conversion.'
SYMBOL  Rtemp = $AA       ' Protocol for 'Read Temperature.'
' >>> Constants for programming thermostat functions.
SYMBOL  RhiT = $A1        ' Protocol for 'Read High-Temperature Setting.'
SYMBOL  WhiT = $01        ' Protocol for 'Write High-Temperature Setting.'
SYMBOL  RloT = $A2        ' Protocol for 'Read Low-Temperature Setting.'
SYMBOL  WloT = $02        ' Protocol for 'Write Low-Temperature Setting.'

' ===================== Begin Program ============================
' Start by setting initial conditions of I/O lines.
low RSTn        ' Deactivate the DS1620 for now.
```

```
high CLKn       ' Initially high as shown in DS specs.
pause 100       ' Wait a bit for things to settle down.

' Now configure the DS1620 for thermometer operation. The
' configuration register is nonvolatile EEPROM. You only need to
' configure the DS1620 once. It will retain those configuration
' settings until you change them—even with power removed. To
' conserve Stamp program memory, you can preconfigure the DS1620,
' then remove the configuration code from your final program.
' (You'll still need to issue a start-conversion command, though.)
let DSout=Wconfig           ' Put write-config command into output byte.
gosub Shout                 ' And send it to the DS1620.
let DSout=CPU+Cont          ' Configure as thermometer, continuous conversion.
gosub Shout                 ' Send to DS1620.
low RSTn                    ' Deactivate '1620.
Pause 50                    ' Wait 50ms for EEPROM programming cycle.
let DSout=StartC            ' Now, start the conversions by
gosub Shout                 ' sending the start protocol to DS1620.
low RSTn                    ' Deactivate '1620.

' The loop below continuously reads the latest temperature data from
' the DS1620. The '1620 performs one temperature conversion per second.
' If you read it more frequently than that, you'll get the result
' of the most recent conversion. The '1620 data is a 9-bit number
' in units of 0.5 deg. C. See the ConverTemp subroutine below.
Again:
  pause 1000                ' Wait 1 second for conversion to finish.
  let DSout=Rtemp           ' Send the read-temperature opcode.
  gosub Shout
  gosub Shin                ' Get the data.
  low RSTn                  ' Deactivate the DS1620.
  gosub ConverTemp          ' Convert the temperature reading to absolute.
  gosub DisplayF            ' Display in degrees F.
  gosub DisplayC            ' Display in degrees C.
goto Again

' ==================== DS1620 I/O Subroutines ==================
' Subroutine: Shout
' Shift bits out to the DS1620. Sends the lower 8 bits stored in
' DSout (w0). Note that Shout activates the DS1620, since all trans-
' actions begin with the Stamp sending a protocol (command). It does
' not deactivate the DS1620, though, since many transactions either
' send additional data, or receive data after the initial protocol.
' Note that Shout destroys the contents of DSout in the process of
' shifting it. If you need to save this value, copy it to another
' register.
Shout:
high RSTn                   ' Activate DS1620.
output DQn                  ' Set to output to send data to DS1620.
```

```
for clocks = 1 to 8          ' Send 8 data bits.
  low CLKn                   ' Data is valid on rising edge of clock.
  let DQp = bit0             ' Set up the data bit.
  high CLKn                  ' Raise clock.
  let DSout=DSout/2          ' Shift next data bit into position.
next                         ' If less than 8 bits sent, loop.
return                       ' Else return.

' Subroutine: Shin
' Shift bits in from the DS1620. Reads 9 bits into the lsbs of DSin
' (w0). Shin is written to get 9 bits because the DS1620's temperature
' readings are 9 bits long. If you use Shin to read the configuration
' register, just ignore the 9th bit. Note that DSin overlaps with DSout.
' If you need to save the value shifted in, copy it to another register
' before the next Shout.
Shin:
input DQn                    ' Get ready for input from DQ.
for clocks = 1 to 9          ' Receive 9 data bits.
  let DSin = DSin/2          ' Shift input right.
  low CLKn                   ' DQ is valid after falling edge of clock.
  let bit8 = DQp             ' Get the data bit.
  high CLKn                  ' Raise the clock.
next                         ' If less than 9 bits received, loop.
return                       ' Else return.

' ================ Data Conversion/Display Subroutines ===============
' Subroutine: ConverTemp
' The DS1620 has a range of -55 to +125 degrees C in increments of 1/2
' degree. It's awkward to work with negative numbers in the Stamp's
' positive-integer math, so I've made up  a temperature scale called
' DSabs (DS1620 absolute scale) that ranges from 0 (-55 C) to 360 (+125 C).
' Internally, your program can do its math in DSabs, then convert to
' degrees F or C for display.
ConverTemp:
if bit8 = 0 then skip        ' If temp > 0 skip "sign extension" procedure.
  let w0 = w0 | $FE00        ' Make bits 9 through 15 all 1s to make a
                             ' 16-bit two's complement number.
skip:
  let w0 = w0 + 110          ' Add 110 to reading and return.
return

' Subroutine: DisplayF
' Convert the temperature in DSabs to degrees F and display on the
' PC screen using debug.
DisplayF:
let w1 = w0*9/10             ' Convert to degrees F relative to -67.
if w1 < 67 then subzF        ' Handle negative numbers.
  let w1 = w1-67
  Debug #w1, " F",cr
```

```
return
subzF:
  let w1 = 67-w1              ' Calculate degrees below 0.
  Debug "-",#w1," F",cr       ' Display with minus sign.
return

' Subroutine: DisplayC
' Convert the temperature in DSabs to degrees C and display on the
' PC screen using debug.
DisplayC:
let w1 = w0/2                 ' Convert to degrees C relative to -55.
if w1 < 55 then subzC         ' Handle negative numbers.
  let w1 = w1-55
  Debug #w1, " C",cr
return
subzC:
  let w1 = 55-w1              ' Calculate degrees below 0.
  Debug "-",#w1," C",cr       ' Display with minus sign.
return
```

The following section deals with the BASIC Stamp II. In the following pages, you'll find installation instructions, programming procedures, PBASIC2 command definitions, and several application notes.

System Requirements

To program the BASIC Stamp II, you'll need the following system:

- IBM PC or compatible computer
- 3.5-inch disk drive
- Parallel port
- 128K of RAM
- MS-DOS 2.0 or greater

If you have the BASIC Stamp II carrier board, you can use a 9-volt battery as a convenient means to power the BASIC Stamp. You can also use a 5-15 (5-40 volts on BS2-IC rev. d) volt power supply, but you should be careful to connect the supply to the appropriate part of the BASIC Stamp. A 5-volt supply should be connected directly to the +5V pin, but a higher voltage should be connected to the PWR pin. **Connecting a high voltage supply (greater than 6 volts) to the 5-volt pin can permanently damage the BASIC Stamp.**

Packing List

If you purchased the BASIC Stamp Programming Package, you should have received the following items:

- BASIC Stamp manual (this manual)
- BASIC Stamp I programming cable (parallel port DB25-to-3 pin)
- BASIC Stamp II programming cable (serial port DB9-to-DB9)
- 3.5-inch diskette

If you purchased the BASIC Stamp II Starter Kit, you should have received the following items:

- BASIC Stamp Manual (this manual)
- BASIC Stamp II programming cable (serial port DB9-to-DB9)
- 3.5-inch diskette
- BS2-IC module
- BASIC Stamp 2 Carrier Board

If any items are missing, please let us know.

Connecting to the PC

To program a BASIC Stamp II, you'll need to connect it to your PC and then run the editor software. In this section, it's assumed that you have a BS2-IC and its corresponding carrier board (shown below).

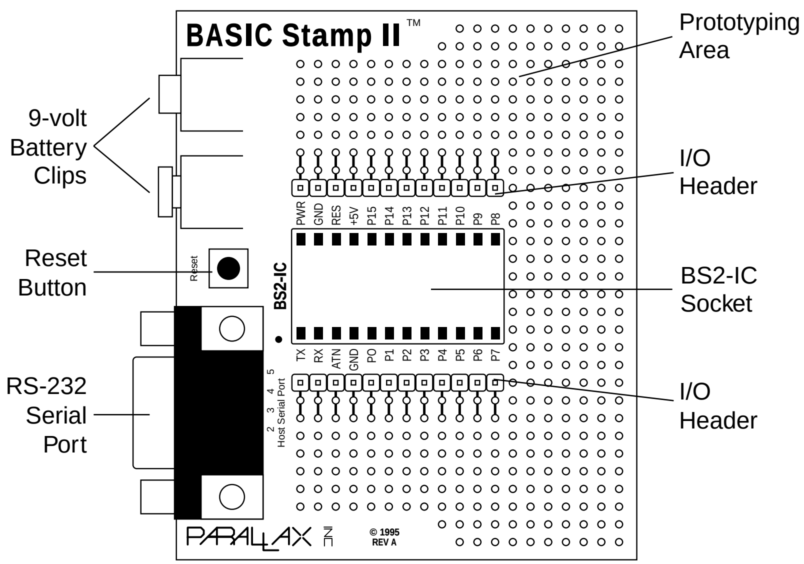
To connect the BASIC Stamp II to your PC, follow these steps:

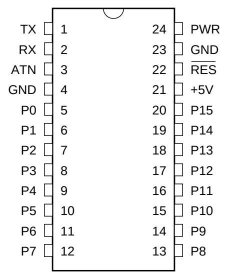
1) Plug the BS2-IC onto the carrier board. The BS2-IC plugs into a 24-pin DIP socket, located in the center of the carrier. When plugged onto the board, the interpreter chip, the largest chip on the BS2-IC, should be furthest from the reset button.

2) In the BASIC Stamp Programming Package, you received a serial cable to connect the BASIC Stamp II to your PC. Plug the female end into an available serial port on your PC.

3) Plug the male end of the serial cable into the carrier board's serial port.

4) Supply power to the carrier board, either by connecting a 9-volt battery or by providing an external power source.





Pin	Name	Description	Comments
1	TX	Serial output	Connect to pin 2 of PC serial DB9 (RX) *
2	RX	Serial input	Connect to pin 3 of PC serial DB9 (TX) *
3	ATN	Active-high reset	Connect to pin 4 of PC serial DB9 (DTR) *
4	GND	Serial ground	Connect to pin 5 of PC serial DB9 (GND) *
5	P0	I/O pin 0	Each pin can source 20 ma and sink 25 ma.
6	P1	I/O pin 1	
7	P2	I/O pin 2	P0-P7 and P8-P15, as groups, can each
8	P3	I/O pin 3	source a total of 40 ma and sink 50 ma.
9	P4	I/O pin 4	
10	P5	I/O pin 5	
11	P6	I/O pin 6	
12	P7	I/O pin 7	
13	P8	I/O pin 8	
14	P9	I/O pin 9	
15	P10	I/O pin 10	
16	P11	I/O pin 11	
17	P12	I/O pin 12	
18	P13	I/O pin 13	
19	P14	I/O pin 14	
20	P15	I/O pin 15	
21	+5V **	+5V supply	5-volt input or regulated output.
22	$\overline{\text{RES}}$	Active-low reset	Pull low to reset; goes low during reset.
23	GND	System ground	
24	PWR **	Regulator input	Voltage regulator input; takes 6-15 volts.

* For automatic serial port selection by the BASIC Stamp II software, there must also be a connection from DSR (DB9 pin 6) to RTS (DB9 pin 7). This connection is made on the BASIC Stamp II carrier board. If you are not using the carrier board, then you must make this connection yourself, or use the command-line option to tell the software which serial port to use.

** During normal operation, the BASIC Stamp II takes about 7 mA. In various power-down modes, consumption can be reduced to about 50 µA.

Starting the Editor

With the BASIC Stamp II connected and powered, insert the BASIC Stamp diskette and then enter the BASIC Stamp II directory by typing the following command from the DOS prompt:

```
CD STAMP2
```

Once in the BASIC Stamp II directory, you can run the BASIC Stamp II editor / downloader software by typing the following command:

```
STAMP2
```

The software will start running after several seconds. The editor screen is dark blue, with one line across the top that indicates how to get on-screen editor help. Except for the top line, the entire screen is available for entering and editing PBASIC programs.

Command-line options:
There are several command-line options that may be useful when running the software; these options are shown below:

STAMP2 filename	Runs the editor and loads *filename.*
STAMP2 /m	Runs the editor in monochrome mode. May give a better display on some systems, especially laptop computers.
STAMP2 /n	Runs the editor and specifies which serial port to use when downloading to the BASIC Stamp II (note that n must be replaced with a serial port number of 1-4).

Normally, the software finds the BASIC Stamp II by looking on all serial ports for a connection between DSR and RTS (this connection is made on the carrier board). If the DSR-RTS connection is not present, then you must tell the software which port to use, as shown above.

Entering & Editing Programs

We've tried to make the editor as intuitive as possible: to move up, press the *up arrow*; to highlight one character to the right, press *shift-right arrow*; etc.

Most functions of the editor are easy to use. Using single keystrokes, you can perform the following common functions:

- Load, save, and run programs.
- Move the cursor in increments of one character, one word, one line, one screen, or to the beginning or end of a file.
- Highlight text in blocks of one character, one word, one line, one screen, or to the beginning or end of a file.
- Cut, copy, and paste highlighted text.
- Search for and / or replace text.
- See how the BASIC Stamp II memory is being allocated.
- Identify the version of the PBASIC interpreter.

Editor Function Keys

The following list shows the keys that are used to perform various functions:

F1	Display editor help screen.
Alt-R	Run program in BASIC Stamp II *(download the program on the screen, then run it)*
Alt-L	Load program from disk
Alt-S	Save program on disk
Alt-M	Show memory usage maps
Alt-I	Show version number of PBASIC interpreter
Alt-Q	Quit editor and return to DOS
Enter	Enter information and move down one line
Tab	Same as Enter

Left arrow	Move left one character
Right arrow	Move right one character
Up arrow	Move up one line
Down arrow	Move down one line
Ctrl-Left	Move left to next word
Ctrl-Right	Move right to next word
Home	Move to beginning of line
End	Move to end of line
Page Up	Move up one screen
Page Down	Move down one screen
Ctrl-Page Up	Move to beginning of file
Ctrl-Page Down	Move to end of file
Shift-Left	Highlight one character to the left
Shift-Right	Highlight one character to the right
Shift-Up	Highlight one line up
Shift-Down	Highlight one line down
Shift-Ctrl-Left	Highlight one word to the left
Shift-Ctrl-Right	Highlight one word to the right
Shift-Home	Highlight to beginning of line
Shift-End	Highlight to end of line
Shift-Page Up	Highlight one screen up
Shift-Page Down	Highlight one screen down
Shift-Ctrl-Page Up	Highlight to beginning of file
Shift-Ctrl-Page Down	Highlight to end of file
Shift-Insert	Highlight word at cursor
ESC	Cancel highlighted text
Backspace	Delete one character to the left
Delete	Delete character at cursor
Shift-Backspace	Delete from left character to beginning of line
Shift-Delete	Delete to end of line
Ctrl-Backspace	Delete line
Alt-X	Cut marked text and place in clipboard
Alt-C	Copy marked text to clipboard
Alt-V	Paste (insert) clipboard text at cursor
Alt-F	Find string (establish search information)
Alt-N	Find next occurrence of string

The following list is a summary of the PBASIC instructions used by the BASIC Stamp II.

◆ This symbol indicates new or greatly improved instructions (compared to the BASIC Stamp I).

BRANCHING

IF...THEN	Compare and conditionally branch.
BRANCH	Branch to address specified by offset.
GOTO	Branch to address.
GOSUB	Branch to subroutine at address. GOSUBs may be nested up to four levels deep, and you may have up to 255 GOSUBs in your program.
RETURN	Return from subroutine.

LOOPING

FOR...NEXT	Establish a FOR-NEXT loop.

NUMERICS

LOOKUP	Lookup data specified by offset and store in variable. This instruction provides a means to make a lookup table.
LOOKDOWN	Find target's match number (0-N) and store in variable.
RANDOM	Generate a pseudo-random number.

DIGITAL I/O

INPUT	Make pin an input
OUTPUT	Make pin an output.
REVERSE	If pin is an output, make it an input. If pin is an input, make it an output.
LOW	Make pin output low.
HIGH	Make pin output high.
TOGGLE	Make pin an output and toggle state.
PULSIN	Measure an input pulse (resolution of 2 µs).

	PULSOUT	Output a timed pulse by inverting a pin for some time (resolution of 2 µs).
	BUTTON	Debounce button, perform auto-repeat, and branch to address if button is in target state.
◆	SHIFTIN	Shift bits in from parallel-to-serial shift register.
◆	SHIFTOUT	Shift bits out to serial-to-parallel shift register.
◆	COUNT	Count cycles on a pin for a given amount of time (0 - 125 kHz, assuming a 50/50 duty cycle).
◆	XOUT	Generate X-10 powerline control codes. For use with TW523 or TW513 powerline interface module.

SERIAL I/O

◆	SERIN	Serial input with optional qualifiers, time-out, and flow control. If qualifiers are given, then the instruction will wait until they are received before filling variables or continuing to the next instruction. If a time-out value is given, then the instruction will abort after receiving nothing for a given amount of time. Baud rates of 300 - 50,000 are possible (0 - 19,200 with flow control). Data received must be N81 (no parity, 8 data bits, 1 stop bit) or E71 (even parity, 7 data bits, 1 stop bit).
◆	SEROUT	Send data serially with optional byte pacing and flow control. If a pace value is given, then the instruction will insert a specified delay between each byte sent (pacing is not available with flow control). Baud rates of 300 - 50,000 are possible (0 - 19,200 with flow control). Data is sent as N81 (no parity, 8 data bits, 1 stop bit) or E71 (even parity, 7 data bits, 1 stop bit).

ANALOG I/O

	PWM	Output PWM, then return pin to input. This can be used to output analog voltages (0-5V) using a capacitor and resistor.
◆	RCTIME	Measure an RC charge/discharge time. Can be used to measure potentiometers.

SOUND

◆	FREQOUT	Generate one or two sinewaves of specified frequencies (each from 0 - 32767 hz.).
◆	DTMFOUT	Generate DTMF telephone tones.

EEPROM ACCESS

◆	DATA	Store data in EEPROM before downloading PBASIC program.
	READ	Read EEPROM byte into variable.
	WRITE	Write byte into EEPROM.

TIME

PAUSE	Pause execution for 0–65535 milliseconds.

POWER CONTROL

NAP	Nap for a short period. Power consumption is reduced.
SLEEP	Sleep for 1-65535 seconds. Power consumption is reduced to approximately 50 µA.
END	Sleep until the power cycles or the PC connects. Power consumption is reduced to approximately 50 µA.

PROGRAM DEBUGGING

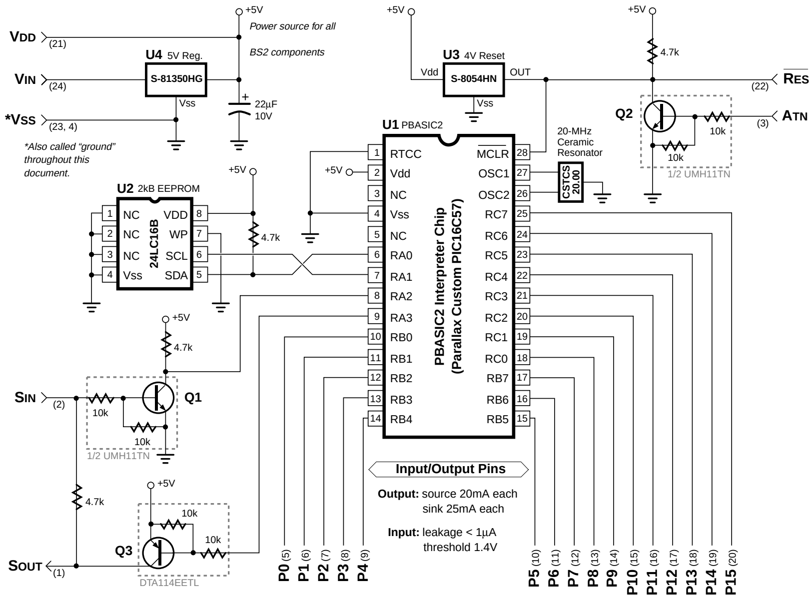
DEBUG	Send variables to PC for viewing.

BS2 Hardware

Figure H-1 is a schematic diagram of the BASIC Stamp II (BS2). In this section we'll describe each of the major components and explain its function in the circuit.

Figure H-1

Schematic Diagram of the BASIC Stamp II (BS2-IC rev. A)



NOTES

1. This diagram depicts the DIP/SOIC version of the PBASIC2 interpreter chip, since users wishing to construct a BS2 from discrete components are most likely to use those parts. Contact Parallax for a schematic depicting the SSOP (ultra-small surface mount) package used in the BS2-IC module.
2. Numbers in parenthesesÑ(#)Ñare pin numbers on the BS2-IC module. The BS2-IC has the form factor of a 24-pin, 0.6" DIP.
3. Q1, Q2 and Q3 are Rohm part numbers. Other components may be substituted in custom circuits, subject to appropriate design. Contact Parallax for design assistance.
4. U3 and U4 are Seiko part numbers. Other components may be substituted in custom circuits, subject to appropriate design. Contact Parallax for design assistance.

PBASIC2 Interpreter Chip (U1)

The brain of the BS2 is a custom PIC16C57 microcontroller (U1). U1 is permanently programmed with the PBASIC2 instruction set. When you program the BS2, you are telling U1 to store symbols, called tokens, in EEPROM memory (U2). When your program runs, U1 retrieves tokens from memory (U2), interprets them as PBASIC2 instructions, and carries out those instructions.

U1 executes its internal program at 5 million instructions per second. Many internal instructions go into a single PBASIC2 instruction, so PBASIC2 executes more slowly—approximately 3000 to 4000 instructions per second.

The PIC16C57 controller has 20 input/output (I/O) pins; in the BS2 circuit, 16 of these are available for general use by your programs. Two others may also be used for serial communication. The remaining two are used solely for interfacing with the EEPROM and may not be used for anything else.

The general-purpose I/O pins, P0 through P15, can interface with all modern 5-volt logic, from TTL (transistor-transistor logic) through CMOS (complementary metal-oxide semiconductor). To get technical, their properties are very similar to those of 74HCTxxx-series logic devices.

The direction—input or output—of a given pin is entirely under the control of your program. When a pin is an input, it has very little effect on circuits connected to it, with less than 1 microampere (µA) of current leaking in or out. You may be familiar with other terms for input mode like *tristate*, *high-impedance*, or *hi-Z*.

There are two purposes for putting a pin into input mode: (1) To passively read the state (1 or 0) of the pin as set by external circuitry, or (2) To disconnect the output drivers from the pin. For lowest current draw, inputs should always be as close to +5V or ground as possible. They should not be allowed to float. Unused pins that are not connected to circuitry should be set to output.

When a pin is an output, it is internally connected to ground or +5V through a very efficient CMOS switch. If it is lightly loaded (< 1mA), the output voltage will be within a few millivolts of the power supply rail (ground for 0; +5V for 1). Pins can sink as much as 25mA (outputting 0) and source up to 20 mA (outputting 1). Each of the two eight-pin ports should not carry more than a total of 50mA (sink) or 40mA (source). Pins P0 through P7 make up one port; P8 through P15 the other.

2048-byte Erasable Memory Chip (U2)

U1 is permanently programmed at the factory and cannot be reprogrammed, so your PBASIC2 programs must be stored elsewhere. That's the purpose of U2, the 24LC16B electrically erasable, programmable read-only memory (EEPROM). EEPROM is a good medium for program storage because it retains data without power, but can be reprogrammed easily.

EEPROMs have two limitations: (1) They take a relatively long time (as much as several milliseconds) to write data into memory, and (2) There is a limit to the number of writes (approximately 10 million) they will accept before wearing out. Because the primary purpose of the BS2's EEPROM is program storage, neither of these is normally a problem. It would take many lifetimes to write and download 10 million PBASIC2 programs! However, when you use the PBASIC2 Write instruction to store data in EEPROM space be sure to bear these limitations in mind.

Reset Circuit (U3)

When you first power up the BS2, it takes a fraction of a second for the supply to reach operating voltage. During operation, weak batteries, varying input voltages or heavy loads may cause the supply voltage to wander out of acceptable operating range. When this happens, normally infallible processor and memory chips (U1 and U2) can make mistakes or lock up. To prevent this, U1 must be stopped and reset until the supply stabilizes. That is the job of U3, the S-8045HN reset circuit. When the supply voltage is below 4V, U3 puts a logic low on U1's master-clear reset (MCLR) input. This stops U1 and causes all of its I/O lines to electrically disconnect. In reset, U1 is dormant; alive but inert.

When the supply voltage is above 4V, U3 allows its output to be pulled high by a 4.7k resistor to +5V, which also puts a high on U1's MCLR input. U1 starts its internal program at the beginning, which in turn starts your PBASIC2 program from the beginning.

Power Supply (U4)

The previous discussion of the reset circuit should give you some idea of how important a stable power supply is to correct operation of the BS2. The first line of defense against power-supply problems is U4, the S-81350HG 5-volt regulator. This device accepts a range of slightly over 5V up to 15V and regulates it to a steady 5V. This regulator draws minimal current for its own use, so when your program tells the BS2 to go into low-power Sleep, End or Nap modes, the total current draw averages out to approximately 100 microamperes (µA). (That figure assumes no loads are being driven and that all I/O pins are at ground or +5V.) When the BS2 is active, it draws approximately 8mA. Since U4 can provide up to 50mA, the majority of its capacity is available for powering your custom circuitry.

Circuits requiring more current than U4 can provide may incorporate their own 5V supply. Connect this supply to V_{DD} and leave U4's input (VIN) open.

Note that figure H-1 uses CMOS terms for the power supply rails, V_{DD} for the positive supply and V_{SS} for ground or 0V reference. These terms are correct because the main components are CMOS. Don't be concerned that other circuits you may come across use different nomenclature; for our purposes, the terms V_{DD}, V_{CC}, and +5V are interchangeable, as are V_{SS}, earth (British usage) and ground.

Serial Host Interface (Q1, Q2, and Q3)

The BS2 has no keyboard or monitor, so it relies on PC-based host software to allow you to write, edit, download and debug PBASIC2 programs. The PC communicates with the BS2 through an RS-232 (COM port) interface consisting of pins SIN, SOUT, and ATN (serial in, serial out, and attention, respectively).

RS-232 uses two signaling voltages to represent the logic states 0 and 1; +12V is 0 and –12V is 1. When an RS-232 sender has nothing to say, it leaves its output in the 1 state (-12V). To begin a transmission, it outputs a 0 (+12V) for one bit time (the baud rate divided into 1 second; e.g., bit time for 2400 baud = 1/2400 = 416.6µs).

You can see how the BS2 takes advantage of these characteristics in the design of its serial interface. NPN transistor Q1 serves as a serial line receiver. When SIN is negative, Q1 is switched off, so the 4.7k resistor on its collector puts a high on pin RA2 of U1, the PBASIC2 interpreter chip. When SIN goes high, Q1 switches on, putting a 0 on RA2/U1.

SOUT transmits data from U1 to the PC. When SOUT outputs a 1, it borrows the negative resting-state voltage of SIN and reflects it back to SOUT through a 4.7k resistor. When SOUT transmits a 0, it turns on PNP transistor Q3 to put a +5V level on SOUT. In this way the BS2 outputs +5/–12V RS-232.

Of course, this method works only with the cooperation of the PC software, which must not transmit serial data at the same time the BS2 is transmitting.

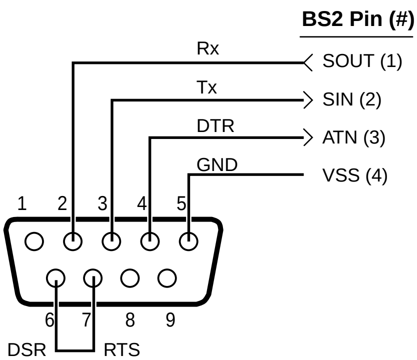
The ATN line interfaces with the data-terminal ready (DTR) handshaking line of the PC COM port. Electrically, it works like the SIN line receiver, with a +12V signal at ATN turning on the Q2 transistor, pulling its collector to ground. Q2's collector is connected to the MCLR (reset) line of the PBASIC2 interpreter chip, so turning on Q2 resets U1. During programming, the STAMP2 host program pulses ATN high to reset U1, then transmits a signal to U1 through SIN indicating that it wants to download a new program. Other than when it wants to initiate programming, the STAMP2 host program holds ATN at –12V, allowing U1 to run normally.

Your PBASIC2 programs may use the serial host interface to communicate with PC programs other than the STAMP2 host program. The only requirement is that ATN must be either disconnected or at less than +1V to avoid unintentionally resetting the BS2. See the Serin listing for further information.

PC-to-BS2 Connector Hookup

Figure H-2 shows how a DB9 programming connector for the BS2 is wired. This connector allows the PC to reset the BS2 for programming, download programs, and receive Debug data from the BS2. An additional pair of connections, pins 6 and 7 of the DB9 socket, lets the STAMP2 host software identify the port to which the BS2 is connected. If you plan to construct your own carrier board or make temporary programming connections to a BS2 on a prototyping board, use this drawing as a guide. If you also want to use this host interface connection to communicate between the BS2 and other PC programs, see the writeup in the Serin listing for suggestions.

Figure H-2



BS2 Memory Organization

The BS2 has two kinds of memory; RAM for variables used by your program, and EEPROM for storing the program itself. EEPROM may also be used to store long-term data in much the same way that desktop computers use a hard drive to hold both programs and files.

An important distinction between RAM and EEPROM is this:

- RAM loses its contents when the BS2 loses power; when power returns, all RAM locations are cleared to 0s.
- EEPROM retains the contents of memory, with or without power, until it is overwritten (such as during the program-downloading process or with a Write instruction.)

In this section, we'll look at both kinds of BS2 memory, how it's organized, and how to use it effectively. Let's start with RAM.

BS2 Data Memory (RAM)

The BS2 has 32 bytes of RAM. Of these, 6 bytes are reserved for input, output, and direction control of the 16 input/output (I/O) pins. The remaining 26 bytes are available for use as variables.

The table below is a map of the BS2's RAM showing the built-in PBASIC names.

Table M-1. BS2 Memory Map

Stamp II I/O and Variable Space				
Word Name	**Byte Name**	**Nibble Names**	**Bit Names**	**Special Notes**
INS	INL INH	INA, INB, INC, IND	IN0 - IN7, IN8 - IN15	Input pins; word, byte, nibble and bit addressable.
OUTS	OUTL OUTH	OUTA, OUTB, OUTC, OUTD	OUT0 - OUT7, OUT8 - OUT15	Output pins; word, byte, nibble and bit addressable.
DIRS	DIRL DIRH	DIRA, DIRB, DIRC, DIRD	DIR0 - DIR7, DIR8 - DIR15	I/O pin direction control; word, byte, nibble and bit addressable.
W0	B0 B1			General Purpose; word, byte, nibble and bit addressable.
W1	B2 B3			General Purpose; word, byte, nibble and bit addressable.
W2	B4 B5			General Purpose; word, byte, nibble and bit addressable.
W3	B6 B7			General Purpose; word, byte, nibble and bit addressable.
W4	B8 B9			General Purpose; word, byte, nibble and bit addressable.
W5	B10 B11			General Purpose; word, byte, nibble and bit addressable.
W6	B12 B13			General Purpose; word, byte, nibble and bit addressable.
W7	B14 B15			General Purpose; word, byte, nibble and bit addressable.
W8	B16 B17			General Purpose; word, byte, nibble and bit addressable.
W9	B18 B19			General Purpose; word, byte, nibble and bit addressable.
W10	B20 B21			General Purpose; word, byte, nibble and bit addressable.
W11	B22 B23			General Purpose; word, byte, nibble and bit addressable.
W12	B24 B25			General Purpose; word, byte, nibble and bit addressable.

The Input/Output (I/O) Variables

As the map shows, the first three words of the memory map are associated with the Stamp's 16 I/O pins. The word variable INS is unique in that it is read-only. The 16 bits of INS reflect the bits present at Stamp I/O pins P0 through P15. It may only be read, not written. OUTS contains the states of the 16 output latches. DIRS controls the direction (input or output) of each of the 16 pins.

If you are new to devices that can change individual pins between input and output, the INS / OUTS / DIRS trio may be a little confusing, so we'll walk through the possibilities.

A 0 in a particular DIRS bit makes the corresponding pin, P0 through P15, an input. So if bit 5 of DIRS is 0, then P5 is an input. A pin that is an input is at the mercy of circuitry outside the Stamp; the Stamp cannot change its state. When the Stamp is first powered up, all memory locations are cleared to 0, so all pins are inputs (DIRS = %0000000000000000).

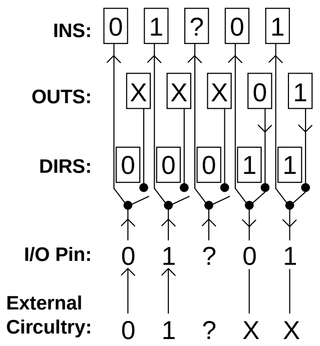
A 1 in a DIRS bit makes the corresponding pin an output. This means that the corresponding bit of OUTS determines that pin's state.

Suppose all pins' DIRS are set to output (1s) and you look at the contents of INS. What do you see? You see whatever is stored in the variable OUTS.

OK, suppose all pins' DIRS are set to input (0s) and external circuits connected to the pins have them all seeing 0s. What happens to INS if you write 1s to all the bits of OUTS? Nothing. INS will still contain 0s, because with all pins set to input, the external circuitry is in charge. However, when you change DIRS to output (1s), the bits stored in OUTS will appear on the I / O pins.

These possibilities are summarized in the Figure M-1 below. To avoid making the table huge, we'll look at only one bit. The rules shown for a single bit apply to all of the I / O bits / pins. Additionally, the external circuitry producing the "external state" listed in the table can be overridden by a Stamp output. For example, a 10k resistor to +5V will place a 1 on an input pin, but if that pin is changed to output and cleared to 0, a 0 will appear on the pin, just as the table shows. However, if the pin is connected directly to +5V and changed to output 0, the pin's state will remain 1. The Stamp simply cannot overcome a direct short, and will probably be damaged in the bargain.

Figure M-1. Interaction of DIRS, INS and OUTS



The DIRS register controls which I/O pins are inputs and which are outputs. When set to input (0), the corresponding bit in the OUTS register is disconnected and ignored.

When set to output (1), the corresponding bit in the OUTS register is connected.

NOTE: "X" indicates state could be a 1 or a 0 and does not affect other elements.

"?" indicates state is unknown and could change erratically.

To summarize: DIRS determines whether a pin's state is set by external circuitry (input, 0) or by the state of OUTS (output, 1). INS always matches the actual states of the I/O pins, whether they are inputs or outputs. OUTS holds bits that will only appear on pins whose DIRS bits are set to output.

In programming the BS2, it's often more convenient to deal with individual bytes, nibbles or bits of INS, OUTS and DIRS rather than the entire 16-bit words. PBASIC2 has built-in names for these elements, listed below. When we talk about the low byte of these words, we mean the byte corresponding to pins P0 through P7.

Table M-2. Predefined Names for Elements of DIRS, INS and OUTS

DIRS	INS	OUTS	The entire 16-bit word
DIRL	INL	OUTL	The low byte of the word
DIRH	INH	OUTH	The high byte of the word
DIRA	INA	OUTA	The low nibble of low byte
DIRB	INB	OUTB	The high nibble of low byte
DIRC	INC	OUTC	The low nibble of high byte
DIRD	IND	OUTD	The high nibble of high byte
DIR0	IN0	OUT0	The low bit; corresponds to P0
...(continues 1 through 14)...			Bits 1 - 14; corresponds to P1 through P14
DIR15	IN15	OUT15	The high bit; corresponds to P15

Using the names listed above, you can access any piece of any I/O variables. And as we'll see in the next section, you can use modifiers to access any piece of any variable.

Predefined "Fixed" Variables

As table M-1 shows, the BS2's memory is organized into 16 words of 16 bits each. The first three words are used for I/O. The remaining 13 words are available for use as general purpose variables.

Just like the I/O variables, the user variables have predefined names: W0 through W12 and B0 through B25. B0 is the low byte of W0; B1 is the high byte of W0; and so on through W12 (B24=low byte, B25=high byte).

Unlike I/O variables, there's no reason that your program variables have to be stuck in a specific position in the Stamp's physical memory. A byte is a byte regardless of its location. And if a program uses a mixture of variables of different sizes, it can be a pain in the neck to logically dole them out or allocate storage.

More importantly, mixing fixed variables with automatically allocated variables (discussed in the next section) is an invitation to bugs. A fixed variable can overlap an allocated variable, causing data meant for one variable to show up in another!

We recommend that you avoid using the fixed variables in most situations. Instead, let PBASIC2 allocate variables as described in the next section. The host software will organize your storage requirements to make optimal use of the available memory.

Why have fixed variables at all? First, for a measure of compatibility with the BS1, which has only fixed variables. Second, for power users who may dream up some clever hack that requires the use of fixed variables. You never know...

Defining and Using Variables

Before you can use a variable in a PBASIC2 program you must declare it. "Declare" is jargon for letting the Stamp know that you plan to use a variable, what you want to call it, and how big it is. Although PBASIC does have predefined variables that you can use without declaring them first (see previous section), the preferred way to set up variables is to use the directive VAR. The syntax for VAR is:

```
symbol      VAR      size
```

where:

- *Symbol* is the name by which you will refer to the variable. Names must start with a letter, can contain a mixture of letters, numbers, and underscore (_) characters, and must not be the same as PBASIC keywords or labels used in your program. Additionally, symbols can be up to 32 characters long. See Appendix B for a list of PBASIC keywords. PBASIC does not distinguish between upper and lower case, so the names MYVARIABLE, myVariable, and MyVaRiAbLe are all equivalent.

- *Size* establishes the number of bits of storage the variable is to contain. PBASIC2 gives you a choice of four sizes:

  bit (1 bit)
  nib (nibble; 4 bits)
  byte (8 bits)
  word (16 bits)

Optionally, specifying a number within parentheses lets you define a variable as an array of bits, nibs, bytes, or words. We'll look at arrays later on.

Here are some examples of variable declarations using VAR:

```
' Declare variables.
mouse    var    bit        ' Value can be 0 or 1.
cat      var    nib        ' Value in range 0 to 15.
dog      var    byte       ' Value in range 0 to 255.
rhino    var    word       ' Value in range 0 to 65535.
```

A variable should be given the smallest size that will hold the largest value that might ever be stored in it. If you need a variable to hold the on/off status (1 or 0) of switch, use a bit. If you need a counter for a FOR/NEXT loop that will count from 1 to 10, use a nibble. And so on.

If you assign a value to a variable that exceeds its size, the excess bits will be lost. For example, suppose you use the nibble variable cat from the example above and write cat = 91 (%1011011 binary), what will cat contain? It will hold only the lowest 4 bits of 91—%1011 (11 decimal).

You can also define multipart variables called arrays. An array is a group of variables of the same size, and sharing a single name, but broken up into numbered cells. You can define an array using the following syntax:

```
symbol      VAR       size(n)
```

where *symbol* and *size* are the same as for normal variables. The new element, *(n)*, tells PBASIC how many cells you want the array to have. For example:

```
myList      var       byte(10)          ' Create a 10-byte array.
```


Once an array is defined, you can access its cells by number. Numbering starts at 0 and ends at n–1. For example:

```
myList(3) = 57
debug ? myList(3)
```

The debug instruction will display 57. The real power of arrays is that the index value can be a variable itself. For example:

```
myBytes     var       byte(10)          ' Define 10-byte array.
index       var       nib               ' Define normal nibble variable.

For index = 0 to 9                      ' Repeat with index= 0,1,2...9
  myBytes(index)= index*13              ' Write index*13 to each cell of array.
Next

For index = 0 to 9                      ' Repeat with index= 0,1,2...9
  debug ? myBytes(index)                ' Show contents of each cell.
Next
stop
```

If you run this program, Debug will display each of the 10 values stored in the cells of the array: myBytes(0) = 0*13 = 0, myBytes(0) = 1*13 = 13, myBytes(2) = 2*13 = 26...myBytes(9) = 9*13 = 117.

A word of caution about arrays: If you're familiar with other BASICs and have used their arrays, you have probably run into the "subscript out of range" error. Subscript is another term for the index value. It's 'out of range' when it exceeds the maximum value for the size of the array. For instance, in the example above, myBytes is a 10-cell array. Allowable index numbers are 0 through 9. If your program exceeds this range, PBASIC2 will *not* respond with an error message. Instead, it will access the next RAM location past the end of the array. This can cause all sorts of bugs.

If accessing an out-of-range location is bad, why does PBASIC2 allow it? Unlike a desktop computer, the BS2 doesn't always have a display device connected to it for displaying error messages. So it just continues the best way it knows how. It's up to the programmer (you!) to prevent bugs.

Another unique property of PBASIC2 arrays is this: You can refer to the 0th cell of the array by using just the array's name without an index value. For example:

```
myBytes         var             byte(10)            ' Define 10-byte array.
myBytes(0) = 17                                     ' Store 17 to 0th cell.

debug ? myBytes(0)                                  ' Display contents of 0th cell.
debug ? myBytes                                     ' Also displays contents of 0th cell.
```

This works with the string capabilities of the Debug and Serout instructions. A string is a byte array used to store text. A string must include some indicator to show where the text ends. The indicator can be either the number of bytes of text, or a marker (usually a byte containing 0; also known as a null) located just after the end of the text. Here are a couple of examples:

```
' Example 1 (counted string):
myText          var             byte(10)            ' An array to hold the string.

myText(0) = "H":myText(1) = "E"                     ' Store "HELLO" in first 5 cells...
myText(2) = "L":myText(3) = "L"
myText(4) = "0":myText(9) = 5                       ' Put length (5) in last cell*

debug str myText\myText(9)                          ' Show "HELLO" on the PC screen.
```

```
' Example 2 (null-terminated string):
myText      var      byte(10)            ' An array to hold the string.

myText(0) = "H":myText(1) = "E"          ' Store "HELLO" in first 5 cells...
myText(2) = "L":myText(3) = "L"
myText(4) = "0":myText(5) = 0            ' Put null (0) after last character.

debug str myText                         ' Show "HELLO" on the PC screen.
```

(*Note to experienced programmers: Counted strings normally store the count value in their 0th cell. This kind of string won't work with the STR prefix of Debug and Serout. STR cannot be made to start reading at cell 1; debug str myText(1) causes a syntax error. Since arrays have a fixed length anyway, it does no real harm to put the count in the last cell.)

Aliases and Variable Modifiers

An alias variable is an alternative name for an existing variable. For example:

```
cat         var      nib                 ' Assign a 4-bit variable.
tabby       var      cat                 ' Another name for the same 4 bits.
```

In that example, *tabby* is an alias to the variable *cat*. Anything stored in *cat* shows up in *tabby* and vice versa. Both names refer to the same physical piece of RAM. This kind of alias can be useful when you want to reuse a temporary variable in different places in your program, but also want the variable's name to reflect its function in each place. Use caution, because it is easy to forget about the aliases. During debugging, you'll end up asking 'how did that value get here?!' The answer is that it was stored in the variable's alias.

An alias can also serve as a window into a portion of another variable. Here the alias is assigned with a modifier that specifies what part:

```
rhino       var      word                ' A 16-bit variable.
head        var      rhino.highbyte      ' Highest 8 bits of rhino.
tail        var      rhino.lowbyte       ' Lowest 8 bits of rhino.
```

Given that example, if you write the value %1011000011111101 to *rhino*, then *head* would contain %10110000 and *tail* %11111101.

Table M-3 lists all the variable modifiers. PBASIC2 lets you apply these modifiers to any variable name, including fixed variables and I/O variables, and to combine them in any fashion that makes sense. For example, it will allow:

```
rhino     var     word                          ' A 16-bit variable.
eye       var     rhino.highbyte.lownib.bit1    ' A bit.
```

Table M-3. Variable Modifiers

SYMBOL	DEFINITION
LOWBYTE	'low byte of a word
HIGHBYTE	'high byte of a word
BYTE0	'byte 0 (low byte) of a word
BYTE1	'byte 1 (high byte) of a word
LOWNIB	'low nibble of a word or byte
HIGHNIB	'high nibble of a word or byte
NIB0	'nib 0 of a word or byte
NIB1	'nib 1 of a word or byte
NIB2	'nib 2 of a word
NIB3	'nib 3 of a word
LOWBIT	'low bit of a word, byte, or nibble
HIGHBIT	'high bit of a word, byte, or nibble
BIT0	'bit 0 of a word, byte, or nibble
BIT1	'bit 1 of a word, byte, or nibble
BIT2	'bit 2 of a word, byte, or nibble
BIT3	'bit 3 of a word, byte, or nibble
BIT4	'bit 4 of a word or byte
BIT5	'bit 5 of a word or byte
BIT6	'bit 6 of a word or byte
BIT7	'bit 7 of a word or byte
BIT8	'bit 8 of a word
BIT9	'bit 9 of a word
BIT10	'bit 10 of a word
BIT11	'bit 11 of a word
BIT12	'bit 12 of a word
BIT13	'bit13 of a word
BIT14	'bit14 of a word
BIT15	'bit15 of a word

The commonsense rule for combining modifiers is that they must get progressively smaller from left to right. It would make no sense to specify, for instance, the low byte of a nibble, because a nibble is smaller than a byte! And just because you can stack up modifiers doesn't mean that you should unless it is the clearest way to express the location of the part you want get at. The example above might be improved:

```
rhino       var     word            ' A 16-bit variable.
eye         var     rhino.bit9      ' A bit.
```

Although we've only discussed variable modifiers in terms of creating alias variables, you can also use them within program instructions. Example:

```
rhino       var     word            ' A 16-bit variable.
head        var     rhino.highbyte  ' Highest 8 bits of rhino.

rhino = 13567
debug ? head                        ' Show the value of alias variable head.
debug ? rhino.highbyte              ' rhino.highbyte works too.
stop
```

You'll run across examples of this usage in application notes and sample programs—it's sometimes easier to remember one variable name and specify parts of it within instructions than to define and remember names for the parts.

Modifiers also work with arrays; for example:

```
myBytes     var     byte(10)            ' Define 10-byte array.
myBytes(0) = $AB                        ' Hex $AB into 0th byte
debug hex ? myBytes.lownib(0)           ' Show low nib ($B)
debug hex ? myBytes.lownib(1)           ' Show high nib ($A)
```

If you looked closely at that example, you probably thought it was a misprint. Shouldn't myBytes.lownib(1) give you the low nibble of byte 1 of the array rather than the high nibble of byte 0? Well, it doesn't. The modifier changes the meaning of the index value to match its own size. In the example above, when myBytes() is addressed as a byte array, it has 10 cells numbered 0 through 9. When it is addressed as a nibble array, using myBytes.lownib(), it has 20 cells numbered 0 through 19. You could also address it as individual bits using myBytes.lowbit(), in which case it would have 80 cells numbered 0 through 79.

What if you use something other than a "low" modifier, say myBytes.highnib()? That will work, but its only effect will be to *start* the nibble array with the high nibble of myBytes(0). The nibbles you address with this nib array will all be contiguous—one right after the other—as in the previous example.

```
myBytes         var         byte(10)            ' Define 10-byte array.

myBytes(0) = $AB                                ' Hex $AB into 0th byte
myBytes(1) = $CD                                ' Hex $CD into next byte
debug hex ? myBytes.highnib(0)                  ' Show high nib of cell 0 ($A)
debug hex ? myBytes.highnib(1)                  ' Show next nib ($D)
```

This property of modified arrays makes the names a little confusing. If you prefer, you can use the less-descriptive versions of the modifier names; bit0 instead of lowbit, nib0 instead of low nib, and byte0 instead of low byte. These have exactly the same effect, but may be less likely to be misconstrued.

You may also use modifiers with the 0th cell of an array by referring to just the array name without the index value in parentheses. It's fair game for aliases and modifiers, both in VAR directives and in instructions:

```
myBytes         var         byte(10)            ' Define 10-byte array.
zipBit          var         myBytes.lowbit      ' Bit 0 of myBytes(0).
debug ? myBytes.lownib                          ' Show low nib of 0th byte.
```

Memory Map

If you're working on a program and wondering how much variable space you have left, you can view a memory map by pressing ALT-M. The Stamp host software will check your program for syntax errors and, if the program's syntax is OK, will present you with a color-coded map of the available RAM. You'll be able to tell at a glance how much memory you have used and how much remains. (You may also press the space bar to cycle through similar maps of EEPROM program memory.)

Two important points to remember about this map are:

(1) It does not correlate the names of your variables to their locations. The Stamp software arranges variables in descending order of size, starting with words and working downward to bits. But there's no way to tell from the memory map exactly which variable is located where.

(2) Fixed variables like B3 and W1 and any aliases you give them do not show up on the memory map as memory used. The Stamp software ignores fixed variables when it arranges automatically allocated variables in memory. Fixed and allocated variables can overlap. As we've said before, this can breed some Godzilla-sized bugs!

BS2 Constants and Compile-Time Expressions

Suppose you're working on a program called "Three Cheers" that flashes LEDs, makes hooting sounds, and activates a motor that crashes cymbals together—all in sets of three. A portion of your PBASIC2 program might contain something like:

```
FOR count = 1 to 3
  GOSUB makeCheers
NEXT
...
FOR count = 1 to 3
  GOSUB blinkLEDs
NEXT
...
FOR count = 1 to 3
  GOSUB crashCymbals
NEXT
```

The numbers 1 and 3 in the line FOR count = 1 to 3... are called constants. That's because while the program is running nothing can happen to change those numbers. This distinguishes constants from variables, which can change while the program is running.

PBASIC2 allows you to use several numbering systems. By default, it assumes that numbers are in decimal (base 10), our everyday system of numbers. But you can also use binary and hexadecimal (hex) numbers by identifying them with prefixes. And PBASIC2 will automatically convert quoted text into the corresponding ASCII code(s).

For example:

```
99          decimal
%1010       binary
$FE         hex
"A"         ASCII code for A (65)
```

You can assign names to constants using the CON directive. Once created, named constants may be used in place of the numbers they represent. For example:

```
cheers      con     3               ' Number of cheers.

FOR count = 1 to cheers
  GOSUB makeCheers
NEXT
...
```

That code would work exactly the same as the previous FOR / NEXT loops. The Stamp host software would substitute the number 3 for the constant name *cheers* throughout your program. Note that it would not mess with the label *makeCheers*, which is not an exact match for cheers. (Like variable names, labels, and instructions, constant names are not case sensitive. CHEERS, and ChEErs would all be processed as identical to cheers.)

Using named constants does not increase the amount of code downloaded to the BS2, and it often improves the clarity of the program. Weeks after a program is written, you may not remember what a particular number was supposed to represent—using a name may jog your memory (or simplify the detective work needed to figure it out).

Named constants have another benefit. Suppose the "Three Cheers" program had to be upgraded to "Five Cheers." In the original example you would have to change all of the 3s to 5s. Search and replace would help, but you might accidentally change some 3s that weren't numbers of cheers, too. A debugging mess! However, if you made smart use of a named constant; all you would have to do is change 3 to 5 in one place, the CON directive:

```
cheers      con     5               ' Number of cheers.
```

Now, assuming that you used the constant *cheers* wherever your program needed 'the number of cheers,' your upgrade would be complete.

You can take this idea a step further by defining constants with *expressions*—groups of math and/or logic operations that the Stamp host software solves (*evaluates*) at compile time (the time right after you press ALT-R and before the BS2 starts running your program). For example, suppose the "Cheers" program also controls a pump to fill glasses with champagne. The number of glasses to fill is always twice the number of cheers, minus 1. Another constant:

```
cheers      con     5               ' # of cheers.
glasses     con     cheers*2-1      ' # of glasses.
```


As you can see, one constant can be defined in terms of another. That is, the number glasses depends on the number cheers.

The expressions used to define constants must be kept fairly simple. The Stamp host software solves them from left to right, and doesn't allow you to use parentheses to change the order of evaluation. Only nine operators are legal in constant expressions as shown in Table M-4. This may seem odd, since the BS2's runtime math operations can be made quite complex with bushels of parentheses and fancy operators, but it's the way things are. Seriously, it might not make sense to allow really wild math in constant expressions, since it would probably obscure rather than clarify the purpose of the constants being defined.

Table M-4. Operators Allowed in Constant Expressions

(all operations performed as 16-bit math)	
+	add
–	subtract
*	multiply
/	divide
<<	shift left
>>	shift right
&	logical AND
|	logical OR
^	logical XOR

BS2 EEPROM Data Storage

When you press ALT-R (run), your program is loaded into the BS2's EEPROM starting at the highest address (2047) and working downward. Most programs don't use the entire EEPROM, so PBASIC2 lets you store data in the unused lower portion of the EEPROM.

Since programs are stored from the top of memory downward, your data is stored in the bottom of memory working upward. If there's an overlap, the Stamp host software will detect it and display an error message.

Data directives are used to store data in EEPROM, or to assign a name to an unused stretch of EEPROM (more on that later). For example:

```
table       data        72,69,76,76,79
```

That data directive places a series of numbers into EEPROM memory starting at address 0, like so:

Address:	0	1	2	3	4
Contents:	72	69	76	76	79

Data uses a counter, called a pointer, to keep track of available EEPROM addresses. The value of the pointer is initially 0. When PBASIC2 encounters a Data directive, it stores a byte at the current pointer address, then increments (adds 1 to) the pointer. The name that Data assigns (*table* in the example above) becomes a constant that is equal to the first value of the pointer; the address of the first of the series of bytes stored by that Data directive. Since the data above starts at 0, the constant *table* equals 0.

If your program contains more than one Data directive, subsequent Datas start with the pointer value left by the previous Data. For example, if your program contains:

```
table1      data        72,69,76,76,79
table2      data        104,101,108,108,111
```

The first Data directive will start at 0 and increment the pointer: 1, 2, 3, 4, 5. The second Data directive will pick up the pointer value of 5 and work upward from there. As a result, the first 10 bytes of EEPROM will contain:

Address:	0	1	2	3	4	5	6	7	8	9
Contents:	72	69	76	76	79	104	101	108	108	111

...and the constants *table1* and *table2* will be equal to 0 and 5, respectively.

A common use for Data is to store strings; sequences of bytes representing text. As we saw earlier, PBASIC2 converts quoted text like "A" into the corresponding ASCII character code (65 in this case). You can place quotes around a whole chunk of text used in a Data directive, and PBASIC2 will understand it to mean a series of bytes. The following three Data directives are equivalent:


```
table1      data      72,69,76,76,79
table2      data      "H","E","L","L","O"
table3      data      "HELLO"
```

Data can also break word-sized (16-bit) variables into bytes for storage in the EEPROM. Just precede the 16-bit value with the prefix "word" as follows:

```
twoPiece    data      word $F562          ' Put $62 in low byte, $F5 in high.
```

Moving the Data Pointer

You can specify a pointer address in your Data directive, like so:

```
greet       data      @32,"Hello there"
```

The number following the at sign (@) becomes the initial pointer value, regardless of the pointer's previous value. Data still automatically increments the pointer value as in previous examples, so Data directives that follow the example above will start at address 43.

Another way to move the pointer is to tell Data to set aside space for a particular number of bytes. For example:

```
table1      data      13,26,117,0,19,56      ' Place bytes into EEPROM.
table2      data      (20)                   ' Move pointer ahead by 20.
```

The value in parentheses tells Data to move its pointer, but not to store anything in those bytes. The bytes at the addresses starting at *table2* could therefore contain leftover data from previous programs. If that's not acceptable, you can tell Data to fill those bytes up with a particular value:

```
table2      data      0(20)                  ' Fill 20 bytes with 0s.
```

The previous contents of those 20 EEPROM bytes will be overwritten with 0s.

If you are writing programs that store data in EEPROM at runtime, this is an important concept: EEPROM is not overwritten during programming unless it is (1) needed for program storage, or (2) filled by a Data directive specifying data to be written. A directive like Data (20) does not change the data stored in the corresponding EEPROM locations.

BS2 Runtime Math and Logic

The BS2, like any computer, excels at math and logic. However, being designed for control applications, the BS2 does math a little differently than a calculator or spreadsheet program. This section will help you understand BS2 numbers, math, and logic.

Number Representations

In your programs, you may express a number in various ways, depending on how the number will be used and what makes sense to you. By default, the BS2 recognizes numbers like 0, 99 or 62145 as being in our everyday decimal (base-10) system. However, you may also use hexadecimal (base-16; also called hex) or binary (base-2).

Since the symbols used in decimal, hex and binary numbers overlap (e.g., 1 and 0 are used by all; 0 through 9 apply to both decimal and hex) the Stamp software needs prefixes to tell the numbering systems apart:

99	Decimal (no prefix)
$1A6	Hex
%1101	Binary

The Stamp also automatically converts quoted text into ASCII codes, and allows you to apply names (symbols) to constants from any of the numbering systems. Examples:

```
letterA     con     "A"               ' ASCII code for A (65).
cheers      con     3
hex128      con     $80
fewBits     con     %1101
```

For more information on constants, see the section BS2 Constants and Compile-Time Expressions.

When is Runtime?

Not all of the math or logic operations in a BS2 program are solved by the BS2. Operations that define constants are solved by the Stamp host software before the program is downloaded to the BS2. This preprocessing before the program is downloaded is referred to as “compile time.” (See the section BS2 Constants and Compile-Time Expressions.)

After the download is complete and the BS2 starts executing your program—this is referred to as "runtime." At runtime the BS2 processes math and logic operations involving variables, or any combination of variables and constants.

Because compile-time and runtime expressions appear similar, it can be hard to tell them apart. A few examples will help:

```
cheers      con     3
glasses     con     cheers*2-1          ' Compile time.
oneNinety   con     100+90              ' Compile time.
noWorkee    con     3*b2                ' ERROR: no variables allowed.

b1 = glasses                            ' Same as b1 = 5.
b0 = 99 + b1                            ' Run time.
w1 = oneNinety                          ' 100 + 90 solved at compile time.
w1 = 100 + 90                           ' 100 + 90 solved at runtime.
```

Notice that the last example is solved at runtime, even though the math performed could have been solved at compile time since it involves two constants. If you find something like this in your own programs, you can save some EEPROM space by converting the run-time expression 100+90 into a compile-time expression like oneNinety con 100+90.

To sum up: compile-time expressions are those that involve only constants; once a variable is involved, the expression must be solved at runtime. That's why the line "noWorkee con 3*b2" would generate an error message. The CON directive works only at compile time, so variables are not allowed.

Order of Operations

Let's talk about the basic four operations of arithmetic: addition (+), subtraction (-), multiplication (*), and division (/).

You may recall that the order in which you do a series of additions and subtractions doesn't affect the result. The expression 12+7-3+22 works out the same as 22-3+12+7. Howver, when multiplication or division are involved, it's a different story; 12+3*2/4 is not the same as 2*12/4+3. In fact, you may have the urge to put parentheses around portions of those equations to clear things up. Good!

The BS2 solves math problems in the order they are written—from left to right. The result of each operation is fed into the next operation. So to compute 12+3*2/4, the BS2 goes through a sequence like this:

12 + 3 = 5
5 * 2 = 10
10 / 4 = 2
the answer is 2

Note that because the BS2 performs integer math (whole numbers only) that 10 / 4 results in 2, not 2.5. We'll talk more about integers in the next section.

Some other dialects of BASIC would compute that same expression based on their precedence of operators, which requires that multiplication and division be done before addition. So the result would be:

3 * 2 = 6
6 / 4 = 1
12 + 1 = 13
the answer is 13

Once again, because of integer math, the fractional portion of 6 / 4 is dropped, so we get 1 instead of 1.5.

Given the potential for misinterpretation, we must use parentheses to make our mathematical intentions clear to the BS2 (not to mention ourselves and other programmers who may look at our program). With parentheses. Enclosing a math operation in parentheses gives it priority over other operations. For example, in the expression 1+(3*4), the 3*4 would be computed first, then added to 1.

To make the BS2 compute the previous expression in the conventional BASIC way, you would write it as 12 + (3*2/4). Within the parentheses, the BS2 works from left to right. If you wanted to be even more specific, you could write 12 + ((3*2)/4). When there are parentheses within parentheses, the BS2 works from the innermost parentheses outward. Parentheses placed within parentheses are said to be nested. The BS2 lets you nest parentheses up to eight levels deep.

Integer Math

The BS2 performs all math operations by the rules of positive integer math. That is, it handles only whole numbers, and drops any fractional portions from the results of computations. Although the BS2 can interpret two's complement negative numbers correctly in Debug and Serout instructions using modifiers like SDEC (for signed decimal), in calculations it assumes that all values are positive. This yields correct results with two's complement negative numbers for addition, subtraction, and multiplication, but not for division.

This subject is a bit too large to cover here. If you understood the preceding paragraph, great. If you didn't, but you understand that handling negative numbers requires a bit more planning (and probably should be avoided when possible), good. And if you didn't understand the preceding paragraph at all, you might want to do some supplemental reading on computer-oriented math.

Unary and Binary Operators

In a previous section we discussed the operators you're already familiar with: +, - ,* and / . These operators all work on two values, as in 1 + 3 or 26*144. The values that operators process are referred to as arguments. So we say that these operators take two arguments.

The minus sign (-) can also be used with a single argument, as in -4. Now we can fight about whether that's really shorthand for 0-4 and therefore does have two arguments, or we can say that - has two roles: as a subtraction operator that takes two arguments, and as a negation operator that takes one. Operators that take one argument are called unary operators and those that take two are called binary operators. Please note that the term "binary operator" has nothing to do with binary numbers—it's just an inconvenient coincidence that the same word, meaning 'involving two things' is used in both cases.

In classifying the BS2's math and logic operators, we divide them into two types: unary and binary. Remember the previous discussion of operator precedence? Unary operators take precedence over binary—the unary operation is always performed first. For example SQR is the unary operator for square root. In the expression 10 - SQR 16, the BS2 first takes the square root of 16, then subtracts it from 10.

16-bit Workspace

Most of the descriptions that follow say something like 'computes (some function) of a 16-bit value.' This does not mean that the operator does not work on smaller byte or nibble values. It just means that the computation is done in a 16-bit workspace. If the value is smaller than 16 bits, the BS2 pads it with leading 0s to make a 16-bit value. If the 16-bit result of a calculation is to be packed into a smaller variable, the higher-order bits are discarded (truncated).

Keep this in mind, especially when you are working with two's complement negative numbers, or moving values from a larger variable to a smaller one. For example, look what happens when you move a two's complement negative number into a byte:

```
b2 = -99
debug sdec ? b2              ' Show signed decimal result (157).
```


How did -99 become 157? Let's look at the bits: 99 is %01100011 binary. When the BS2 negates 99, it converts the number to 16 bits %0000000001100011, and then takes the two's complement, %1111111110011101. Since we've asked for the result to be placed in an 8-bit (byte) variable, the upper eight bits are truncated and the lower eight bits stored in the byte: %10011101.

Now for the second half of the story. Debug's SDEC modifier expects a 16-bit, two's complement value, but has only a byte to work with. As usual, it creates a 16-bit value by padding the leading eight bits with 0s: %0000000010011101. And what's that in signed decimal? 157.

Each of the instruction descriptions below includes an example. It's a good idea to test your understanding of the operators by modifying the examples and seeing whether you can predict the results. Experiment, learn, and work the Debug instruction until it screams for mercy! The payoff will be a thorough understanding of both the BS2 and computer-oriented math.

Unary (one-argument) Operators

Six Unary Operators are listed and explained below.

Table M-5. Unary Operators

Operator	Description
ABS	Returns absolute value
SQR	Returns square root of value
DCD	2^n-power decoder
NCD	Priority encoder of a 16-bit value
SIN	Returns two's compliment sine
COS	Returns two's compliment cosine

ABS

Converts a signed (two's complement) 16-bit number to its absolute value. The absolute value of a number is a positive number representing the difference between that number and 0. For example, the absolute value of -99 is 99. The absolute value of 99 is also 99. ABS can be said to strip off the minus sign from a negative number, leaving positive numbers unchanged.

ABS works on two's complement negative numbers. Examples of ABS at work:

```
w1 = -99              ' Put -99 (two's complement format) into w1.
debug sdec ? w1       ' Display it on the screen as a signed #.
w1 = ABS w1           ' Now take its absolute value.
debug sdec ? w1       ' Display it on the screen as a signed #.
```

SQR

Computes the integer square root of an unsigned 16-bit number. (The number must be unsigned, when you think about it, because the square root of a negative number is an 'imaginary' number.) Remember that most square roots have a fractional part that the BS2 discards in doing its integer-only math. So it computes the square root of 100 as 10 (correct), but the square root of 99 as 9 (the actual is close to 9.95). Example:

```
debug SQR 100        ' Display square root of 100 (10).
debug SQR 99         ' Display of square root of 99 (9 due to truncation)
```

DCD

2^n-power decoder of a four-bit value. DCD accepts a value from 0 to 15, and returns a 16-bit number with that bit number set to 1. For example:

```
w1 = DCD 12          ' Set bit 12.
debug bin ? w1       ' Display result (%0001000000000000)
```

NCD

Priority encoder of a 16-bit value. NCD takes a 16-bit value, finds the highest bit containing a 1 and returns the bit position plus one (1 through 16). If no bit is set—the input value is 0—NCD returns 0. NCD is a fast way to get an answer to the question "what is the largest power of two that this value is greater than or equal to?" The answer that NCD returns will be that power, plus one. Example:

```
w1 = %1101           ' Highest bit set is bit 3.
debug ? NCD w1       ' Show the NCD of w1 (4).
```

-

Negates a 16-bit number (converts to its two's complement).

```
w1 = -99             ' Put -99 (two's complement format) into w1.
debug sdec ? w1      ' Display it on the screen as a signed #.
w1 = ABS w1          ' Now take its absolute value.
debug sdec ? w1      ' Display it on the screen as a signed #.
```

~

Complements (inverts) the bits of a number. Each bit that contains a 1 is changed to 0 and each bit containing 0 is changed to 1. This process is also known as a "bitwise NOT." For example:

```
b1 = %11110001       ' Store bits in byte b1.
debug bin ? b1       ' Display in binary (%11110001).
b1 = ~ b1            ' Complement b1.
debug bin ? b1       ' Display in binary (%00001110).
```

SIN

Returns the two's complement, 8-bit sine of an angle specified as an 8-bit (0 to 255) angle. To understand the BS2 SIN operator more completely, let's look at a typical sine function. By definition: given a circle with a radius of 1 unit (known as a unit circle), the sine is the y-coordinate distance from the center of the circle to its edge at a given angle. Angles are measured relative to the 3-o'clock position on the circle, increasing as you go around the circle counterclockwise.

At the origin point (0 degrees) the sine is 0, because that point has the same y (vertical) coordinate as the circle center; at 45 degrees, sine is 0.707; at 90 degrees, 1; 180 degrees, 0 again; 270 degrees, -1.

The BS2 SIN operator breaks the circle into 0 to 255 units instead of 0 to 359 degrees. Some textbooks call this unit a *binary radian* or *brad*. Each brad is equivalent to 1.406 degrees. And instead of a unit circle, which results in fractional sine values between 0 and 1, BS2 SIN is based on a 127-unit circle. Results are given in two's complement in order to accommodate negative values. So, at the origin, SIN is 0; at 45 degrees (32 brads), 90; 90 degrees (64 brads), 127; 180 degrees (128 brads), 0; 270 degrees (192 brads), -127.

To convert brads to degrees, multiply by 180 then divide by 128; to convert degrees to brads, multiply by 128, then divide by 180. Here's a small program that demonstrates the SIN operator:

```
degr            var         w1                              ' Define variables.
sine            var         w2
for degr = 0 to 359 step 45                                 ' Use degrees.
  sine = SIN (degr * 128 / 180)                             ' Convert to brads, do SIN.
  debug "Angle: ",DEC degr,tab,"Sine: ",SDEC sine,cr        ' Display.
next
```

COS

Returns the two's complement, 8-bit cosine of an angle specified as an 8-bit (0 to 255) angle. See the explanation of the SIN operator above. COS is the same in all respects, except that the cosine function returns the x distance instead of the y distance. To demonstrate the COS operator, use the example program from SIN above, but substitute COS for SIN.

Binary (two-argument) Operators

Sixteen Binary Operators are listed and explaned below.

Table M-6. Binary Operators

Operator	Description
+	Addition
-	Subtraction
/	Division
//	Remainder of division
*	Multiplication
**	High 16-bits of multiplication
*/	Multiply by 8-bit whole and 8-bit part
MIN	Limits a value to specified low
MAX	Limits a value to specified high
DIG	Returns specified digit of number
<<	Shift bits left by specified amount
>>	Shift bits right by specified amount
REV	Reverse specified number of bits
&	Bitwise AND of two values
|	Bitwise OR of two values
^	Bitwise XOR of two values

+

Adds variables and/or constants, returning a 16-bit result. Works exactly as you would expect with unsigned integers from 0 to 65535. If the result of addition is larger than 65535, the carry bit will be lost. If the values added are signed 16-bit numbers and the destination is a 16-bit variable, the result of the addition will be correct in both sign and value. For example, the expression -1575 + 976 will result in the signed value -599. See for yourself:

```
w1 = -1575
w2 = 976
w1 = w1 + w2                    ' Add the numbers.
debug sdec ? w1                 ' Show the result (-599).
```

-

Subtracts variables and/or constants, returning a 16-bit result. Works exactly as you would expect with unsigned integers from 0 to 65535. If the result is negative, it will be correctly expressed as a signed 16-bit number. For example:

```
w1 = 1000
w2 = 1999
w1 = w1 - w2                    ' Subtract the numbers.
debug sdec ? w1                 ' Show the result (-999).
```

/

Divides variables and/or constants, returning a 16-bit result. Works exactly as you would expect with unsigned integers from 0 to 65535. Use / only with positive values; signed values do not provide correct results. Here's an example of unsigned division:

```
w1 = 1000
w2 = 5
w1 = w1 / w2                    ' Divide w1 by w2.
debug dec ? w1                  ' Show the result (200).
```

A workaround to the inability to divide signed numbers is to have your program divide absolute values, then negate the result if one (and only one) of the operands was negative. All values must lie within the range of -32767 to +32767. Here is an example:

```
sign      var      bit          ' Bit to hold the sign.
w1 = 100
w2 = -3200

sign = w1.bit15 ^ w2.bit15      ' Sign = (w1 sign) XOR (w2 sign).
w2 = abs w2 / abs w1            ' Divide absolute values.
if sign = 0 then skip0          ' Negate result if one of the
  w2 = -w2                      ' arguments was negative.
skip0:
debug sdec ? w2                 ' Show the result (-32)
```

//

Returns the remainder left after dividing one value by another. Some division problems don't have a whole-number result; they return a whole number and a fraction. For example, 1000 / 6 = 166.667. Integer math doesn't allow the fractional portion of the result, so 1000 / 6 = 166. However, 166 is an approximate answer, because 166*6 = 996. The division operation left a remainder of 4. The / / (double-slash) returns the remainder of a given division operation. Naturally, numbers that divide evenly, such as 1000 / 5, produce a remainder of 0. Example:

```
w1 = 1000
w2 = 6
w1 = w1 // w2              ' Get remainder of w1 / w2.
debug dec ? w1             ' Show the result (4).
```


*

Multiplies variables and / or constants, returning the low 16 bits of the result. Works exactly as you would expect with unsigned integers from 0 to 65535. If the result of multiplication is larger than 65535, the excess bits will be lost. Multiplication of signed variables will be correct in both number and sign, provided that the result is in the range -32767 to +32767.

```
w1 = 1000
w2 = -19
w1 = w1 * w2               ' Multiply w1 by w2.
debug sdec ? w1            ' Show the result (-19000).
```

**

Multiplies variables and / or constants, returning the high 16 bits of the result. When you multiply two 16-bit values, the result can be as large as 32 bits. Since the largest variable supported by PBASIC2 is 16 bits, the highest 16 bits of a 32-bit multiplication result are normally lost. The ** (double-star) instruction gives you these upper 16 bits. For example, suppose you multiply 65000 ($FDE8) by itself. The result is 4,225,000,000 or $FBD46240. The * (star, or normal multiplication) -instruction would return the lower 16 bits, $6240. The ** instruction returns $FBD4.

```
w1 = $FDE8
w2 = w1 ** w1          ' Multiply $FDE8 by itself
debug hex ? w2         ' Return high 16 bits.
```

*/

Multiplies variables and / or constants, returning the middle 16 bits of the 32-bit result. This has the effect of multiplying a value by a whole number and a fraction. The whole number is the upper byte of the multiplier (0 to 255 whole units) and the fraction is the lower byte of the multiplier (0 to 255 units of 1 / 256 each). The */ (star-slash) instruction gives you an excellent workaround for the BS2's integer-only math. Suppose you want to multiply a value by 1.5. The whole number, and therefore the upper byte of the multiplier, would be 1, and the lower byte (fractional part) would be 128, since 128 / 256 = 0.5. It may be clearer to express the */ multiplier in hex—as $0180—since hex keeps the contents of the upper and lower bytes separate. An example:

```
w1 = 100
w1 = w1 */ $0180       ' Multiply by 1.5 [1 + (128/256)]
debug ? w1             ' Show result (150).
```

To calculate constants for use with the */ instruction, put the whole number portion in the upper byte, then multiply the fractional part by 256 and put that in the lower byte. For instance, take Pi (π, 3.14159). The upper byte would be $03 (the whole number), and the lower would be 0.14159 * 256 = 36 ($24). So the constant Pi for use with */ would be $0324. This isn't a perfect match for Pi, but the error is only about 0.1%.

MIN

Limits a value to a specified 16-bit positive minimum. The syntax of MIN is:

```
value MIN limit
```

Where:

- value is value to perform the MIN function upon.
- limit is the minimum value that value is allowed to be.

Its logic is, 'if value is less than limit, then make value = limit; if value is greater than or equal to limit, leave value alone.' MIN works in positive math only; its comparisons are not valid when used on two's complement negative numbers, since the positive-integer representation of a number like -1 ($FFFF or 65535 in unsigned decimal) is larger than that of a number like 10 ($000A or 10 decimal). Use MIN only with unsigned integers. Because of the way fixed-size integers work, you should be careful when using an expression involving MIN 0. For example, 0-1 MIN 0 will result in 65535 because of the way fixed-size integers wrap around.

```
for w1 = 100 to 0 step -10          ' Walk value of w1 from 100 to 0.
  debug ? w1 MIN 50                 ' Show w1, but use MIN to clamp at 50.
next
```

MAX

Limits a value to a specified 16-bit positive maximum. The syntax of MAX is:

```
value MAX limit
```

Where:

- value is value to perform the MAX function upon.
- limit is the maximum value that value is allowed to be.

Its logic is, 'if value is greater than limit, then make value = limit; if value is less than or equal to limit, leave value alone.' MAX works in positive math only; its comparisons are not valid when used on two's complement negative numbers, since the positive-integer representation of a number like -1 ($FFFF or 65535 in unsigned decimal) is larger than that of a number like 10 ($000A or 10 decimal). Use MAX only with unsigned integers. Also be careful of expressions involving MAX 65535. For example 65535 + 1 MAX 65535 will result in 0 because of the way fixed-size integers wrap around.

```
for w1 = 0 to 100 step 10           ' Walk value of w1 from 0 to 100.
  debug ? w1 MAX 50                 ' Show w1, but use MAX to clamp at 50.
next
```

DIG

Returns the specified decimal digit of a 16-bit positive value. Digits are numbered from 0 (the rightmost digit) to 4 (the leftmost digit of a 16-bit number; 0 to 65535). Example:

```
w1 = 9742
debug ? w1 DIG 2                    ' Show digit 2 (7)

for b0 = 0 to 4
  debug ? w1 DIG b0                 ' Show digits 0 through 4 of 9742.
next
```

<<

Shifts the bits of a value to the left a specified number of places. Bits shifted off the left end of a number are lost; bits shifted into the right end of the number are 0s. Shifting the bits of a value left *n* number of times also has the effect of multiplying that number by two to the *nth* power. For instance 100 << 3 (shift the bits of the decimal number 100 left three places) is equivalent to 100 * 2^3. Example:

```
w1 = %1111111111111111
for b0 = 1 to 16                    ' Repeat with b0 = 1 to 16.
  debug BIN ? w1 << b0              ' Shift w1 left b0 places.
next
```

>>

Shifts the bits of a variable to the right a specified number of places. Bits shifted off the right end of a number are lost; bits shifted into the left end of the number are 0s. Shifting the bits of a value right *n* number of times also has the effect of dividing that number by two to the *nth* power. For instance 100 >> 3 (shift the bits of the decimal number 100 right three places) is equivalent to 100 / 2^3. Example:

```
w1 = %1111111111111111
for b0 = 1 to 16                    ' Repeat with b0 = 1 to 16.
  debug BIN ? w1 >> b0              ' Shift w1 right b0 places.
next
```

REV

Returns a reversed (mirrored) copy of a specified number of bits of a value, starting with the rightmost bit (lsb). For instance, %10101101 REV 4 would return %1011, a mirror image of the first four bits of the value. Example:

```
debug bin ? %11001011 REV 4                    ' Mirror 1st 4 bits (%1101)
```

&

Returns the bitwise AND of two values. Each bit of the values is subject to the following logic:

0 AND 0 = 0
0 AND 1 = 0
1 AND 0 = 0
1 AND 1 = 1

The result returned by & will contain 1s in only those bit positions in which both input values contain 1s. Example:

```
debug bin ? %00001111 & %10101101              ' Show AND result (%00001101)
```

|

Returns the bitwise OR of two values. Each bit of the values is subject to the following logic:

0 OR 0 = 0
0 OR 1 = 1
1 OR 0 = 1
1 OR 1 = 1

The result returned by | will contain 1s in any bit positions in which one or the other or both input values contain 1s. Example:

```
debug bin ? %00001111 | %10101001              ' Show OR result (%10101111)
```

^

Returns the bitwise XOR of two values. Each bit of the values is subject to the following logic:

0 XOR 0 = 0
0 XOR 1 = 1
1 XOR 0 = 1
1 XOR 1 = 0

The result returned by ^ will contain 1s in any bit positions in which one or the other (but not both) input values contain 1s. Example:

```
debug bin ? %00001111 ^ %10101001          ' Show XOR result (%10100110)
```

Branch

BRANCH *offset, [address0, address1, ...addressN]*

Go to the address specified by offset (if in range).

- ***Offset*** is a variable/constant that specifies which of the listed address to go to (0—N).
- ***Addresses*** are labels that specify where to go.

Explanation

Branch is useful when you might want to write something like this:

```
if b2 = 0 then case_0                         ' b2=0: go to label "case_0"
if b2 = 1 then case_1                         ' b2=1: go to label "case_1"
if b2 = 2 then case_2                         ' b2=2: go to label "case_2"
```

You can use Branch to organize this logic into a single statement:

```
BRANCH  b2,[case_0,case_1,case_2]
```


This works exactly the same as the previous If...Then example. If the value isn't in range—in this case, if b2 is greater than 2—Branch does nothing and the program continues execution on the next instruction after Branch.

Demo Program

This program shows how the value of the variable *pick* controls the destination of the Branch instruction.

```
pick          var         nib                 ' Variable to pick destination of
Branch.

for pick = 0 to 3                             ' Repeat with pick= 0,1,2,3.
  debug "Pick= ", DEC pick, cr                ' Show value of pick.
  BRANCH pick,[zero,one,two]                  ' Branch based on pick.
  debug "Pick exceeded # of items",cr,"in BRANCH list. Fell through!",cr

nextPick:
next                                          ' Next value of pick.

stop

zero:
  debug "Branched to 'zero.'",cr,cr
  goto nextPick
one:
  debug "Branched to 'one.'",cr,cr
  goto nextPick
```

```
two:
  debug "Branched to 'two.'",cr,cr
  goto nextPick
```

Button

BUTTON ***pin, downstate, delay, rate, bytevariable, targetstate, address***

Debounce button input, perform auto-repeat, and branch to address if button is in target state. Button circuits may be active-low or active-high.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. This pin will be made an input.
- ***Downstate*** is a variable / constant (0 or 1) that specifies which logical state occurs when the button is pressed.
- ***Delay*** is a variable / constant (0–255) that specifies how long the button must be pressed before auto-repeat starts. The delay is measured in cycles of the Button routine. Delay has two special settings: 0 and 255. If Delay is 0, Button performs no debounce or auto-repeat. If Delay is 255, Button performs debounce, but no auto-repeat.
- ***Rate*** is a variable / constant (0–255) that specifies the number of cycles between autorepeats. The rate is expressed in cycles of the Button routine.
- ***Bytevariable*** is the workspace for Button. It must be cleared to 0 before being used by Button for the first time.
- ***Targetstate*** is a variable / constant (0 or 1) that specifies which state the button should be in for a branch to occur. (0=not pressed, 1=pressed)
- ***Address*** is a label that specifies where to branch if the button is in the target state.

Explanation

When you press a button or flip a switch, the contacts make or break a connection. A brief (1 to 20-ms) burst of noise occurs as the contacts scrape and bounce against each other. Button's debounce feature prevents this noise from being interpreted as more than one switch action. (For a demonstration of switch bounce, see the demo program for the Count instruction.)

Button also lets PBASIC react to a button press the way your computer keyboard does to a key press. When you press a key, a character immediately appears on the screen. If you hold the key down, there's a delay, then a rapid-fire stream of characters appears on the screen. Button's auto-repeat function can be set up to work much the same way.

Button is designed to be used inside a program loop. Each time through the loop, Button checks the state of the specified pin. When it first matches *downstate,* Button debounces the switch. Then, in accordance with *targetstate,* it either branches to address (targetstate = 1) or doesn't (targetstate=0).

If the switch stays in *downstate,* Button counts the number of program loops that execute. When this count equals *delay,* Button once again triggers the action specified by *targetstate* and *address.* Hereafter, if the switch remains in *downstate,* Button waits *rate* number of cycles between actions.

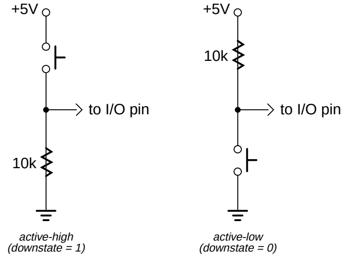
Button does not stop program execution. In order for its delay and autorepeat functions to work properly, Button must be executed from within a program loop.

Demo Program

Connect the active-low circuit shown in figure I-1 to pin P7 of the BS2. When you press the button, the Debug screen will display an asterisk (*). Feel free to modify the program to see the effects of your changes on the way Button responds.

```
btnWk       var       byte                 ' Workspace for BUTTON instruction.
btnWk = 0                                  ' Clear the workspace variable.
' Try changing the Delay value (255) in BUTTON to see the effect of
' its modes: 0=no debounce; 1-254=varying delays before autorepeat;
' 255=no autorepeat (one action per button press).
Loop:
  BUTTON 7,0,255,250,btnWk,0,noPress       ' Go to noPress UNLESS..
  debug "* "                               ' ..P7 is 0.
noPress: goto loop                         ' Repeat endlessly.
```

Figure I-1



Count

COUNT *pin, period, variable*

Count the number of cycles (0-1-0 or 1-0-1) on the specified pin during *period* number of milliseconds and store that number in *variable*.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. This pin will be placed into input mode by writing a 0 to the corresponding bit of the DIRS register.
- ***Period*** is a variable / constant (1 to 65535) specifying the time in milliseconds during which to count.
- ***Variable*** is a variable (usually a word) in which the count will be stored.

Explanation

The Count instruction makes a pin an input, then for the specified number of milliseconds counts cycles on that pin and stores the total in a variable. A cycle is a change in state from 1 to 0 to 1, or from 0 to 1 to 0.

Count can respond to transitions as fast as 4 microseconds (µs). A cycle consists of two transitions (e.g., 0 to 1, then 1 to 0), so Count can respond to square waves with periods as short as 8 µs; up to 125 kilohertz (kHz) in frequency. For non-square waves (those whose high time and low time are unequal), the shorter of the high and low times must be greater than 4 µs.

If you use Count on slowly-changing analog waveforms like sine waves, you may find that the count value returned is higher than expected. This is because the waveform may pass through the BS2's 1.5-volt logic threshold slowly enough that noise causes false counts. You can fix this by passing the signal through a Schmitt trigger, like one of the inverters of a 74HCT14.

Demo Program

Connect the active-low circuit shown in figure I-1 (Button instruction) to pin P7 of the BS2. The Debug screen will prompt you to press the button as quickly as possible for a 1-second count. When the count is done, the screen will display your "score," the total number of cycles registered by count. Note that this score will almost always be greater than the actual number of presses because of switch bounce.

```
cycles      var       word              ' Variable to store counted cycles.
loop:
  debug cls,"How many times can you press the button in 1 second?",cr
  pause 1000: debug "Ready, set... ":pause 500:debug "GO!",cr
  count 7,1000,cycles
  debug cr,"Your score: ", DEC cycles,cr
  pause 3000
  debug "Press button to go again."
hold: if IN7 = 1 then hold
goto loop
```

Debug

DEBUG ***outputData{,outputData...}***

Display variables and messages on the PC screen within the STAMP2 host program.

- ***OutputData*** consists of one or more of the following: text strings, variables, constants, expressions, formatting modifiers, and control characters

Explanation

Debug provides a convenient way for your programs to send messages to the PC screen during programming. The name Debug suggests its most popular use—debugging programs by showing you the value of a variable or expression, or by indicating what portion of a program is currently executing. Debug is also a great way to rehearse programming techniques. Throughout this instruction guide, we use Debug to give you immediate feedback on the effects of instructions. Let's look at some examples:


```
DEBUG "Hello World!"                    ' Test message.
```

After you press ALT-R to download this one-line program to the BS2, the STAMP2 host software will put a Debug window on your PC screen and wait for a response. A moment later, the phrase "Hello World!" will appear. Pressing any key other than space eliminates the Debug window. Your program keeps executing after the screen is gone, but you can't see the Debug data. Another example:

```
x            var          byte: x = 65
DEBUG dec x                             ' Show decimal value of x.
```

Since x = 65, the Debug window would display "65." In addition to decimal, Debug can display values in hexidecimal and binary. See table I-1 for a complete list of Debug prefixes.

Suppose that your program contained several Debug instructions showing the contents of different variables. You would want some way to tell them apart. Just add a question mark (?) as follows:

```
x            var          byte: x = 65
DEBUG dec ? x                           ' Show decimal value of x with label "x =
"
```

Now Debug displays "x = 65." Debug works with expressions, too:

```
x                var           byte: x = 65
DEBUG dec ? 2*(x-1)                          ' Show decimal result with "2*(x-1) = "
```

The Debug window would display "2*(x-1) = 128." If you omit the ?, the display would be just "128." If you tell Debug to display a value without formatting it as a number, you get the ASCII character equivalent of the value:

```
x var byte: x = 65
DEBUG x                                      ' Show x as ASCII.
```

Since x = 65, and 65 is the ASCII character code for the letter A (see appendix), the Debug window would show A. Up to now, we've shown Debug with just one argument, but you can display additional items by adding them to the Debug list, separated by commas:

```
x                var           byte: x = 65
DEBUG "The ASCII code for A is: ", dec x     ' Show phrase, x.
```

Since individual Debug instructions can grow to be fairly complicated, and since a program can contain many Debugs, you'll probably want to control the formatting of the Debug screen. Debug supports six formatting characters:

Symbol	Value	Effect
CLS	0	clear Debug screen
HOME	1	home cursor to top left corner of screen
BELL	7	beep the PC speaker
BKSP	8	back up one space
TAB	9	tab to the next multiple-of-8 text column
CR	13	carriage return to the beginning of the next line

Try the example below with and without the CR at the end of the first Debug:

```
Debug "A carriage return",CR
Debug "starts a new line"
```

Technical Background

Debug is actually a special case of the Serout instruction. It is set for inverted (RS-232-compatible) serial output through the BS2 programming connector (SOUT on the BS2-IC) at 9600 baud, no parity, 8 data bits, and 1 stop bit. You may view Debug output using a terminal program set to these parameters, but you must modify either your carrier board or the serial cable to temporarily disconnect pin 3 of the BS2-IC (pin 4 of the DB-9 connector). The reason is that the STAMP2 host software uses this line to reset the BS2 for programming, while terminal software uses the same line to signal "ready" for serial communication.

If you make this modification, be sure to provide a way to reconnect pin 3 of the BS2-IC to pin 4 of the DB-9 connector for reprogramming. With these pins disconnected, the STAMP2 host software will not be able to download new programs.

Demo Program

This demo shows the letters of the alphabet and their corresponding ASCII codes. A brief pause slows the process down a little so that it doesn't go by in a blur. You can freeze the display while the program is running by pressing the space bar.

```
letter          var          byte

Debug "ALPHABET -> ASCII CHART",BELL,CR,CR
for letter = "A" to "Z"
  Debug "Character: ", letter, tab, "ASCII code: ",dec letter, cr
  pause 200
next
```

Table I-1. Debug Modifiers

Modifier	Effect	Notes
ASC?	Displays "variablename = 'character'" + carriage return; where character is an ASCII character.	1
DEC {1..5}	Decimal text, optionally fixed for 1 to 5 digits	
SDEC {1..5}	Signed decimal text, optionally fixed for 1 to 5 digits	1, 2
HEX {1..4}	Hexadecimal text, optionally fixed for 1 to 4 digits	1
SHEX {1..4}	Signed hex text, optionally fixed for 1 to 4 digits	1, 2
IHEX {1..4}	Indicated hex text ($ prefix; e.g., $7A3), optionally fixed for 1 to 4 digits	1
ISHEX {1..4}	Indicated signed hex text, optionally fixed for 1 to 4 digits	1, 2
BIN {1..16}	Binary text, optionally fixed for 1 to 16 digits	1
SBIN {1..16}	Signed binary text, optionally fixed for 1 to 16 digits	1, 2
IBIN {1..16}	Indicated binary text (% prefix; e.g., %10101100), optionally fixed for 1 to 16 digits	1, 2
ISBIN {1..16}	Indicated signed binary text, optionally fixed for 1 to 16 digits	1, 2
STR bytearray	Display an ASCII string from bytearray until byte = 0.	
STR bytearray\n	Display an ASCII string consisting of n bytes from bytearray.	
REP byte\n	Display an ASCII string consisting of byte repeated n times (e.g., REP "X"\10 sends XXXXXXXXXX).	

NOTES:

(1) Fixed-digit modifiers like DEC4 will pad text with leading 0s if necessary; e.g., DEC4 65 sends 0065. If a number is larger than the specified number of digits, the leading digits will be dropped; e.g., DEC4 56422 sends 6422.

(2) Signed modifiers work under two's complement rules, same as PBASIC2 math. Value must be no less than a word variable in size.

DTMFout

DTMFOUT ***pin,{ontime,offtime,}{,tone...}***

Generate dual-tone, multifrequency tones (DTMF, i.e., telephone "touch" tones).

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

This pin will be put into output mode temporarily during generation of tones. After tone generation is complete, the pin is left in input mode, even if it was previously an output.

- ***Ontime*** is an optional entry; a variable or constant (0 to 65535) specifying a duration of the tone in milliseconds. If ontime is not specified, DTMFout defaults to 200 ms on.

- ***Offtime*** is an optional entry; a variable or constant (0 to 65535) specifying the length of silent pause after a tone (or between tones, if multiple tones are specified). If offtime is not specified, DTMFout defaults to 50 ms off.

- ***Tone*** is a variable or constant (0—15) specifying the DTMF tone to send. Tones 0 through 11 correspond to the standard layout of the telephone keypad, while 12 through 15 are the fourth-column tones used by phone test equipment and in ham-radio applications.

0—9	Digits 0 through 9
10	Star (*)
11	Pound (#)
12—15	Fourth column tones A through D

2

Explanation

DTMF tones are used to dial the phone or remotely control certain radio equipment. The BS2 can generate these tones digitally using the DTMFout instruction. Figure I-2 shows how to connect a speaker or audio amplifier to hear these tones; figure I-3 shows how to connect the BS2 to the phone line. A typical DTMFout instruction to dial a phone through pin 0 with the interface circuit of figure I-3 would look like this:

```
DTMFOUT  0,[6,2,4,8,3,3,3]                    ' Call Parallax.
```

That instruction would be equivalent to dialing 624-8333 from a phone keypad. If you wanted to slow the pace of the dialing to accommodate a noisy phone line or radio link, you could use the optional *ontime* and *offtime* values:

```
DTMFOUT 0,500,100,[6,2,4,8,3,3,3]                ' Call Parallax, slowly.
```

In that instruction, ontime is set to 500 ms (1 / 2 second) and offtime to 100 ms (1 / 10th second).

Technical Background

The BS2's controller is a purely digital device. DTMF tones are analog waveforms, consisting of a mixture of two sine waves at different audio frequencies. So how does a digital device generate analog output? The BS2 creates and mixes the sine waves mathematically, then uses the resulting stream of numbers to control the duty cycle of a very fast pulse-width modulation (PWM) routine. So what's actually coming out of the BS2 pin is a rapid stream of pulses. The purpose of the filtering arrangements shown in the schematics of figures I-2 and I-3 is to smooth out the high-frequency PWM, leaving only the lower frequency audio behind.

Keep this in mind if you want to interface BS2 DTMF output to radios and other equipment that could be adversely affected by the presence of high-frequency noise on the input. Make sure to filter the DTMF output thoroughly. The circuits shown here are only a starting point; you may want to use an active low-pass filter with a roll-off point around 2 kHz.

Demo Program

This demo program is a rudimentary memory dialer. Since DTMF digits fit within a nibble (four bits), the program below packs two DTMF digits into each byte of three EEPROM data tables. The end of a phone number

Figure I-2

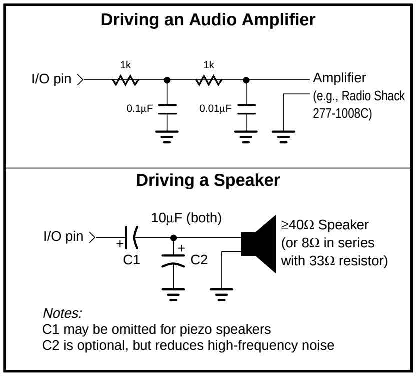
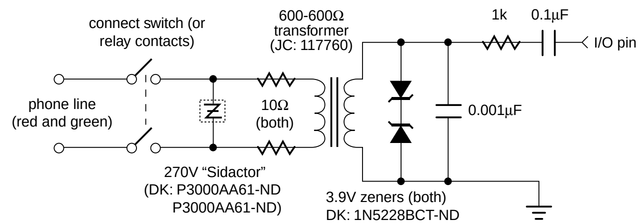


Figure I-3

Interfacing to the Telephone Line



Parts Sources

Digi-Key (DK), 1-800-344-4539 or 218-681-6674	Jameco (JC), 1-800-831-4242 or 415-592-8097

is marked by the nibble $F, since this is not a valid phone-dialing digit.

```
EEloc     var   byte                       ' EEPROM address of stored number.
EEbyte    var   byte                       ' Byte containing two DTMF digits.
DTdigit   var   EEbyte.highnib             ' Digit to dial.
phone     var   nib                        ' Pick a phone #.
hiLo      var   bit                        ' Bit to select upper and lower nibble.

Scott     data  $45,$94,$80,$2F            ' Phone: 459-4802
Chip      data  $19,$16,$62,$48,$33,$3F    ' Phone: 1-916-624-8333
Info      data  $15,$20,$55,$51,$21,$2F    ' Phone: 1-520-555-1212

for phone = 0 to 2                         ' Dial each phone #.
 lookup phone,[Scott,Chip,Info],EEloc      ' Get location of # in EEPROM.
dial:
  read EEloc,EEbyte                        ' Retrieve byte from EEPROM.
   for hiLo = 0 to 1                       ' Dial upper and lower digits.
     if DTdigit = $F then done             ' Hex $F is end-of-number flag
      DTMFout 0,[DTdigit]                  ' Dial digit.
     EEbyte = EEbyte << 4                  ' Shift in next digit.
   next
  EEloc = EEloc+1                          ' Next pair of digits.
 goto dial                                 ' Keep dialing until done ($F in DTdigit).
done:                                      ' This number is done.
 pause 2000                                                          '
Wait a couple of seconds.
next                                       ' Dial next phone number.
stop
```

End

END

End the program, placing the BS2 in a low-power mode.

Explanation

End puts the BS2 into its inactive, low-power mode. In this mode the BS2's current draw (exclusive of loads driven by the I/O pins) is approximately 50µA.

End keeps the BS2 inactive until the reset button is pushed or the power is cycled off and back on.

Just as during Sleep intervals, pins will retain their input or output settings after the BS2 is deactivated by End. So if a pin is driving a load when End occurs, it will continue to drive that load after End. However, at approximate 2.3-second intervals, output pins will disconnect (go into input mode) for a period of approximately 18 ms. Then they will revert to their former states.

For example, if the BS2 is driving an LED on when End executes, the LED will stay lit after end. But every 2.3 seconds, there will be a visible wink of the LED as the output pin driving it disconnects for 18 ms.

For...Next

FOR *variable = start to end {STEP stepVal} ... NEXT*

Create a repeating loop that executes the program lines between For and Next, incrementing or decrementing *variable* according to *stepVal* until the value of the variable passes the *end* value.

- ***Variable*** is a bit, nib, byte or word variable used as a counter.
- ***Start*** is a variable or constant that specifies the initial value of the variable.
- ***End*** is a variable or constant that specifies the end value of the variable. When the value of the variable passes *end*, the For...Next loop stops executing and the program goes on to the instruction after Next.
- ***StepVal*** is an optional variable or constant by which the variable increases or decreases with each trip through the For / Next loop. If *start* is larger than *end*, PBASIC2 understands *stepVal* to be negative, even though no minus sign is used.

2

Explanation

For...Next loops let your program execute a series of instructions for a specified number of repetitions. In simplest form:

```
reps   var   nib                          ' Counter for the FOR/NEXT loop.
FOR reps = 1 to 3          ' Repeat with reps = 1, 2, 3.
  debug "*"                ' Each rep, put one * on the screen.
NEXT
```

Each time the For...Next loop above executes, the value of reps is updated. See for yourself:

```
reps   var   nib                          ' Counter for the FOR/NEXT loop.
FOR reps = 1 to 10         ' Repeat with reps = 1, 2... 10.
  debug dec ? reps         ' Each rep, show values of reps.
NEXT
```

For...Next can also handle cases in which the start value is greater than the end value. It makes the commonsense assumption that you want to count down from start to end, like so:

```
reps   var  nib            ' Counter for the FOR/NEXT loop.
FOR reps = 10 to 1         ' Repeat with reps = 10, 9...1.
  debug dec ? reps         ' Each rep, show values of reps.
NEXT
```

If you want For...Next to count by some amount other than 1, you can specify a *stepVal*. For example, change the previous example to count down by 3:

```
reps   var   nib                                                          '
Counter for the FOR/NEXT loop.
FOR reps = 10 to 1 STEP 3               ' Repeat with reps = 10, 7...1.
  debug dec ? reps                      ' Each rep, show values of reps.
NEXT
```

Note that even though you are counting down, *stepVal* is still positive. For...Next takes its cue from the relationship between *start* and *end*, not the sign of *stepVal*. In fact, although PBASIC2 won't squawk if you use a negative entry for *stepVal*, its positive-integer math treats these values as large positive numbers. For example, –1 in two's complement is 65535. So the following code executes only once:

```
reps   var   word                       ' Counter for the FOR/NEXT loop.
FOR reps = 1 to 10 STEP -1              ' Actually FOR reps = 1 to 10 step
65535
  debug dec ? reps                      ' Executes only once.
NEXT
```

This brings up a good point: the instructions inside a For...Next loop always execute once, no matter what *start*, *end* and *stepVal* values are assigned.

There is a potential bug that you should be careful to avoid. PBASIC uses unsigned 16-bit integer math to increment / decrement the counter variable and compare it to the stop value. The maximum value a 16-bit variable can hold is 65535. If you add 1 to 65535, you get 0 as the 16-bit register rolls over (like a car's odometer does when you exceed the maximum mileage it can display).

If you write a For...Next loop whose step value is larger than the difference between the stop value and 65535, this rollover will cause the loop to execute more times than you expect. Try the following example:

```
reps   var   word                       ' Counter for the loop.
FOR reps = 0 to 65500 STEP 3000         ' Each loop add 3000.
  debug dec ? reps                      ' Show reps in debug window.
NEXT                                    ' Again until reps>65500.
```

The value of reps increases by 3000 each trip through the loop. As it approaches the stop value, an interesting thing happens: 57000, 60000, 63000, 464, 3464... It passes the stop value and keeps going. That's because the result of the calculation 63000 + 3000 exceeds the maximum capacity of a 16-bit number. When the value rolls over to 464, it passes the test "Is w1 > 65500?" used by Next to determine when to end the loop.

Demo Program

Here's an example that uses a For...Next loop to churn out a series of sequential squares (numbers 1, 2, 3, 4... raised to the second power) by using a variable to set the For...Next *stepVal*, and incrementing *stepVal* within the loop. Sir Isaac Newton is generally credited with the discovery of this technique.

```
square          var         byte            ' For/Next counter and series of
squares.
stepSize        var         byte            ' Step size, which will increase by 2
each loop.

stepSize = 1: square = 1
for square = 1 to 250 step stepSize         ' Show squares up to 250.
  debug dec ? square                        ' Display on screen.
  stepSize = stepSize +2                    ' Add 2 to stepSize
next                                        ' Loop til square > 250.
```

2

Freqout

FREQOUT *pin, duration, freq1{,freq2}*

Generate one or two sine-wave tones for a specified duration.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

  This pin will be put into output mode during generation of tones and left in that state after the instruction finishes.

- ***Duration*** is a variable / constant specifying the length in milliseconds (1 to 65535) of the tone(s).

- ***Freq1*** is a variable / constant specifying frequency in hertz (Hz, 0 to 32767) of the first tone.

- ***Freq2*** is a variable / constant specifying frequency (0 to 32767 Hz) of the optional second tone

Explanation

Freqout generates one or two sinewaves using fast PWM. The circuits shown in figure I-4 filter the PWM in order to play the tones through a speaker or audio amplifier. Here's an example Freqout instruction:

```
FREQOUT  2,1000,2500
```

This instruction generates a 2500-Hz tone for 1 second (1000 ms) through pin 2. To play two frequencies:

```
FREQOUT  2,1000,2500,3000
```

The frequencies mix together for a chord- or bell-like sound. To generate a silent pause, specify frequency value(s) of 0.

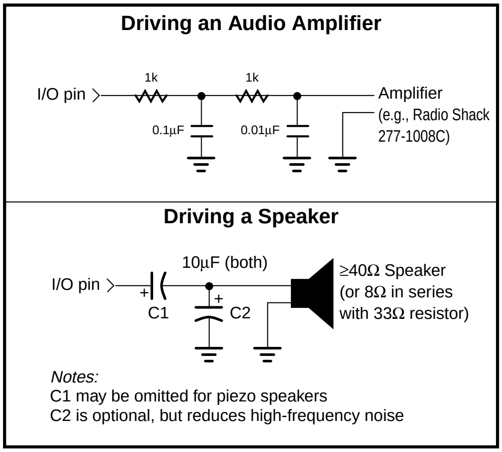
Frequency Considerations

The circuits in figure I-4 work by filtering out the high-frequency PWM used to generate the sinewaves. Freqout works over a very wide range of frequencies from 0 to 32767 Hz, so at the upper end of its range, those PWM filters will also filter out most of the desired frequency. You may find it necessary to reduce values of the parallel capacitors shown in the circuit, or to devise a custom active filter for your application.

Demo Program

This program plays "Mary Had a Little Lamb" by reading the notes from a Lookup table. To demonstrate the effect of mixing sine waves, the first

Figure I-4



2

frequency is the musical note itself, while the second is 8 Hz lower. When sines mix, sum and difference frequencies are generated. The difference frequency imposes an 8-Hz quiver (vibrato) on each note. Subtracting 8 from the note frequency poses a problem when the frequency is 0, because the BS2's positive-integer math wraps around to 65530. Freqout would ignore the highest bit of this value and generate a frequency of 32762 Hz rather than a truly silent pause. Although humans can't hear 32762 Hz, slight imperfections in filtering will cause an audible noise in the speaker. To clean this up we use the expression "(f-8) max 32768," which changes 65530 to 32768. Freqout discards the highest bit of 32768, which results in 0, the desired silent pause.

```
i       var     byte        ' Counter for position in tune.
f       var     word        ' Frequency of note for Freqout.
C       con     523         ' C note.
D       con     587         ' D note
E       con     659         ' E note
G       con     784         ' G note
R       con     0           ' Silent pause (rest).

for i = 0 to 28             ' Play the 29 notes of the Lookup table.
  lookup i,[E,D,C,D,E,E,E,R,D,D,D,R,E,G,G,R,E,D,C,D,E,E,E,E,D,D,E,D,C],f
  FREQOUT 0,350,f,(f-8) max 32768
next
stop
```

Gosub

GOSUB *addressLabel*

Store the address of the next instruction after Gosub, then go to the point in the program specified by addressLabel.

- ***AddressLabel*** is a label that specifies where to go.

Explanation

Gosub is a close relative of Goto. After Gosub, the program executes code beginning at the specified address label. (See the entry on Goto for more information on assigning address labels) Unlike Goto, Gosub also stores the address of the instruction immediately following itself. When the program encounters a Return instruction, it interprets it to mean “go to the instruction that follows the most recent Gosub.”

Up to 255 Gosubs are allowed per program, but they may be nested only four deep. In other words, the subroutine that’s the destination of a Gosub can contain a Gosub to another subroutine, and so on, to a maximum depth (total number of Gosubs before the first Return) of four. Any deeper, and the program will never find its way back to the starting point—the instruction following the very first Gosub.

When Gosubs are nested, each Return takes the program back to the instruction after the most-recent Gosub.

If a series of instructions is used at more than one point in your program, you can conserve program memory by turning those instructions into a subroutine. Then, wherever you would have had to insert that code, you can simply write Gosub label (where *label* is the name of your subroutine). Writing subroutines is like adding new commands to PBASIC.

You can avoid a potential bug in using subroutines by making sure that your program cannot wander into them without executing a Gosub. In the demo program, what would happen if the stop instruction were removed? After the loop finished, execution would continue in pickAnumber. When it reached Return, the program would jump back into the middle of the For...Next loop because this was the last return address assigned. The For...Next loop would execute indefinitely.

Demo Program

This program is a guessing game that generates a random number in a subroutine called pickAnumber. It is written to stop after three guesses. To see a common bug associated with Gosub, delete or comment out the line beginning with Stop after the For / Next loop. This means that after the loop is finished, the program will wander into the pickAnumber subroutine. When the Return at the end executes, the program will go back to the last known return address in the middle of the For / Next loop. This will cause the program to execute endlessly. Make sure that your programs can't accidentally execute subroutines!

```
rounds      var       nib                       ' Number of reps.
numGen      var       word                      ' Random-number generator
(must be 16 bits).
myNum       var       nib                       ' Random number, 1-10.

for rounds = 1 to 3                             ' Go three rounds.
  debug cls,"Pick a number from 1 to 10",cr
  GOSUB pickAnumber                             ' Get a random number, 1-10.
  pause 2000                                    ' Dramatic pause.
  debug "My number was: ", dec myNum            ' Show the number.
  pause 2000                                    ' Another pause.
next
stop                                            ' When done, stop execution
here.

' Random-number subroutine. A subroutine is just a piece of code
' with the Return instruction at the end. The proper way to use
' a subroutine is to enter it through a Gosub instruction. If
' you don't, the Return instruction won't have the correct
' return address, and your program will have a bug!
pickAnumber:
  random numGen                                 ' Stir up the bits of numGen.
  myNum = numGen/6550 min 1                     ' Scale to fit 1-10 range.
                                                ' Go back to the 1st instruction
return                                          ' after the GOSUB that got us
here.
```

2

Goto

GOTO *addressLabel*

Go to the point in the program specified by addressLabel.

- ***AddressLabel*** is a label that specifies where to go.

Explanation

Programs execute from the top of the page (or screen) toward the bottom, and from left to right on individual lines; just the same way we read and write English. Goto is one of the instructions that can change the order in which a program executes by forcing it to go to a labeled point in the program.

A common use for Goto is to create endless loops; programs that repeat a group of instructions over and over.

Goto requires an address label for a destination. A label is a word starting with a letter, containing letters, numbers, or underscore (_) characters, and ending with a colon. Labels may be up to 32 characters long. Labels must not duplicate names of PBASIC2 instructions, or variables, constants or Data labels, refer to Appendix B for a list of reserved words. Labels are not case-sensitive, so doItAgain, doitagain and DOitAGAIN all mean the same thing to PBASIC. Don't worry too much about the rules for devising labels; PBASIC will complain with an error message at download time if it doesn't like your labels.

Demo Program

This program is an endless loop that sends a Debug message to your computer screen. Although you can clear the screen by pressing a key, the BS2 program itself won't stop unless you shut it off.

```
doItAgain:
  debug "Looping...",cr
GOTO  doItAgain
```

High

HIGH *pin*

Make the specified pin output high (write 1s to the corresponding bits of both DIRS and OUTS).

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

Explanation

In order for the BS2 to actively output a 1 (a +5-volt level) on one of its pins, two conditions must be satisfied:

(1) The corresponding bit of the DIRS variable must contain a 1 in order to connect the pin's output driver.

(2) The corresponding bit of the OUTS variable must contain a 1.

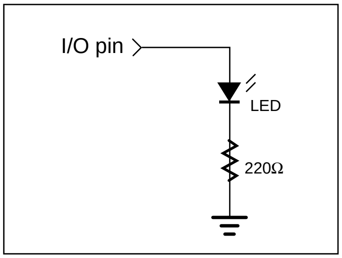
High performs both of these actions with a single, fast instruction.

Demo Program

This program shows the bitwise state of the DIRS and OUTS variables before and after the instruction High 4. You may also connect an LED to pin P4 as shown in figure I-5 to see it light when the High instruction executes.

```
debug "Before: ",cr
debug bin16 ? dirs,bin16 ? outs,cr,cr
pause 1000

HIGH 4

debug "After: ",cr
debug bin16 ? dirs,bin16 ? outs
```

Figure I-5



If...Then

IF *condition* THEN *addressLabel*

Evaluate condition and, if true, go to the point in the program marked by addressLabel.

- *Condition* is a statement, such as "x = 7" that can be evaluated as true or false.
- *AddressLabel* is a label that specifies where to go in the event that the condition is true.

Explanation

If...Then is PBASIC's decision maker. It tests a condition and, if that condition is true, goes to a point in the program specified by an address label. The condition that If...Then tests is written as a mixture of comparison and logic operators. The comparison operators are:

=	equal
<>	not equal
>	greater than
<	less than
>=	greater than or equal to
<=	less than or equal to

The values to be compared can be any combination of variables (any size), constants, or expressions. All comparisons are performed using unsigned, 16-bit math. An example:

```
aNumber   var   byte
aNumber = 99

IF aNumber < 100 THEN isLess
debug "greater than or equal to 100"
stop

isLess:
debug "less than 100"
stop
```

When you run that code, Debug shows, "less than 100." If...Then evaluated the condition "aNumber < 100" and found it to be true, so it redirected the program to the label after Then, “isLess.” If you change “aNumber = 99” to “aNumber = 100” the other message, “greater than or equal to 100,” will appear instead. The condition “aNumber < 100” is false if aNumber contains 100 or more. The values compared in the If...Then condition can also be expressions:

```
Number1      var          byte
Number2      var          byte
Number1 = 99
Number2 = 30

IF Number1 = Number2 * 4 - 20 THEN equal
debug "not equal"
stop

equal:
debug "equal"
stop
```


Since Number2 * 4 - 20 = (30 x 4) - 20 = 100, the message “not equal” appears on the screen, Changing that expression to Number2 * 4 - 21 would get the “equal” message.

Beware of mixing signed and unsigned numbers in If...Then comparisons. Watch what happens when we change our original example to include a signed number (–99):

```
IF -99 < 100 THEN isLess
debug "greater than or equal to 100"
stop

isLess:
debug "less than 100"
stop
```

Although –99 is obviously less than 100, the program says it is greater. The problem is that –99 is internally represented as the two’s complement value 65437, which (using unsigned math) is greater than 100. Don’t mix signed and unsigned values in If...Then comparisons.

Logic Operators

If...Then supports the logical operators NOT, AND, OR, and XOR. NOT inverts the outcome of a condition, changing false to true, and true to false. The following If...Thens are equivalent:

```
IF x <> 100 THEN notEqual                    ' Goto notEqual if x is not 100.
IF NOT x=100 THEN notEqual                   ' Goto notEqual if x is not 100.
```

The operators AND, OR, and XOR join the results of two conditions to produce a single true / false result. AND and OR work the same as they do in everyday speech. Run the example below once with AND (as shown) and again, substituting OR for AND:

```
b1 = 5
b2 = 9
IF b1 = 5 AND b2 = 10 THEN True              ' Change AND to OR and see
debug "Statement was not true."              ' what happens.
stop

True:
debug "Statement was true."
stop
```

The condition "b1 = 5 AND b2 = 10" is not true. Although b1 is 5, b2 is not 10. AND works just as it does in English—both conditions must be true for the statement to be true. OR also works in a familiar way; if one or the other or both conditions are true, then the statement is true. XOR (short for exclusive-OR) may not be familiar, but it does have an English counterpart: If one condition or the other (but not both) is true, then the statement is true.

Table I-2 below summarizes the effects of the logical operators. As with math, you can alter the order in which comparisons and logical operations are performed by using parentheses. Operations are normally evaluated left-to-right. Putting parentheses around an operation forces PBASIC2 to evaluate it before operations not in parentheses.

Table I-2. Effects of the Logical Operators Used by If...Then

Condition A	NOT A
false	true
true	false

Condition A	Condition B	A AND B
false	false	false
false	true	false
true	false	false
true	true	true

Condition A	Condition B	A OR B
false	false	false
false	true	true
true	false	true
true	true	true

Condition A	Condition B	A XOR B
false	false	false
false	true	true
true	false	true
true	true	false

Unlike some versions of the If...Then instruction, PBASIC's If...Then can only go to a label as the result of a decision. It cannot conditionally perform some instruction, as in "IF x < 20 THEN y = y + 1." The PBASIC version requires you to invert the logic using NOT and skip over the conditional instruction *unless* the condition is met:

```
IF NOT x < 20 THEN noInc                                  '
Don't increment y unless x < 20.
  y = y + 1                         ' Increment y if x < 20.
noInc: ...                          ' Program continues.
```

You can also code a conditional Gosub, as in "IF x = 100 THEN GOSUB centennial." In PBASIC:

```
IF NOT x = 100 then noCent
  gosub centennial                  ' IF x = 100 THEN gosub centennial.
noCent: ...                            ' Program continues.
```

Internal Workings and Potential Bugs

Internally, the BS2 defines "false" as 0 and "true" as any value other than 0. Consider the following instructions:

```
flag            var         bit
flag = 1

IF flag THEN isTrue
debug "false"
stop

isTrue:
debug "true"
stop
```

Since flag is 1, If...Then would evaluate it as true and print the message "true" on the screen. Suppose you changed the If...Then instruction to read "IF NOT flag THEN isTrue." That would also evaluate as true. Whoa! Isn't NOT 1 the same thing as 0? No, at least not in the 16-bit world of the BS2.

Internally, the BS2 sees a bit variable containing 1 as the 16-bit number %0000000000000001. So it sees the NOT of that as %1111111111111110. Since any non-zero number is regarded as true, NOT 1 is true. Strange but true.

The easiest way to avoid the kinds of problems this might cause is to always use a conditional operator with If...Then. Change the example above to read IF flag=1 THEN isTrue. The result of the comparison will follow If...Then rules. And the logical operators will work as they should; IF NOT flag=1 THEN isTrue will correctly evaluate to false when flag contains 1.

This also means that you should only use the named logic operators NOT, AND, OR, and XOR with If...Then. These operators format their results correctly for If...Then instructions. The other logical operators, represented by symbols ~ & | and ^ do not.

Demo Program

The program below generates a series of 16-bit random numbers and tests each to determine whether they're divisible by 3. (A number is divisible by another if the remainder from division, determined by the // operator, is 0.) If a number is divisible by 3, then it is printed, otherwise, the program generates another random number. The program counts how many numbers it prints, and quits when this number reaches 10.

```
sample       var        word                  ' Random number to be tested.
samps        var        nib                   ' Number of samples taken.
mul3:
  random sample                               ' Put a random number into sample.
  IF NOT sample//3 = 0 THEN mul3              ' Not multiple of 3? Try again.
    debug dec sample," is divisible by 3.",cr ' Print message.
    samps = samps + 1                         ' Count multiples of 3.
    IF samps = 10 THEN done                   ' Quit with 10 samples.
goto mul3

done:
debug cr,"All done."
stop
```

Input

INPUT *pin*

Make the specified pin an input (write a 0 to the corresponding bit of DIRS).

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

Explanation

There are several ways to make a pin an input. When a program begins, all of the BS2's pins are inputs. Input instructions (Pulsin, Serin) automatically change the specified pin to input and leave it in that state. Writing 0s to particular bits of the variable DIRS makes the corresponding pins inputs. And then there's the Input instruction.

When a pin is an input, your program can check its state by reading the corresponding INS variable. For example:

```
INPUT 4
Hold:   if IN4 = 0 then Hold                      ' Stay here until P4 is 1.
```

The program is reading the state of P4 as set by external circuitry. If nothing is connected to P4, it could be in either state (1 or 0) and could change states apparently at random.

What happens if your program writes to the OUTS bit of a pin that is set up as an input? The state is stored in OUTS, but has no effect on the outside world. If the pin is changed to output, the last value written to the corresponding OUTS bit will appear on the pin. The demo program shows how this works.

Demo Program

This program demonstrates how the input / output direction of a pin is determined by the corresponding bit of DIRS. It also shows that the state of the pin itself (as reflected by the corresponding bit of INS) is determined by the outside world when the pin is an input, and by the corresponding bit of OUTS when it's an output. To set up the demo, connect a 10k resistor from +5V to P7 on the BS2. The resistor to +5V puts a high (1) on the pin when it's an input. The BS2 can override this state by writing a low (0) to bit 7 of OUTS and changing the pin to output.

```
INPUT 7                                        ' Make pin 7 an input.
debug "State of pin 7: ", bin IN7,cr
OUT7 = 0                                       ' Write 0 to output latch.
debug  "After 0 written to OUT7: ",bin IN7,cr
output 7                                       ' Make pin 7 an output.
debug  "After pin 7 changed to output: ",bin IN7
```

Lookdown

LOOKDOWN*value,{comparisonOp,}[value0, value1,...valueN],resultVariable*

Compare a value to a list of values according to the relationship specified by the comparison operator. Store the index number of the first value that makes the comparison true into *resultVariable*. If no value in the list makes the comparison true, *resultVariable* is unaffected.

- ***Value*** is a variable or constant to be compared to the values in the list.
- ***ComparisonOp*** is optional and maybe one of the following:

=	equal
<>	not equal
>	greater than
<	less than
>=	greater than or equal to
<=	less than or equal to

If no comparison operator is specified, PBASIC2 uses equal (=).

- ***Value0***, **value1**... make up a list of values (constants or variables) up to 16 bits in size.
- ***ResultVariable*** is a variable in which the index number will be stored if a true comparison is found.

Explanation

Lookdown works like the index in a book. You search for a topic and the index gives you the page number. Lookdown searches for a value in a list, and stores the item number of the first match in a variable. For example:

```
value   var   byte
result  var   nib
value = 17
result = 15

LOOKDOWN  value,[26,177,13,1,0,17,99],result
debug "Value matches item ",dec result," in list"
```

Debug prints, “Value matches item 5 in list” because the value (17) matches item 5 of [26,177,13,1,0,17,99]. Note that index numbers count up from 0, not 1; that is in the list [26,177,13,1,0,17,99], 26 is item 0. What happens if the value doesn’t match any of the items in the list? Try changing “value = 17” to “value = 2.” Since 2 is not on the list, Lookdown does nothing. Since result contained 15 before Lookdown executed, Debug prints “Value matches item 15 in list.” Since there is no item 15, the program should look upon this number as a no-match indication.

Don’t forget that text phrases are just lists of byte values, so they too are eligible for Lookdown searches, as in this example:

```
value           var         byte
result          var         byte
value = "f"
result = 255

LOOKDOWN  value,["The  quick  brown  fox"],result
debug "Value matches item ",dec result," in list"
```

Debug prints, “Value matches item 16 in list” because the phrase “The quick brown fox” is a list of 19 bytes representing the ASCII values of each letter. A common application for Lookdown in conjunction with the Branch instruction, is to interpret single-letter instructions:

```
cmd   var   byte
cmd = "M"

LOOKDOWN  cmd,["SLMH"],cmd
Branch  cmd,[stop_,low_,medium,high_]
debug "Command not in list":                    stop
stop_:          debug  "stop":                  stop
low_:           debug "low":                    stop
medium:         debug  "medium":                stop
high_:          debug  "high":                  stop
```

In that example, the variable *cmd* contains “M” (ASCII 77). Lookdown finds that this is item 2 of a list of one-character commands and stores 2 into cmd. Branch then goes to item 2 of its list, which is the program label “medium” at which point the program continues. Debug prints “medium” on the PC screen. This is a powerful method for interpreting user input, and a lot neater than the alternative If...Then instructions.

Lookdown with Variables and Comparison Operators

The examples above show Lookdown working with lists of constants, but it also works with variables. Check out this example that searches the cells of an array:

```
value       var       byte
result      var       nib
a           var       byte(7)
value = 17
result = 15
a(0)=26:a(1)=177:a(2)=13:a(3)=1:a(4)=0:a(5)=17:a(6)=99

LOOKDOWN  value,[a(0),a(1),a(2),a(3),a(4),a(5),a(6)],result
debug "Value matches item ",dec result," in the list"
```

Debug prints, “Value matches item 5 in list” because a(5) is 17.

All of the examples above use Lookdown’s default comparison operator of = that searches for an exact match. But Lookdown also supports other comparisons, as in this example:

```
value       var       byte
result      var       nib
value = 17
result = 15

LOOKDOWN  value,>[26,177,13,1,0,17,99],result
debug "Value greater than item ",dec result," in list"
```

Debug prints, “Value greater than item 2 in list” because the first item that value (17) is greater than is 13, which is item 2 in the list. Value is also greater than items 3 and 4, but these are ignored, because Lookdown only cares about the first true condition. This can require a certain amount of planning in devising the order of the list. See the demo program below.

Lookdown comparison operators use unsigned 16-bit math. They will not work correctly with signed numbers, which are represented internally as two’s complement (large 16-bit integers). For example, the two’s complement representation of -99 is 65437. So although -99 is certainly less than 0, it would appear to be larger than zero to the Lookdown comparison operators. The bottom line is: Don’t used signed numbers with Lookdown comparisons.

Demo Program

This program uses Lookdown to determine the number of decimal digits in a number. The reasoning is that numbers less than 10 have one digit; greater than or equal to 10 but less than 100 have two; greater than or equal to 100 but less than 1000 have three; greater than or equal to 1000 but less than 10000 have four; and greater than or equal to 10000 but less than 65535 (the largest number we can represent in 16-bit math) have five. There are two loopholes that we have to plug: (1) The number 0 does not have zero digits, and (2) The number 65535 has five digits.

To ensure that 0 is accorded one-digit status, we just put 0 at the beginning of the Lookdown list. Since 0 is not less than 0, an input of 0 results in 1 as it should. At the other end of the scale, 65535 is not less than 65535, so Lookdown will end without writing to the result variable, numDig. To ensure that an input of 65535 returns 5 in numDig, we just put 5 into numDig beforehand.


```
i           var       word              ' Variable (0-65535).
numDig      var       nib               ' Variable (0-15) to hold # of
digits.

for i = 0 to 1000 step 8
 numDig = 5                             ' If no 'true' in list, must be 65535.
  LOOKDOWN i,<[0,10,100,1000,10000,65535],numDig
  debug "i= ", rep " "\(5-numdig) ,dec i,tab,"digits=", dec numdig,cr
  pause 200
next
```

Lookup

LOOKUP *index, [value0, value1,...valueN], resultVariable*

Look up the value specified by the index and store it in a variable. If the index exceeds the highest index value of the items in the list, variable is unaffected. A maximum of 256 values can be included in the list.

- ***Index*** is the item number (constant or variable) of the value to be retrieved from the list of values.
- ***Value0*, *value1***... make up a list of values (constants or variables) up to 16 bits in size.
- ***ResultVariable*** is a variable in which the retrieved value will be stored (if found).

Explanation

Lookup retrieves an item from a list based on the item's position (index) in the list. For example:

```
index           var          nib
result          var          byte
index = 3
result = 255

LOOKUP  index,[26,177,13,1,0,17,99],result
debug "Item ", dec index," is: ", dec result
```

Debug prints "Item 3 is: 1." Note that Lookup lists are numbered from 0; in the list above item 0 is 26, item 1 is 177, etc. If the index provided to Lookup is beyond the end of the list the result variable is unchanged. In the example above, if *index* were greater than 6, the debug message would have reported the result as 255, because that's what *result* contained before Lookup executed.

Demo Program

This program uses Lookup to create a debug-window animation of a spinning propeller. The animation consists of the four ASCII characters | / - \ which, when printed rapidly in order at a fixed location, appear to spin. (A little imagination helps a lot here.)

```
i           var     nib
frame       var     byte

rotate:
  for i = 0 to 3
     LOOKUP i,["|/-\"],frame
     debug cls,frame
     pause 50
  next
goto rotate
```

2

Low

LOW *pin*

Make the specified pin output low (write 1 to the corresponding bit of DIRS and 0 to the corresponding bit of OUTS).

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

Explanation

In order for the BS2 to actively output a 0 (a 0-volt level) on one of its pins, two conditions must be satisfied:

(1) The corresponding bit of the DIRS variable must contain a 1 in order to connect the pin's output driver.

(2) The corresponding bit of the OUTS variable must contain a 0.

Low performs both of these actions with a single, fast instruction.

Demo Program

This program shows the bitwise state of the DIRS and OUTS variables before and after the instruction Low 4. You may also connect an LED to pin P4 as shown in figure I-6 to see it light when the Low instruction executes.

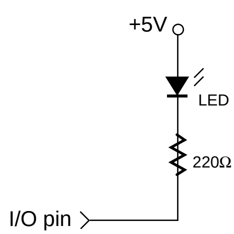


Figure I-6

```
Dirs = % 10000             ' Initialize P4 to high
debug "Before: ",cr
debug bin16 ? dirs,bin16 ? outs,cr,cr
pause 1000

LOW 4

debug "After: ",cr
debug bin16 ? dirs,bin16 ? outs
```

Nap

NAP *period*

Enter sleep mode for a short period. Power consumption is reduced to about 50 µA assuming no loads are being driven.

- ***Period*** is a variable / constant that determines the duration of the reduced power nap. The duration is (2^period) * 18 ms. (Read that as “2 raised to the power period, times 18 ms.”) Period can range from 0 to 7, resulting in the following nap lengths:

Period	2^{period}	Length of Nap
0	1	18 ms
1	2	36 ms
2	4	72 ms
3	8	144 ms
4	16	288 ms
5	32	576 ms
6	64	1152 ms (1.152 seconds)
7	128	2304 ms (2.304 seconds)

Explanation

Nap uses the same shutdown / startup mechanism as Sleep, with one big difference. During Sleep, the BS2 automatically compensates for variations in the speed of the watchdog timer oscillator that serves as its alarm clock. As a result, longer Sleep intervals are accurate to approximately ±1 percent. Nap intervals are directly controlled by the watchdog timer without compensation. Variations in temperature, supply voltage, and manufacturing tolerance of the BS2 interpreter chip can cause the actual timing to vary by as much as –50, +100 percent (i.e., a period-0 Nap can range from 9 to 36 ms). At room temperature with a fresh battery or other stable power supply, variations in the length of a Nap will be less than ±10 percent.

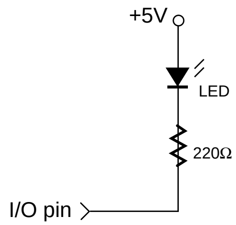
If your application is driving loads (sourcing or sinking current through output-high or output-low pins) during a Nap, current will be interrupted for about 18 ms when the BS2 wakes up. The reason is that the watchdog-timer reset that awakens the BS2 also causes all of the pins to switch to input mode for approximately 18 ms. When the PBASIC2 interpreter firmware regains control of the processor, it restores the

I/O direction dictated by your program.

If you plan to use End, Nap, or Sleep in your programs, make sure that your loads can tolerate these power outages. The simplest solution is often to connect resistors high or low (to +5V or ground) as appropriate to ensure a continuing supply of current during the reset glitch.

The demo program can be used to demonstrate the effects of the Nap glitch with an LED and resistor as shown in figure I-7.

Figure I-7



Demo Program

The program below lights an LED by placing a low on pin 0. This completes the circuit from +5V, through the LED and resistor, to ground. During the Nap interval, the LED stays lit, but blinks off for a fraction of a second. This blink is caused by the Nap wakeup mechanism described above. During wakeup, all pins briefly slip into input mode, effectively disconnecting them from loads.

```
low 0                       ' Turn LED on.
snooze:
  NAP 4                     ' Nap for 288 ms.
goto  snooze
```

Output

OUTPUT *pin*

Make the specified pin an output (write a 1 to the corresponding bit of DIRS).

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use.

Explanation

There are several ways to make a pin an output. When a program begins, all of the BS2's pins are inputs. Output instructions (Pulsout, High, Low, Serout, etc.) automatically change the specified pin to output and leave it in that state. Writing 1s to particular bits of the variable DIRS makes the corresponding pins outputs. And then there's the Output instruction.

When a pin is an output, your program can change its state by writing to the corresponding bit in the OUTS variable. For example:

```
OUTPUT  4
OUT4 = 1                                    ' Make pin 4 high (1).
```

When your program changes a pin from input to output, whatever state happens to be in the corresponding bit of OUTS sets the state of the pin. To simultaneously make a pin an output and set its state use the High and Low instructions.

Demo Program

This program demonstrates how the input / output direction of a pin is determined by the corresponding bit of DIRS. To set up the demo, connect a 10k resistor from +5V to P7 on the BS2. The resistor to +5V puts a high (1) on the pin when it's initially an input. The BS2 then overrides this state by writing a low (0) to bit 7 of OUTS and executing Output 7.

```
input 7                                     ' Make pin 7 an input.
debug "State of pin 7: ", bin IN7,cr
OUT7 = 0                                    ' Write 0 to output latch.
debug  "After 0 written to OUT7: ",bin IN7,cr
OUTPUT  7                                   ' Make pin 7 an output.
debug  "After pin 7 changed to output: ",bin IN7
```

Pause

PAUSE ***milliseconds***

Pause the program (do nothing) for the specified number of milliseconds.

- ***Milliseconds*** is a variable / constant specifying the length of the pause in ms. Pauses may be up to 65535 ms (65+ seconds) long.

Explanation

Pause delays the execution of the next program instruction for the specified number of milliseconds. For example:

```
flash:
  low 0
  PAUSE 100
  high 0
  PAUSE 100
goto flash
```

This code causes pin 0 to go low for 100 ms, then high for 100 ms. The delays produced by Pause are as accurate as the ceramic-resonator timebase, ±1 percent. When you use Pause in timing-critical applications, keep in mind the relatively low speed of the PBASIC interpreter; about 3000 instructions per second. This is the time required for the BS2 to read and interpret an instruction stored in the EEPROM.

Since the chip takes 0.3 milliseconds to read in the Pause instruction, and 0.3 milliseconds to read in the instruction following it, you can count on loops involving Pause taking almost 1 millisecond longer than the Pause period itself. If you're programming timing loops of fairly long duration, keep this (and the 1-percent tolerance of the timebase) in mind.

Demo Program

This program demonstrates the Pause instruction's time delays. Once a second, the program will put the debug message "paused" on the screen.

```
again:
  PAUSE 1000
   debug "paused",cr
goto again
```

Pulsin

PULSIN *pin, state, resultVariable*

Measure the width of a pulse in 2µs units.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. This pin will be placed into input mode during pulse measurement and left in that state after the instruction finishes.
- ***State*** is a variable or constant (0 or 1) that specifies whether the pulse to be measured begins with a 0-to-1 transition (1) or a 1-to-0 transition (0).
- ***ResultVariable*** is a variable in which the pulse duration (in 2µs units) will be stored.

Explanation

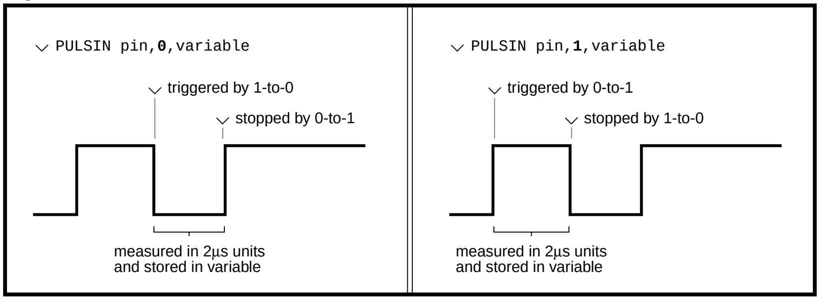
You can think of Pulsin as a fast stopwatch that is triggered by a change in state (0 or 1) on the specified pin. When the state on the pin changes to the state specified in Pulsin, the stopwatch starts. When the state on the pin changes again, the stopwatch stops.

If the state of the pin doesn't change–even if it is already in the state specified in the Pulsin instruction–the stopwatch won't trigger. Pulsin waits a maximum of 0.131 seconds for a trigger, then returns with 0 in *resultVariable*. If the pulse is longer than 0.131 seconds, Pulsin returns a 0 in *resultVariable*.

If the variable is a word, the value returned by Pulsin can range from 1 to 65535 units of 2 µs. If the variable is a byte, the value returned can range from 1 to 255 units of 2 µs. Regardless of the size of the variable, Pulsin internally uses a 16-bit timer. When your program specifies a byte variable, Pulsin stores the lower 8 bits of the internal counter into it. This means that pulse widths longer than 510 µs will give false, low readings with a byte variable. For example, a 512-µs pulse would return a Pulsin reading of 256 with a word variable and 0 with a byte variable.

Figure I-8 shows how the state bit controls triggering of Pulsin.

Figure I-8

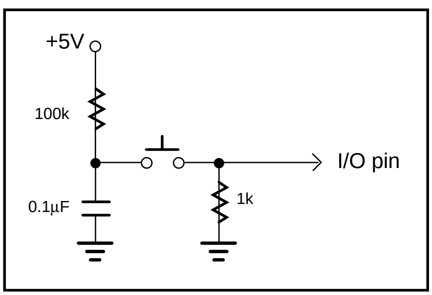


Demo Program

This program uses Pulsin to measure a pulse generated by discharging a 0.1µF capacitor through a 1k resistor as shown in figure I-9. Pressing the switch generates the pulse, which should ideally be approximately 120µs (60 Pulsin units of 2µs) long. Variations in component values may produce results that are up to 10 units off from this value. For more information on calculating resistor-capacitor timing, see the RCtime instruction.

```
time            var          word

again:
  PULSIN 7,1,time                          ' Measure positive pulse.
  if time = 0 then again                   ' If 0, try again.
  debug cls,dec ? time                     ' Otherwise, display result.
goto again                                 ' Do it again.
```

Figure I-9



Pulsout

PULSOUT *pin, time*

Output a pulse of 2µs to 131 ms in duration.

- ***Pin*** is a variable / constant (0-15) that specifies the I / O pin to use. This pin will be placed into output mode immediately before the pulse and left in that state after the instruction finishes.
- ***Time*** is a variable / constant (0-65535) that specifies the duration of the pulse in 2µs units.

Explanation

Pulsout combines several actions into a single instruction. It puts the specified pin into output mode by writing a 1 to the corresponding bit of DIRS; inverts the state of that pin's OUTS bit; waits for the specified number of 2µs units; then inverts the corresponding bit of OUTS again, returning the bit to its original state. An example:

```
PULSOUT 5,50                ' Make a 100-us pulse on pin 5.
```

The polarity of the pulse depends on the state of the pin's OUTS bit when the instruction executes. In the example above, if OUT5 = 0, then Pulsout 5,50 produces a 100µs positive pulse. If the pin is an input, the OUTS bit won't necessarily match the state of the pin. What does Pulsout do then? Example: pin 7 is an input (DIR7 = 0) and pulled high by a resistor as shown in figure I-10a. Suppose that OUT7 is 0 when we execute the instruction:

```
PULSOUT 7,5' 10-us pulse on pin 7.
```

Figure I-10b shows the sequence of events as they would look on an oscilloscope. Initially, pin 7 is high. Its output driver is turned off (because it is in input mode), so the 10k resistor sets the state on the pin. When Pulsout executes, it turns on the output driver, allowing OUT7 to control the pin. Since OUT7 is low, the pin goes low. After a few microseconds of preparation, Pulsout inverts OUT7. It leaves OUT7 in that state for 10µs, then inverts it again, leaving OUT7 in its original state.

This sequence of events is different from the original Basic Stamp I. The Basic Stamp I does not have separate INS and OUTS registers; both functions are rolled into the pin variables, such as "pin7." So in the situation outlined above and shown in figure I-10, the BS1 would produce a single negative pulse and leave the pin output high when done.

To make the BS2 work the same way, copy the state of the pin's INS bit to

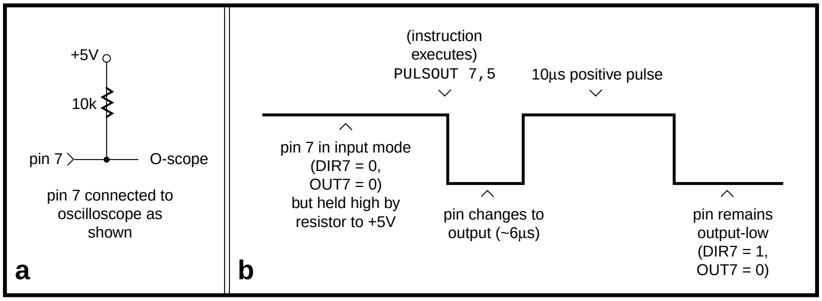


Figure I-10

its OUTS bit before Pulsout:

```
OUT7 = IN7    ' Copy input state to output driver.
PULSOUT 7,5' 10-us pulse on pin 7.
```

Now the instruction would pulse low briefly, then return output-high, just like the BS1. Of course, BS1 Pulsout works in units of 10µs, so you would have to adjust the timing to make an exact match, but you get the idea.

Demo Program

This program blinks an LED on for 10ms at 1-second intervals. Connect the LED to I/O pin 0 as shown in figure I-11.

```
high 0                    ' Set the pin high (LED off).
again:
  pause 1000              ' Wait one second.
  PULSOUT 0,5000          ' Flash the LED for 10 ms.
goto again                ' Repeat endlessly.
```

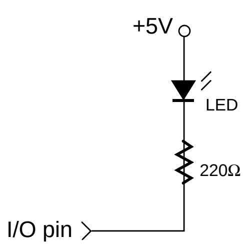


Figure I-11

PWM

PWM *pin, duty, cycles*

Convert a digital value to analog output via pulse-width modulation.

- ***Pin*** is a variable / constant (0-15) that specifies the I / O pin to use. This pin will be placed into output mode during pulse generation then switched to input mode when the instruction finishes.
- ***Duty*** is a variable / constant (0-255) that specifies the analog output level (0 to 5V).
- ***Cycles*** is a variable / constant (0-65535) specifying an approximate number of milliseconds of PWM output.

Explanation

Pulse-width modulation (PWM) allows the BS2—a purely digital device—to generate an analog voltage. The basic idea is this: If you make a pin output high, the voltage at that pin will be close to 5V. Output low is close to 0V. What if you switched the pin rapidly between high and low so that it was high half the time and low half the time? The average voltage over time would be halfway between 0 and 5V—2.5V. This is the idea of PWM; that you can produce an analog voltage by outputting a stream of digital 1s and 0s in a particular proportion.

The proportion of 1s to 0s in PWM is called the duty cycle. The duty cycle controls the analog voltage in a very direct way; the higher the duty cycle the higher the voltage. In the case of the BS2, the duty cycle can range from 0 to 255. Duty is literally the proportion of 1s to 0s output by the PWM instruction. To determine the proportional PWM output voltage, use this formula: (duty / 255) * 5V. For example, if duty is 100, (100 / 255) * 5V = 1.96V; PWM outputs a train of pulses whose average voltage is 1.96V.

In order to convert PWM into an analog voltage we have to filter out the pulses and store the average voltage. The resistor / capacitor combination in figure I-12 will do the job. The capacitor will hold the voltage set by PWM even after the instruction has finished. How long it will hold the voltage depends on how much current is drawn from it by external circuitry, and the internal leakage of the capacitor. In order to hold the voltage relatively steady, a program must periodically repeat the PWM instruction to give the capacitor a fresh charge.

Just as it takes time to discharge a capacitor, it also takes time to charge it in the first place. The PWM instruction lets you specify the charging time in terms of PWM cycles. Each cycle is a period of approximately 1ms. So to charge a capacitor for 5ms, you would specify 5 cycles in the PWM instruction.

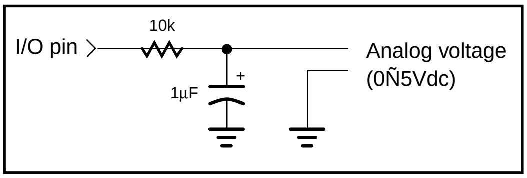
How do you determine how long to charge a capacitor? Use this rule-of-thumb formula: Charge time = 4 * R * C. For instance, figure I-12 uses a 10k (10×10^3 ohm) resistor and a 1µF (1×10^{-6} F) capacitor: Charge time = $4 * 10 \times 10^3 * 1 \times 10^{-6} = 40 \times 10^{-3}$ seconds, or 40ms. Since each cycle is approximately a millisecond, it would take at least 40 cycles to charge the capacitor. Assuming the circuit is connected to pin 0, here's the complete PWM instruction:

```
PWM 0,100,40                    ' Put a 1.96V charge on capacitor.
```

After outputting the PWM pulses, the BS2 leaves the pin in input mode (0 in the corresponding bit of DIRS). In input mode, the pin's output driver is effectively disconnected. If it were not, the steady output state of the pin would change the voltage on the capacitor and undo the voltage setting established by PWM.

PWM charges the capacitor; the load presented by your circuit discharges it. How long the charge lasts (and therefore how often your program should repeat the PWM instruction to refresh the charge) depends on how much current the circuit draws, and how stable the voltage must be. You may need to buffer PWM output with a simple op-amp follower if your load or stability requirements are more than the passive circuit of figure I-12 can handle.

Figure I-12



How PWM is Generated

The term "PWM" applies only loosely to the action of the BS2's PWM instruction. Most systems that output PWM do so by splitting a fixed period of time into an on time (1) and an off time (0). Suppose the interval is 1 ms and the duty cycle is 100 / 255. Conventional PWM would turn the output on for 0.39 ms and off for 0.61 ms, repeating this process each millisecond. The main advantage of this kind of PWM is its predictability; you know the exact frequency of the pulses (in this case, 1kHz), and their widths are controlled by the duty cycle.

BS2 PWM does not work this way. It outputs a rapid sequence of on / off pulses as short as 4µs in duration whose overall proportion over the course of a full PWM cycle of approximately a millisecond is equal to the duty cycle. This has the advantage of very quickly zeroing in on the desired output voltage, but it does not produce the neat, orderly pulses that you might expect. The BS2 also uses this high-speed PWM to generate pseudo-sinewave tones with the DTMFout and Freqout instructions.

Demo Program

Connect a voltmeter (such as a digital multimeter set to its voltage range) to the output of the circuit shown in figure I-12. Connect BS2 pin 0 to point marked I / O pin. Run the program and observe the readings on the meter. They should come very close to 1.96V, then decrease slightly as the capacitor discharges. Try varying the interval between PWM bursts (by changing the Pause value) and the number of PWM cycles to see their effect.

```
again:
  PWM 0,100,40            ' 40 cycles of PWM at 100/255 duty
  pause 1000              ' Wait a second.
goto again                ' Repeat.
```

Random

RANDOM *variable*

Generate a pseudo-random number.

- ***Variable*** is a byte or word variable whose bits will be scrambled to produce a random number.

Explanation

Random generates pseudo-random numbers ranging from 0 to 65535. They're called "pseudo-random" because they appear random, but are generated by a logic operation that always produces the same result for a given input. For example:

```
w1 = 0                                  ' Clear word variable w1 to 0.
RANDOM w1 ' Generate "random" number.
debug dec ? w1                          ' Show the result on screen.
```

In applications requiring more apparent randomness, it's a good idea to seed Random's wordvariable with a different value each time. For instance, in the demo program below, Random is executed continuously while the program waits for the user to press a button. Since the user can't control the timing of button presses to the nearest millisecond, the results approach true randomness.

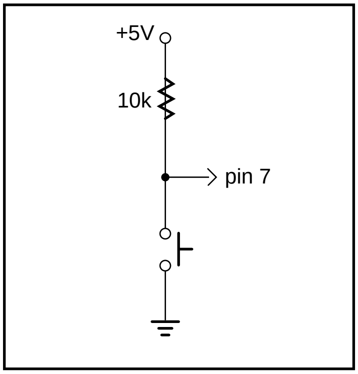
Demo Program

Connect a button to pin 7 as shown in figure I-13 and run the program below. The program uses Random to simulate a coin toss. After 100 trials, it reports the total number of heads and tails thrown.

```
flip        var     word            ' The random number.
coin        var     flip.bit0       ' A single bit of the random
number.
trials      var     byte            ' Number of flips.
heads       var     byte            ' Number of throws that came up
heads.
tails       var     byte            ' Number of throws that came up
tails.
btn         var     byte            ' Workspace for Button instruc-
tion.

start:
  debug cls, "Press button to start"
```

```
for trials = 1 to 100                   ' 100 tosses of the coin.
hold:
   RANDOM flip                          ' While waiting for button,
randomize.
   button 7,0,250,100,btn,0,hold        ' Wait for button.
   branch coin,[head,tail]              ' If 0 then head; if 1 then tail.
head:
   debug cr,"HEADS"                     ' Show heads.
   heads = heads+1                      ' Increment heads counter.
   goto theNext                         ' Next flip.

tail:
   debug cr,"TAILS"                     ' Show tails.
   tails = tails+1                      ' Increment tails counter.
theNext:                                ' Next flip.
next
' When done, show the total number of heads and tails.
debug cr,cr,"Heads: ",dec heads," Tails: ",dec tails
```


Figure I-13



RCtime

RCTIME *pin, state, resultVariable*

Count time while pin remains in state—usually to measure the charge / discharge time of resistor / capacitor (RC) circuit.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. This pin will be placed into input mode and left in that state when the instruction finishes.
- ***State*** is a variable or constant (1 or 0) that will end the RCtime period.
- ***ResultVariable*** is a variable in which the time measurement (0 to 65535 in 2µs units) will be stored.

Explanation

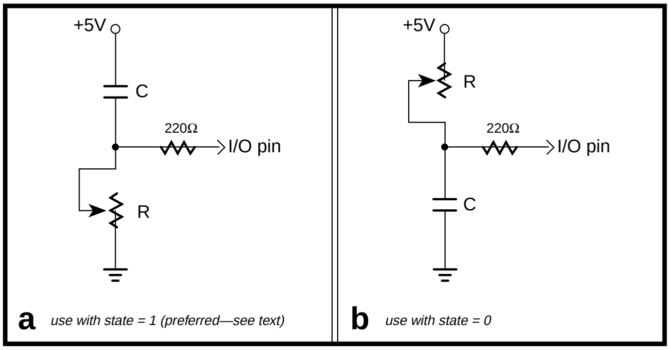
RCtime can be used to measure the charge or discharge time of a resistor / capacitor circuit. This allows you to measure resistance or capacitance; use R or C sensors (such as thermistors or capacitive humidity sensors); or respond to user input through a potentiometer. In a broader sense, RCtime can also serve as a fast, precise stopwatch for events of very short duration (less than 0.131 seconds).

When RCtime executes, it starts a counter that increments every 2µs. It stops this counter as soon as the specified pin is no longer in state (0 or 1). If pin is not in state when the instruction executes, RCtime will return 1 in resultVariable, since the instruction requires one timing cycle to discover this fact. If pin remains in state longer than 65535 timing cycles of 2µs each (0.131 seconds), RCtime returns 0.

Figure I-14 shows suitable RC circuits for use with RCtime. The circuit in I-14a is preferred, because the BS2's logic threshold is approximately 1.5 volts. This means that the voltage seen by the pin will start at 5V then fall to 1.5V (a span of 3.5V) before RCtime stops. With the circuit of I-14b, the voltage will start at 0V and rise to 1.5V (spanning only 1.5V) before RCtime stops. For the same combination of R and C, the circuit shown in I-14a will yield a higher count, and therefore more resolution than I-14b.

Before RCtime executes, the capacitor must be put into the state specified

Figure I-14



in the RCtime instruction. For example, with figure I-14a, the capacitor must be discharged until both plates (sides of the capacitor) are at 5V. It may seem counterintuitive that discharging the capacitor makes the input high, but remember that a capacitor is charged when there is a voltage difference between its plates. When both sides are at +5V, the cap is considered discharged.

Here's a typical sequence of instructions for I-14a (assuming I/O pin 7 is used):

```
result   var   word          ' Word variable to hold result.
high 7                       ' Discharge the cap
pause 1                      ' for 1 ms.
RCTIME 7,1,result            ' Measure RC charge time.
debug ? result               ' Show value on screen.
```

Using RCtime is very straightforward, except for one detail: For a given R and C, what value will RCtime return? It's easy to figure, based on a value called the RC time constant or tau (t) for short. Tau represents the time required for a given RC combination to charge or discharge by 63 percent of the total change in voltage that they will undergo. More importantly, the value t is used in the generalized RC timing calculation. Tau's formula is just R multiplied by C:

t = R x C

The general RC timing formula uses t to tell us the time required for an RC circuit to change from one voltage to another:

$$\text{time} = -\tau\left[\ln\left[\frac{V_{final}}{V_{initial}}\right]\right]$$

In this formula ln is the natural logarithm; it's a key on most scientific calculators. Let's do some math. Assume we're interested in a 10k resistor and 0.1µF cap. Calculate t:

$t = (10 \times 10^{3}) \times (0.1 \times 10^{-6}) = 1 \times 10^{-3}$

The RC time constant is 1×10^{-3} or 1 millisecond. Now calculate the time required for this RC circuit to go from 5V to 1.5V (as in figure I-14a):

In RCtime units of 2µs, that time (1.204×10^{-3}) works out to 602 units. With a 10k resistor and 0.1µF cap, RCtime would return a value of approximately 600. Since Vinitial and Vfinal don't change, we can use a simplified rule of thumb to estimate RCtime results for circuits like I-14a:

RCtime units = 600 x R (in kΩ) x C (in µF)

Another handy rule of thumb can help you calculate how long to charge / discharge the capacitor before RCtime. In the example above that's the purpose of the High and Pause instructions. A given RC charges or discharges 98 percent of the way in 4 time constants (4 x R x C). In figure I-14a / b, the charge / discharge current passes through the 220Ω series resistor and the capacitor. So if the capacitor were 0.1µF, the minimum charge / discharge time should be:

Charge time = $4 \times 220 \times (0.1 \times 10^{-6}) = 88 \times 10^{-6}$

So it takes only 88µs for the cap to charge / discharge, meaning that the 1 ms charge / discharge time of the example is plenty.

A final note about figure I-14: You may be wondering why the 220Ω resistor is necessary at all. Consider what would happen if resistor R in I-14a were a pot, and were adjusted to 0Ω. When the I / O pin went high to discharge the cap, it would see a short direct to ground. The 220Ω series resistor would limit the short circuit current to 5V / 220Ω = 23 milliamperes (mA) and protect the BS2 from damage. (Actual current would be quite a bit less due to internal resistance of the pin's output driver, but you get the idea.)

Demo Program 1

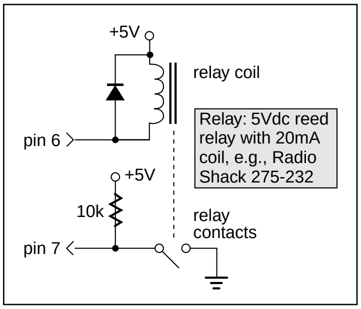
This program shows the standard use of the RCtime instruction—measuring an RC charge / discharge time. Use the circuit of figure I-14a, with R = 10k pot and C = 0.1µf. Connect the circuit to pin 7 and run the program. Adjust the pot and watch the value shown on the Debug screen change.

```
result var word             ' Word variable to hold result.
again:
 high 7                     ' Discharge the cap
 pause 1                    ' for 1 ms.
 RCTIME 7,1,result          ' Measure RC charge time.
 debug cls,dec result       ' Show value on screen.
goto again
```

Demo Program 2

This program illustrates the use of RCtime as a sort of fast stopwatch. The program energizes a relay coil, then has RCtime measures how long it takes for the relay contacts to close. Figure I-15 shows the hookup. In a test run of the program with a storage oscilloscope independently timing the relay coil and contacts, we got the following results: RCtime result = 28 units (56µs); Oscilloscope measurement: 270µs. The 214µs difference is the time required for RCtime to set up and begin its measurement cycle. Bear this in mind—that RCtime doesn't start timing instantly—when designing critical applications.

Figure I-15




```
result      var     word

again:
 low 6                      ' Energize relay coil.
 RCTIME 7,1,result          ' Measure time to contact closure.
 debug "Time to close: ", dec result,cr
 high 6                     ' Release the relay.
 pause 1000                 ' Wait a second.
goto again                  ' Do it again.
```

Read

READ ***location,variable***

Read EEPROM location and store value in variable.

- ***Location*** is a variable / constant (0–2047) that specifies the EEPROM address to read from.
- ***Variable*** holds the byte value read from the EEPROM (0–255).

Explanation

The EEPROM is used for both program storage (which builds downward from address 2047) and data storage (which builds upward from address 0). The Read instruction retrieves a byte of data from any EEPROM address. Although it's unlikely that you would want to read the compressed tokens that make up your PBASIC2 program, storing and retrieving long-term data in EEPROM is a very handy capability. Data stored in EEPROM is not lost when the power is removed.

The demo program below uses the Data directive to preload the EEPROM with a message; see the section BS2 EEPROM Data Storage for a complete explanation of Data. Programs may also write to the EEPROM; see Write.

Demo Program

This program reads a string of data stored in EEPROM. The EEPROM data is downloaded to the BS2 at compile-time (immediately after you press ALT-R) and remains there until overwritten—even with the power off.

```
' Put ASCII characters into EEPROM, followed by 0,
' which will serve as the end-of-message marker.
Message data "BS2 EEPROM Storage!",0
strAddr        var          word
char           var          byte

strAddr = Message           ' Set address to start of Message.

stringOut:
  READ StrAddr,char         ' Get a byte from EEPROM.
  if char <> 0 then cont    ' Not end? Continue.
Stop                        'Stop here when done.
```

```
cont:
  debug char                  ' Show character on screen.
  strAddr = strAddr+1         ' Point to next character.
goto stringOut                ' Get next character.
```

Return

RETURN

Return from a subroutine.

Explanation

Return sends the program back to the address (instruction) immediately following the most recent Gosub. If Return is executed without a prior Gosub to set the return address, a bug will result. For more thorough coverage of Gosub...Return, see the Gosub writeup.

Demo Program

This program demonstrates how Gosub and Return work, using Debug messages to trace the program's execution. For an illustration of the bug caused by accidentally wandering into a subroutine, remove the Stop instruction. Instead of executing once, the program will get stuck in an infinite loop.

```
debug "Executing Gosub...",cr
gosub demoSub
debug "Returned."
stop

demoSub:
  debug "Executing subroutine.",cr
RETURN
```

Reverse

REVERSE *pin*

Reverse the data direction of the specified pin.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. This pin will be placed into the opposite of its current input / output mode by inverting the corresponding bit of the DIRS register.

Explanation

Reverse is convenient way to switch the I / O direction of a pin. If the pin is an input and you Reverse it, it becomes an output; if it's an output, Reverse makes it an input.

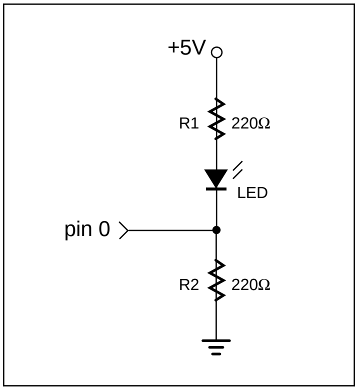
Remember that "input" really has two meanings: (1) Setting a pin to input makes it possible to check the state (1 or 0) of external circuitry connected to that pin. The state is in the corresponding bit of the INS register. (2) Setting a pin to input also disconnects the output driver (corresponding bit of OUTS). The demo program below illustrates this second fact with a two-tone LED blinker.

Demo Program

Connect the circuit of figure I-16 to pin 0 and run the program below. The LED will alternate between two states, dim and bright. What's happening is that the Reverse instruction is toggling pin 0 between input and output states. When pin 0 is an input, current flows through R1, through the LED, through R2 to ground. Pin 0 is effectively disconnected and doesn't play a part in the circuit. The total resistance encountered by current flowing through the LED is R1 + R2 = 440Ω. When pin 0 is Reversed to output, current flows through R1, through the LED, and into pin 0 to ground (because of the 0 written to OUT0). The total resistance encountered by current flowing through the LED is R1, 220Ω. With only half the resistance, the LED glows brighter.

```
OUT0 = 0                    ' Put a low in the pin 0 output driver.
again:
  pause 200                 ' Brief (1/5th second) pause.
  REVERSE 0                 ' Invert pin 0 I/O direction.
goto again                  ' Repeat forever.
```

Figure I-16



Serin

SERIN ***rpin{\fpin},baudmode,{plabel,}{timeout,tlabel,}[inputData]***

Receive asynchronous (e.g., RS-232) data.

- ***Rpin*** is a variable/constant (0–16) that specifies the I/O pin through which the serial data will be received. This pin will switch to input mode and remain in that state after the instruction is completed. If Rpin is set to 16, the Stamp uses the dedicated serial-input pin (SIN), which is normally used by the STAMP2 host program.

- ***Fpin*** is an optional variable/constant (0–15) that specifies the I/O pin to be used for flow control (byte-by-byte handshaking). This pin will switch to output mode and remain in that state after the end of the instruction.

- ***Baudmode*** is a 16-bit variable/constant that specifies serial timing and configuration. The lower 13 bits are interpreted as the bit period minus 20µs. Bit 13 ($2000 hex) is a flag that controls the number of data bits and parity (0=8 bits and no parity, 1=7 bits and even parity). Bit 14 ($4000 hex) controls polarity (0=noninverted, 1=inverted). Bit 15 ($8000 hex) is not used by Serin.

- ***Plabel*** is an optional label indicating where the program should go in the event of a parity error. This argument may only be provided if baudmode indicates 7 bits, and even parity.

- ***Timeout*** is an optional variable/constant (0–65535) that tells Serin how long in milliseconds to wait for incoming data. If data does not arrive in time, the program will jump to the address specified by *tlable*.

- ***Tlabel*** is an optional label which must be provided along with timeout, indicating where the program should go in the event that data does not arrive within the period specified by *timeout*.

- ***InputData*** is a list of variables and modifiers that tells Serin what to do with incoming data. Serin can store data in a variable or array; interpret numeric text (decimal, binary, or hex) and store the corresponding value in a variable; wait for a fixed or variable sequence of bytes; or ignore a specified number of bytes. These actions can be combined in any order in the *inputData* list.

2

Explanation

The BS2 can send and receive asynchronous serial data at speeds up to 50,000 bits per second. Serin, the serial-input instruction, can filter and convert incoming data in powerful ways. With all this power inevitably comes some complexity, which we'll overcome by walking you through the process of setting up Serin and understanding its options.

Physical/Electrical Interface

Since the STAMP2 host software runs on a PC, we'll use its RS-232 COM ports as a basis for discussion of asynchronous serial communication. Asynchronous means "no clock." Data can be sent using a single wire, plus ground.

The other kind of serial, synchronous, uses at least two wires, clock and data, plus ground. The Shiftin and Shiftout commands are used for a form of synchronous serial communication.

RS-232 is the electrical specification for the signals that PC COM ports use. Unlike normal logic, in which a 1 is represented by 5 volts and a 0 by 0 volts, RS-232 uses –12 volts for 1 and +12 volts for 0.

Most circuits that receive RS-232 use a line receiver. This component does two things: (1) It *converts* the ±12 volts of RS-232 to logic-compatible 0/5-volt levels. (2) It *inverts* the relationship of the voltage levels to corresponding bits, so that volts = 1 and 0 volts = 0.

The BS2 has a line receiver on its SIN pin (rpin = 16). See the BS2 hardware description and schematic. The SIN pin goes to a PC's serial data-out pin on the DB9 connector built into BS2 carrier boards. The connector is wired to allow the STAMP2 host program to re-

Figure I-17

Using the Carrier Board DB9 Connector with PC Terminal Programs

Option 1: Custom Software

Write custom software that uses the serial port with the DTR line low. Under DOS, DTR is bit 0 of port $03FC or $02FC (com 1 or 2, respectively). In QBASIC or QuickBASIC, port locations are accessed using the INP and OUT instructions. HereÕs a QBASIC code fragment that clears the DTR bit on com 1:

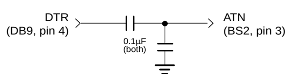
```
temp = INP(&H3FC)
OUT &H3FC,temp AND 254
```

However, even if this instruction is issued immediately after the com port is OPENed, DTR goes high for almost 100ms (more on a slow PC). This will cause the BS2 to reset, unless the code runs *before* the BS2 is connected to the com port.

Do not consider the software approach unless you are an expert programmer able to go it alone, as there are no canned examples available.

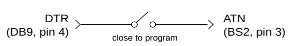
Option 2: Capacitive Coupling of ATN

Insert the circuit below between the PCÕs DTR output and the BS2Õs ATN input. The series capacitor blocks DTRÕs steady state (as set by a terminal program or other software), but passes the attention/programming pulse sent by the STAMP2 host software. The parallel cap soaks up noise that might be coupled into the line.



Option 3: Switch in ATN

The simplest solution is to break the ATN line and insert a switch to let you conveniently connect and disconnect DTR/ATN. When you want to program the BS2, close the switch; when you want to communicate with some other program, open the switch.



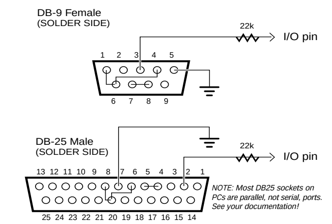
motely reset the BS2 for programming, so it may have to be modified before it can be used with other software; see figure I-17.

The BS2 can also receive RS-232 data through any of its other 16 general-purpose I/O pins (rpin = 0 through 15). The I/O pins don't need a line receiver, just a series resistor (we suggest 22k). The resistor limits current into the I/O pins' built-in clamp diodes, which keep input voltages within a safe range.

Figure I-18 shows the pinouts of the two styles of PC COM ports and how to connect them to the Stamp. The figure also shows loopback connections that defeat hardware handshaking used by some PC software.

Figure I-18

Pinouts for Standard PC COM Port Connectors with Serin Hookup



Function	DB9	DB25
Protective Ground	Ð	1
Transmit Data (TD)	3	2
Receive Data	2	3
Request to Send (RTS)	7	4
Clear to Send (CTS)	8	5
Data Set Ready (DSR)	6	6
Signal Ground (SG)	5	7
Data Carrier Detect (DCD)	1	8
Data Terminal Ready (DTR)	4	20
Ring Indicator (RI)	9	22

NOTE: In the connector drawings above, several handshaking lines are shown connected together: DTR-DSR-DCD and RTS-CTS. This for the benefit of terminal programs that expect hardware handshaking. You may omit these connections if you're using software that doesn't expect handshaking, or if you're writing your own software without handshaking.

Serial Timing and Mode (Baudmode)

Asynchronous serial communication relies on precise timing. Both the sender and receiver must be set for identical timing, usually expressed in bits per second (bps) and called baud.

Serin accepts a 16-bit value called *baudmode* that tells it the important characteristics of the incoming serial data—the bit period, data and parity bits, and polarity. Figure I-19 shows how baudmode is calculated and table I-3 shows common baudmodes for standard serial baud rates.

If you're communicating with existing software, its speed(s) and mode(s) will determine your choice of baud rate and mode. In general, 7-bit/even-parity (7E) mode is used for text, and 8-bit/no-parity (8N) for byte-oriented data. Parity can detect some communication errors, but to use it you lose one data bit. This means that incoming data bytes transferred in 7E mode can only represent values from 0 to 127, rather than the 0 to 255 of 8N mode.

Table I-3

Common Data Rates and Corresponding Baudmode Values

Data Speed	Direct Connection (Inverted)		Through Line Driver (Noninverted)	
Baud Rate	8 data bits, no parity	7 data bits, even parity	8 data bits, no parity	7 data bits, even parity
300	19697	27889	3313	11505
600	18030	26222	1646	9838
1200	17197	25389	813	9005
2400	16780	24972	396	8588
4800	16572	24764	188	8380
9600	16468	24660	84	8276
19200	16416	24608	32	8224
38400	16390	24582	6	8198

Note: If the dedicated serial port (rpin = 16) is used, all data is inverted regardless of the baudmode setting.

Simple Input and Numeric Conversions

Stripped to just the essentials, Serin can be as simple as:

```
Serin rpin,baudmode,[inputData]
```

For example, to receive a byte through pin 1 at 9600 bps, 8N, inverted:

```
serData     var     byte
Serin 1,16468,[serData]
```

Serin would wait for and receive a single byte of data through pin 1 and store it in the variable serData. If the Stamp were connected to a PC running a terminal program set to the same baud rate and the user pressed the A key on the keyboard, after Serin the variable serData would contain 65, the ASCII code for the letter A. (See the ASCII character chart in the appendix.) If you wanted to let the user enter a decimal number at the keyboard and put that value into serData, the appropriate Serin would be:

```
serData     var     byte
Serin 1,16468,[DEC serData]
```

The DEC modifier tells Serin to convert decimal numeric text into binary form and store the result in serData. Receiving "123" followed by a space or other non-numeric text results in the value 123 being stored in

Table I-4 Numeric Conversion Modifiers Used by Serin

Modifier	Type of Number	Numeric Characters	Notes
DEC	Decimal	0,1,2,3,4,5,6,7,8,9	1
DEC1 - DEC5	1 to 5 digit decimal	0,1,2,3,4,5,6,7,8,9	1
SDEC	Signed decimal	0,1,2,3,4,5,6,7,8,9,-	1,2
SDEC1 - SDEC5	1 to 5 digit signed decimal	0,1,2,3,4,5,6,7,8,9,-	1,2
HEX	Hexadecimal (hex)	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F	1,3
HEX1 - HEX4	1 to 4 digit hexadecimal	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F	1,3
SHEX	Signed hexadecimal	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F	1,2,3
SHEX1 - SHEX4	1 to 4 digit signed hexadecimal	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,-	1,2,3
IHEX	Indicated hexadecimal	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,$	1,3,4
ISHEX	Indicated signed hexadecimal	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,$,-	1,2,3,4
ISHEX1 - ISHEX4	1 to 4 digit indicated signed hex	0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F,$,-	1,2,3,4
BIN	Binary	0,1	1
BIN1 - BIN16	1 to 16 digit binary	0,1	1
SBIN	Signed binary	0,1,-	1,2
SBIN1 - SBIN16	1 to 16 digit signed binary	0,1,-	1,2
IBIN	Indicated binary	0,1,%	1,4
IBIN1 - IBIN16	1 to 16 digit indicated binary	0,1,%	1,4
ISBIN	Indicated signed binary	0,1,%,-	2,4
ISBIN1 - ISBIN16	1 to 16 digit indicated signed binary	0,1,%,-	2,4

NOTES:

(1) All numeric conversions will continue to accept new data until receiving either the specified number of digits (e.g., three digits for DEC3) or a non-numeric character.

(2) To be recognized as part of a number, the minus sign (-) must immediately precede a numeric character. The - character occurring in non-numeric text is ignored, and any character (including a space) between a minus and a number causes the minus to be ignored.

(3) The hex modifiers are not case-sensitive; "a" through "f" may be substituted for "A" through "F."

(4) Indicated hex and binary modifiers ignore all characters, even valid numerics, until they receive the appropriate prefix ($ for hex, % for binary). The indicated modifiers can differentiate between text and hex numbers (e.g., "ABC" would be interpreted by HEX as a number; IHEX would ignore it unless expressed as $ABC). Likewise, the binary version can distinguish the decimal number "10" from the binary number "%10." A prefix occurring in non-numeric text is ignored, and any character (including a space) between a prefix and a number causes the prefix to be ignored. Indicated-signed modifiers require that the minus sign come before the prefix, as in "-$1B45."

serData. DEC is one of a family of conversion modifiers available with Serin; see table I-4 for a list. All of the conversion modifiers work similarly: they receive bytes of data, waiting for the first byte that falls within the range of symbols they accept (e.g., “0” or “1” for binary, “0” to “9” for decimal, “0” to “9” and “A” to “F” for hex, and “+” or “-” for signed variations of any type). Once they receive a numeric symbol, they keep accepting input until a non-numeric symbol arrives or (in the case of the fixed length modifiers) the maximum specified number of digits arrives.

While very effective at filtering and converting input text, the modifiers aren't completely foolproof. For instance, in the example above, Serin would keep accepting text until the first non-numeric text arrived—even if the resulting value exceeded the size of the variable. After Serin, a byte variable would contain the lowest 8 bits of the value entered; a word would contain the lowest 16 bits. You can control this to some degree by using a modifier that specifies the number of digits, such as DEC2, which would accept values only in the range of 0 to 99.

Figure I-19

Calculating Baudmode for BS2 Serin

Step 1: Figure the Bit Period (bits 0Ñ12)

Bits 0 through 12 of the baudmode are the bit period, expressed in microseconds (µs). SerinÕs actual bit period is always 20µs longer than specified. Use the following formula to calculate the baudmode bit period for a given baud rate:

$$\mathrm{INT}\left(\frac{1{,}000{,}000}{\text{baud rate}}\right) Ð\ 20$$

(INT means 'convert to integer;' drop the numbers to the right of the decimal point.)

Step 2: Set Data Bits and Parity (bit 13)

Bit 13 lets you select one of two combinations of data bits and parity:

0 = 8 bits, no parity
8192 = 7 bits, even parity

Step 3: Select the Polarity of Serial Input (bit 14)

Bit 14 tells Serin whether the data is inverted (as when it comes directly from a standard COM port) or noninverted (after passing through a line receiver):

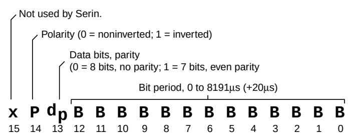
0 = noninverted
16384 = inverted

Add your choice to the sum of steps 1 and 2. The result is the correct serial baudmode for use by Serin.

Serin through pin 16 (SIN) is always inverted, regardless of the polarity setting. However, polarity will still affect fpin, if used.

FYI: Bit Map of Serin Baudmode

If youÕre more comfortable thinking in terms of bits, hereÕs a bit map of SerinÕs baudmode:



Collecting Strings

Serin can grab sequences of incoming bytes and store them in array variables using the STR modifier. See table I-5. Here is an example that receives nine bytes through pin 1 at 2400 bps, N81/inverted and stores them in a 10-byte array:

```
serString   var   byte(10)                    ' Make a 10-byte array.
serString(9) = 0                              ' Put 0 in last byte.
SERIN 1,16780,[STR serString\9]               ' Get 9-byte string.
debug str serString                           ' Display the string.
```

Why store only 9 bytes in a 10-byte array? We want to reserve space for the 0 byte that many BS2 string-handling routines regard as an end-of-string marker. This becomes important when dealing with variable-length arrays. For example, the STR modifier can accept a second parameter telling it to end the string when a particular byte is received, or when the specified length is reached, whichever comes first. An example:

Table I-5. String Collection and Sequence Matching Modifiers Used By Serin

Modifier	Action
STR bytearray \L {\E}	Input a string of length L into an array. If specified, an end character E causes the string input to end before reaching length L. Remaining bytes are filled with 0s (zeros).
WAIT (value, value,...) WAIT ("text")	Wait for a sequence of bytes, which may be expressed as a quoted text string, up to six bytes (characters) long.
WAITSTR bytearray	Wait for a sequence of bytes matching a string stored in an array. The end of the array-string is marked by a byte containing 0 (zero).
SKIP L	Ignore L bytes of serial input.

```
serString   var   byte(10)                 ' Make a 10-byte array.
serString(9) = 0                           ' Put 0 in last byte.
SERIN 1,16780,[STR serString\9\"*"]        ' Stop at "*" or 9 bytes.
debug str serString                        ' Display the string.
```


If the serial input were “hello*” Debug would display “hello” since it collects bytes up to (but not including) the end character. It fills the unused bytes up to the specified length with 0s. Debug’s normal STR modifier understands a 0 to mean end-of-string. However, if you use Debug’s fixed-length string modifier STR bytearray\n you will inadvertently clear the Debug screen. The fixed-length specification forces Debug to read and process the 0s at the end of the string, and 0 is equivalent to Debug’s CLS (clear-screen) instruction! Be alert for the consequences of mixing fixed- and variable-length string operations.

Matching a Sequence

Serin can compare incoming data with a predefined sequence of bytes using the Wait modifiers. The simplest form waits for a sequence of up to six bytes specified as part of the inputData list, like so:

```
SERIN 1,16780,[WAIT ("SESAME")]            'Wait for word SESAME.
debug "Password accepted"
```

Serin will wait for that word, and the program will not continue until it is received. Since Wait is looking for an exact match for a sequence of bytes, it is case-sensitive—“sesame” or “SESAmE” or any other variation from “SESAME” would be ignored.

There are also Waitstr modifiers, which wait for a sequence that matches a string stored in an array variable. In the example below, we'll capture a string with STR then have Waitstr look for an exact match:

```
serString      var        byte(10)             ' Make a 10-byte array.
serString(9) = 0                               ' Put 0 in last byte.
debug "Enter password ending in !",cr
serin 1,16780,[str serString\9\"!"]            ' Get the string.
debug "Waiting for: ",str serString,cr
SERIN 1,16780,[WAITSTR serString]              ' Wait for a match.
debug "Password accepted.",cr
```

You can also use WAITSTR with fixed-length strings as in the following example:

```
serString      var        byte(4)              ' Make a 4-byte array.
debug "Enter 4-character password",cr
serin 1,16780,[str serString\4]                ' Get a 4-byte string.
debug "Waiting for: ",str serString\4,cr
serin 1,16780,[WAITSTR serString\4]            ' Wait for a match.
debug "Password accepted.",cr
```

Building Compound InputData Statements

Serin's inputData can be structured as a list of actions to perform on the incoming data. This allows you to process incoming data in powerful ways. For example, suppose you have a serial stream that contains "pos: xxxx yyyy" (where xxxx and yyyy are 4-digit numbers) and you want to capture just the decimal y value. The following Serin would do the trick:

```
yOffset        var        word
serin 1,16780,[wait ("pos: "), SKIP 4, dec yOffset]
debug ? yOffset
```

The items of the inputData list work together to locate the label "pos: ", skip over the four-byte x data, then convert and capture the decimal y data. This sequence assumes that the x data is always four digits long; if its length varies, the following code would be more appropriate:

```
yOffset        var        word
serin 1,16780,[wait ("pos: "), dec yOffset, dec yOffset]
debug ? yOffset
```

The unwanted x data is stored in yOffset, then replaced by the desired y data. This is a sneaky way to filter out a number of any size without using an extra variable. With a little creativity, you can combine the inputData modifiers to filter and extract almost any data.

Using Parity and Handling Parity Errors

Parity is an error-checking feature. When a serial sender is set for even parity—the mode the BS2 supports—it counts the number of 1s in an outgoing byte and uses the parity bit to make that number even. For instance, if it is sending the seven bits %0011010, it sets the parity bit to 1 in order to make an even number of 1s (four).

The receiver also counts up the data bits to calculate what the parity bit should be. If it matches the parity bit received, the serial receiver assumes that the data was received correctly. Of course, this is not necessarily true, since two incorrectly received bits could make parity seem correct when the data was wrong, or the parity bit itself could be bad when the rest of the data was OK.

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Many systems that work exclusively with text use (or can be set for) 7-bit / even-parity mode. Table I-3 shows appropriate baudmode settings. For example, to receive one data byte through pin 1 at 2400 baud, 7E, inverted:

```
serData         var             byte
Serin  1,24972,[serData]
```

That instruction will work, but it doesn't tell the BS2 what to do in the event of a parity error. Here's an improved version that uses the optional *plabel*:

```
serData         var             byte
  serin  1,24972,badData,[serData]
  debug ? serData
Stop

badData:
  debug "parity error"
```

If the parity matches, the program continues at the Debug instruction after Serin. If the parity doesn't match, the program goes to the label badData. Note that a parity error takes precedence over other inputData specifications; as soon as an error is detected, Serin aborts and goes to the *plabel* routine.

Setting a Serial Timeout

In the examples above, the only way to end the Serin instruction (other than RESET or power-off) is to give Serin the serial data it wants. If no serial data arrives, the program is stuck. However, you can tell the BS2 to abort Serin if it doesn't receive data within a specified number of milliseconds. For instance, to receive a decimal number through pin 1 at 2400 baud, 8N, inverted and abort Serin after 2 seconds (2000 ms) if no data arrives:

```
serin 1,16780,2000,noData,[DEC w1]
debug cls, ? w1
stop

noData:
  debug cls, "timed out"
```

If no data arrives within 2 seconds, the program aborts Serin and continues at the label noData. This timeout feature is not picky about the kind of data Serin receives; *any* serial data stops the timeout. In the example above, Serin wants a decimal number. But even if Serin received letters "ABCD..." at intervals of less than two seconds, it would not abort.

Combining Parity and Timeout

You can combine parity and serial timeouts. Here is an example designed to receive a decimal number through pin 1 at 2400 baud, 7E, inverted with a 10-second timeout:

```
again:
  serin 1,24972,badData,10000,noData,[DEC w1]
  debug cls, ? w1
goto again

noData:
  debug cls, "timed out"
goto again

      badData:
        debug cls, "parity error"
      goto again
```

Controlling Data Flow

When you design an application that requires serial communication between BS2s, you have to work within these limitations:

- When the BS2 is sending or receiving data, it can't execute other instructions.
- When the BS2 is executing other instructions, it can't send or receive data.
- The BS2 executes 3000 to 4000 instructions per second and there is not serial buffer in the BS2 as there is in PCs. At most serial rates, the BS2 cannot receive data via Serin, process it, and execute another Serin in time to catch the next chunk of data, unless there are significant pauses between data transmissions.

These limitations can be addressed by using flow control; the *fpin* option for Serin and Serout (at baud rates of up to 19200). Through *fpin*, Serin can tell a BS2 sender when it is ready to receive data. (For that matter, fpin flow control follows the rules of other serial handshaking schemes, but most computers other than the BS2 cannot start and stop serial transmission on a byte-by-byte basis. That's why this discussion is limited to BS2-to-BS2 communication.)

Here's an example of a flow-control Serin (data through pin 1, flow control through pin 0, 9600 baud, N8, noninverted):

```
serData     var     byte
Serin  1\0,84,[serData]
```

When Serin executes, pin 1 (rpin) is made an input in preparation for incoming data, and pin 0 (fpin) is made output low to signal "go" to the sender. After Serin finishes receiving, pin 0 goes high to tell the sender to stop. If an inverted baudmode had been specified, the fpin's repsonses would have been reversed. Here's the relationship of serial polarity to fpin states.

	Go	Stop
Inverted	1	0
Noninverted	0	1

Here's an example that demonstrates fpin flow control. It assumes that two BS2s are powered up and connected together as shown in figure I-20.

```
' SENDER: data out pin 1, flow control pin 0
' Baudmode: 9600 N8 inverted
Serout  1\0,16468,["HELLO!"]                    ' Send the greeting.

' RECEIVER: data in pin 1, flow control pin 0
' Baudmode: 9600 N8 inverted
letta   var   byte
again:
  Serin 1\0,16468,[letta]                       ' Get 1 byte.
  debug letta                                   ' Display on screen.
  pause 1000                                    ' Wait a second.
goto again
```

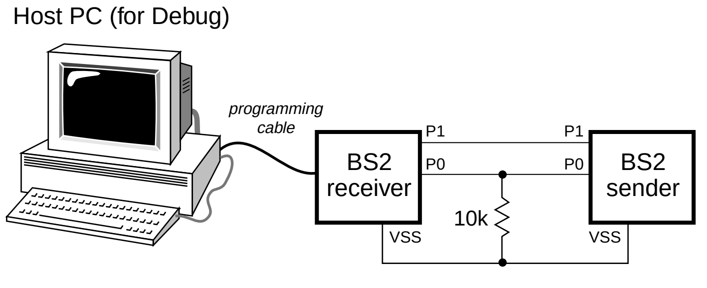
Without flow control, the sender would transmit the whole word "HELLO!" in about 6ms. The receiver would catch the first byte at most; by the time it got back from the first 1-second Pause, the rest of the data would be long gone. With flow control, communication is flawless since the sender waits for the receiver to catch up.

In figure I-20, pin 0, fpin, is pulled to ground through a 10k resistor. This is to ensure that the sender sees a stop signal (0 for inverted comms) when the receiver is being programmed.

Demo Program

See the examples above.

Figure I-20



Serout

SEROUT ***tpin,baudmode,{pace,}[outputData]***
SEROUT ***tpin\fpin,baudmode,{timeout,tlabel,}[outputData]***
Transmit asynchronous (e.g., RS-232) data.

- ***Tpin*** is a variable/constant (0–16) that specifies the I/O pin through which the serial data will be sent. This pin will switch to output mode and will remain in that state after the instruction is completed. If Tpin is set to 16, the Stamp uses the dedicated serial-output pin (SOUT), normally used by the STAMP2 host program.

- ***Baudmode*** is a 16-bit variable/constant that specifies serial timing and configuration. The lower 13 bits are interpreted as the bit period minus 20µs. Bit 13 ($2000 hex) is a flag that controls the number of data bits and parity (0=8 bits and no parity, 1=7 bits and even parity). Bit 14 ($4000 hex) controls the bit polarity (0=noninverted, 1=inverted). Bit 15 ($8000 hex) determines whether the pin is driven to both states (0/1) or to one state and open in the other (0=both driven, 1=open).

- ***Pace*** is an optional variable/constant (0–65535) that tells Serout how long in milliseconds it should pause between transmitting bytes.

- ***OutputData*** is a list of variables, constants and modifiers that tells Serout how to format outgoing data. Serout can transmit individual or repeating bytes; convert values into decimal, hex or binary text representations; or transmit strings of bytes from variable arrays.

- ***Fpin*** is an optional variable/constant (0–15) that specifies the I/O pin to be used for flow control (byte-by-byte handshaking). This pin will switch to input mode and remain in that state after the instruction is completed.

- ***Timeout*** is an optional variable/constant (0–65535) used in conjunction with *fpin* flow control. Timeout tells Serout how long in milliseconds to wait for *fpin* permission to send. If permission does not arrive in time, the program will continue at tlabel.

- ***Tlabel*** is an optional label used with *fpin* flow control and *timeout*. Tlabel indicates where the program should go in the event that

2

permission to transmit data is not granted within the period specified by *timeout*.

Explanation

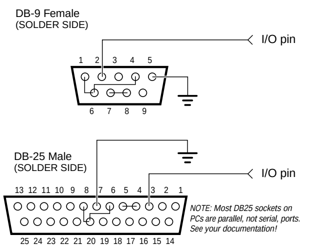
The BS2 can send and receive asynchronous serial data at speeds up to 50,000 bits per second. Serout, the serial-output instruction, can convert and format outgoing data in powerful ways. With all this power inevitably comes some complexity, which we'll overcome by walking you through the process of setting up Serout and understanding its options. For more information on serial-communication fundamentals, see the Serin listing.

Physical/Electrical Interface

The BS2 can transmit data serially through any of its I/O pins (tpin = 0—15) or through the SOUT pin (tpin = 16) that goes to the DB9 programming connector on BS2 carrier boards. Most common serial devices use the RS-232 standard in which a 1 is represented by –12V and a 0 by +12V. Serout through the I/O pins is limited to logic-level voltages of 0V and +5V; however, most RS-232 devices are designed with sufficient leeway to accept logic-level Serout transmissions, provided that they are inverted (see Serial Timing and Mode below).

Figure I-21

Pinouts for Standard PC COM Port Connectors with Serout Hookup



Function	DB9	DB25
Protective Ground	Ð	1
Transmit Data (TD)	3	2
Receive Data	2	3
Request to Send (RTS)	7	4
Clear to Send (CTS)	8	5
Data Set Ready (DSR)	6	6
Signal Ground (SG)	5	7
Data Carrier Detect (DCD)	1	8
Data Terminal Ready (DTR)	4	20
Ring Indicator (RI)	9	22

NOTE: In the connector drawings above, several handshaking lines are shown connected together: DTR-DSR-DCD and RTS-CTS. This for the benefit of terminal programs that expect hardware handshaking. You may omit these connections if you're using software that doesn't expect handshaking, or if you're writing your own software without handshaking.

Figure I-21 shows the pinouts of the two styles of PC com ports and how to connect them to receive data sent by Serout through pins 0—15. The figure also shows loopback connections that defeat hardware handshaking used by some PC software.

The SOUT pin can comply with the RS-232 electrical standard by stealing the negative signal voltage from an RS-232 input at SIN. See the BS2 hardware description and schematic. In order for SOUT to work at the proper voltage levels, there must be an RS-232 output signal connected to SIN, and that signal must be quiet (not transmitting data) when data is being sent through SOUT.

For more information on using the carrier-board DB9 connector for serial communication, see the Serin listing and figure I-17.

Serial Timing and Mode (Baudmode)

Asynchronous serial communication relies on precise timing. Both the sender and receiver must be set for identical timing, usually expressed in bits per second (bps) and called baud.

Serout accepts a single 16-bit value called *baudmode* that specifies important characteristics of the serial transmission—the bit time, data and parity bits, polarity, and drive. Figure I-22 shows how Serout baudmode is calculated and table I-6 shows common baudmodes for standard serial baud rates.

If you're communicating with existing software, its speed(s) and mode(s) will determine your choice of baud rate and mode. In general, 7-bit / even-parity (7E) mode is used for text, and 8-bit / no-parity (8N) for byte-oriented data. Parity can detect some communication errors, but to use it you lose one data bit. This means that incoming data bytes transferred in 7E mode can only represent values from 0 to 127, rather

Figure I-22

Calculating Baudmode for BS2 Serout

Step 1: Calculate the Bit Period (bits 0Ñ12)

Bits 0 through 12 of the baudmode are the bit period, expressed in microseconds (µs). SeroutÕs actual bit period is always 20µs longer than specified. Use the following formula to calculate the baudmode bit period for a given baud rate:

$$\mathrm{INT}\left(\frac{1{,}000{,}000}{\text{baud rate}}\right) \text{ Ð } 20$$

(INT means 'convert to integer;' drop the numbers to the right of the decimal point.)

Step 2: Set Data Bits and Parity (bit 13)

Bit 13 lets you select one of two combinations of data bits and parity:

0 = 8 bits, no parity
8192 = 7 bits, even parity

Step 3: Select the Polarity of Serial Output (bit 14)

Bit 14 tells Serout whether the data should be inverted (as when sent directly to a standard COM port) or noninverted (to pass through a line driver):

0 = noninverted
16384 = inverted

Serout through pin 16 (SOUT) is always inverted, regardless of the polarity setting. However, polarity will still affect fpin, if used.

Step 4: Set Driven or Open Output (bit 15)

Bit 15 tells Serout whether to drive the output in both states (0 and 1), or drive to one state and leave open in the other. If you select open, the state that is driven is determined by polarity: with inverted polarity open modes drive to +5V only; noninverted open modes drive to ground (0V) only. Bit settings:

0 = driven
32768 = open

Add your choice to the sum of steps 1 through 3. The result is the correct serial baudmode for use by Serout.

FYI: Bit Map of Serout Baudmode

If youÕre more comfortable thinking in terms of bits, hereÕs a bit map of SeroutÕs baudmode:

Driven/open (0=driven; 1=open)
Polarity (0 = noninverted; 1 = inverted)
Data bits, parity (0 = 8 bits, no parity; 1 = 7 bits, even parity
Bit period, 0 to 8191µs (+20µs)

D	P	dp	B	B	B	B	B	B	B	B	B	B	B	B	B
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Table I-6
Common Data Rates and Corresponding Baudmode Values

Data Speed	Direct Connection (Inverted)		Through Line Driver (Noninverted)	
Baud Rate	8 data bits, no parity	7 data bits, even parity	8 data bits, no parity	7 data bits, even parity
300	19697	27889	3313	11505
600	18030	26222	1646	9838
1200	17197	25389	813	9005
2400	16780	24972	396	8588
4800	16572	24764	188	8380
9600	16468	24660	84	8276
19200	16416	24608	32	8224
38400	16390	24582	6	8198

Note: For "open" baudmodes used in networking, add 32768 to values from the table above. If the dedicated serial port (tpin=16) is used, the data is inverted and driven regardless of the baudmode setting.

than the 0 to 255 of 8E mode.

Serout's "open" baudmodes are used only in special circumstances, usually networking applications. See the Network example below.

Simple Output and Numeric Conversions

Stripped to just the essentials, Serout can be as simple as:

```
Serout  tpin,baudmode,[outputData]
```

For example, to send a byte through pin 1 at 9600 bps, 8N, inverted:

```
Serout 1,16468,[65]                    ' Send byte value 65 ("A") through pin 1.
```

When that Serout executes, it changes pin 1 to output and transmits the byte value 65 (%01000001 binary). If a PC terminal program was the receiver, the letter A would appear on the screen, since 65 is the ASCII code for A. (See the ASCII character chart in the appendix.) To send a number as text requires a modifier, as in this example:

```
Serout 1,16468,[DEC 65]                ' Send text "65" through pin 1.
```

The modifier DEC tells Serout to convert the value to its decimal-text equivalent before transmitting. Table I-7 lists the numeric-conversion modifiers that Serout understands. You can try these modifiers using Debug (which is actually just a special case of Serout configured specifically to send data to the STAMP2 host program).

Literal Text and Compound OutputData

Serout sends quoted text exactly as it appears in the outputData list:

```
Serout 1,16468,["A"]                    ' Send byte value 65 ("A").
Serout 1,16468,["HELLO"]                ' Send series of bytes, "HELLO".
```

Since outputData is a list, you may combine modifiers, values, text, strings and so on separated by commas:

```
temp  var  byte
temp = 96
Serout 1,16468,["Temperature is ", dec temp, " degrees F."]
```

Serout would send "Temperature is 96 degrees F."

Sending Variable Strings

A string is a byte array used to store variable-length text. Because the number of bytes can vary, strings require either an end-of-string marker (usually the ASCII null character—a byte with all bits cleared to 0) or a variable representing the string's length. PBASIC2 modifiers (shown in Table I-8) for Serout supports both kinds of strings. Here's an example of a null-terminated string:

```
myText  var  byte(10)                   ' An array to hold the string.

myText(0) = "H":myText(1) = "E"         ' Store "HELLO" in 1st 5 cells...
myText(2) = "L":myText(3) = "L"
myText(4) = "0":myText(5) = 0           ' Put null (0) after last character.

Serout 1,16468,[STR myText]             ' Send "HELLO"
```

The other type of string—called a counted string—requires a variable to hold the string length. In most other BASICs, the 0th element of the byte array contains this value. Because PBASIC2 outputs the 0th array element, this is not the best way. It makes more sense to put the count in a

Table I-7. Numeric Conversion Modifiers Used by Serout

Modifier	Effect	Notes
ASC?	ASCII value with equivalent character; e.g., 65 = "A"	
DEC	Decimal text	
DEC1 - DEC5	1 to 5 digit decimal text	1
SDEC	Signed decimal text	2
SDEC1 - SDEC5	1 to 5 digit signed decimal text	1,2
HEX	Hexadecimal (hex) text	
HEX1 - HEX4	1 to 4 digit hexadecimal text	1
SHEX	Signed hexadecimal text	2
SHEX1 - SHEX4	1 to 4 digit signed hexadecimal text	1,2
IHEX	Indicated hexadecimal text ($ prefix; e.g., $7A3	
ISHEX	Indicated signed hexadecimal text	2
ISHEX1 - ISHEX4	1 to 4 digit indicated signed hexidecimal text	1,2
BIN	Binary text	
BIN1 - BIN16	1 to 16 digit binary text	1
SBIN	Signed binary text	2
SBIN1 - SBIN16	1 to 16 digit signed binary text	1,2
IBIN	Indicated binary text (% prefix; e.g., %10101100)	
IBIN1 - IBIN16	1 to 16 digit indicated binary text	1
ISBIN	Indicated signed binary text	2
ISBIN1 - ISBIN16	1 to 16 digit indicated signed binary text	1,2

NOTES:

(1) Fixed-digit modifiers like DEC4 will pad text with leading 0s if necessary; e.g., DEC4 65 sends 0065. If a number is larger than the specified number of digits, the leading digits will be dropped; e.g., DEC4 56422 sends 6422.

(2) Signed modifiers work under two's complement rules, same as PBASIC2 math.

separate variable, or in the last element of the array, as in this example:

```
myText   var   byte(10)                      ' An array to hold the string.

myText(0) = "H":myText(1) = "E"              ' Store "HELLO" in first 5 cells...
myText(2) = "L":myText(3) = "L"
myText(4) = "0":myText(9) = 5                ' Put length (5) in last cell.

Serout 1,16468,[STR myText\myText(9)]        ' Send "HELLO"
```

Note that Serout's string capabilities work only with strings in RAM, not EEPROM. To send a string from EEPROM you must either (1) Read it byte-by-byte into an array then output it using one of the STR modifiers,

Table I-8. String Modifiers Used by Serout

Modifier	Action
STR bytearray	Send a string from bytearray until byte = 0.
STR bytearray\n	Send a string consisting of n bytes from bytearray.
REP byte\n	Send a string consisting of byte repeated n times (e.g., REP "X"\10 sends XXXXXXXXXX).

or (2) Read and output one byte at a time. Since either approach requires Reading individual bytes, method (2) would be simpler. The demo program for the Read instruction gives an example; making it work with Serout requires changing Debug...


```
  debug char                          ' Show character on screen.
...to Serout, as in this example:
  Serout 1,16468,[char]               ' Send the character.
```

If you have just a few EEPROM strings and don't need to manipulate them at runtime, the simplest method of all is to use separate Serouts containing literal text, as shown in the previous section.

Using the Pacing Option and a Serout/Debug Trick

Serout allows you to *pace* your serial transmission by inserting a time delay of 1 to 65535 ms between bytes. Put the pacing value between the baudmode and the outputData list, like so:

```
Serout 1,16468,1000,["Slowly"]        ' 1-sec delay between charac-
ters.
```

Suppose you want to preview the effect of that 1-second pacing without the trouble of booting terminal software and wiring a connector. You can use the BS2 Debug window as a receive-only terminal. Tell Serout to send the data through pin 16 (the programming connector) at 9600 baud:

```
Debug cls                             ' Open a cleared Debug window.
Serout 16,84,1000,["Slowly"]          '
Serout to Debug screen.
```

Controlling Data Flow

In all of the examples above, Serout sent the specified data without checking to see whether the receiving device was ready for it. If the receiver wasn't ready, the data was sent anyway, and lost.

With flow control, the serial receiver can tell Serout when to send data. BS2 flow control works on a byte-by-byte basis; no matter how many bytes Serout is supposed to send, it will look for permission to send before each byte. If permission is denied, Serout will wait until it is granted.

By *permission* we mean the appropriate state of the flow-control pin—fpin—specified in the Serout instruction. The logic of *fpin* depends on whether an inverted or non-inverted baudmode is specified:

	Go	Stop
Inverted	1	0
Noninverted	0	1

Here's an example that demonstrates *fpin* flow control. It assumes that two BS2s are powered up and connected together as shown in figure I-20.

```
' SENDER: data out pin 1, flow control pin 0
' Baudmode: 9600 N8 inverted
Serout  1\0,16468,["HELLO!"]                                        '
Send the greeting.

' RECEIVER: data in pin 1, flow control pin 0
' Baudmode: 9600 N8 inverted
letta         var          byte
again:
  Serin 1\0,16468,[letta]                  ' Get 1 byte.
  debug letta                              ' Display on screen.
  pause 1000                               ' Wait a second.
goto again
```

Without flow control, the sender would transmit the whole word "HELLO!" in about 6ms. The receiver would catch the first byte at most; by the time it got back from the first 1-second Pause, the rest of the data would be long gone. With flow control, communication is flawless since the sender waits for the receiver to catch up.

In figure I-20, pin 0, fpin, is pulled to ground through a 10k resistor. This is to ensure that the sender sees a stop signal (0 for inverted comms) when the receiver is being programmed.

Flow-control Timeout

Flow control solves one problem but can create another—if the receiver isn't connected, Serout may never get permission to send. The program will be stuck in Serout indefinitely. To prevent this, Serout allows you to specify how long it should wait for permission, from 0 to 65535 ms. If the specified time passes without permission to send, Serout aborts, allowing the program to continue at *tlabel*. Here's the previous example (just the Sender code) with a 2.5-second timeout:

```
Serout 1\0,16468,2500,noFlow["HELLO!"]
' ...instructions executed after a successful Serout
stop

noFlow:
' If Serout times-out waiting for flow-control permission,
' It jumps to this label in the program.
```

Networking with Open Baudmodes

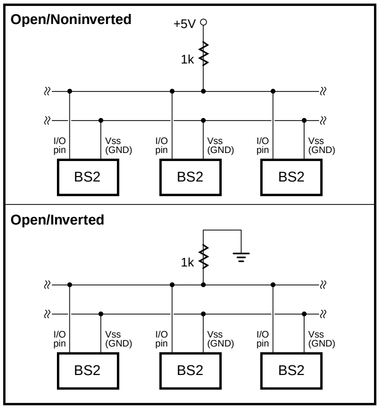
The open baudmodes can be used to connect multiple BS2s to a single pair of wires to create a party-line network. Open baudmodes only actively drive the Serout pin in one state; in the other state they disconnect the pin. If BS2s in a network used the always-driven baudmodes, two BS2s could simultaneously output opposite states. This would create a short circuit from +5V to ground through the output drivers of the BS2s. The heavy current flow would likely damage the BS2s (and it would certainly prevent communication). Since the open baudmodes only drive in one state and float in the other, there's no chance of this kind of short.

The polarity selected for Serout determines which state is driven and which is open, as follows:

	— Polarity —		Resistor
State	**Inverted**	**Noninverted**	**Pulled to**
0	open	driven	GND
1	driven	open	+5V

Since open baudmodes only drive to one state, they need a resistor to pull the network into the other state, as shown in the table above and in figure I-23.

Figure I-23

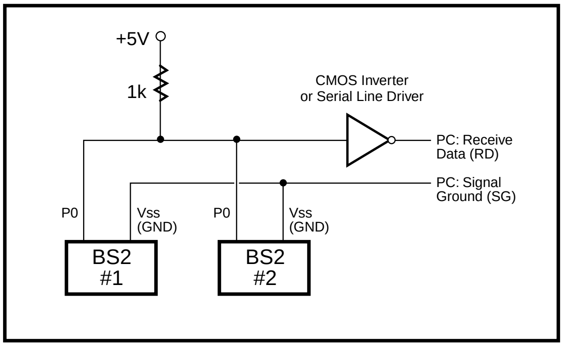


Open baudmodes allow the BS2s to share a party line, but it is up to your program to resolve other networking issues, like who talks when and how to prevent, detect and fix data errors. In the example shown in figure I-24 and the program listings below, two BS2s share a party line. They monitor the serial line for a specific cue ("ping" or "pong"), then transmit data. A PC may monitor net activity via a line driver or CMOS inverter as shown in the figure.

```
' Net #1: This BS2 sends the word "ping" followed by a linefeed
' and carriage return (for the sake of a monitoring PC). It
' then waits to hear the word "pong" (plus LF/CR), pauses
' 2 seconds, then loops.
b_mode   con   32852                    ' Baudmode: 9600 noninverted, open,
8N

again:
  serout 0,b_mode,["ping",10,13]
  serin 0,b_mode,[wait ("pong",10,13)]
  pause 2000
goto again
```

Figure I-24



```
' Net #2: This BS2 waits for the word "ping" (plus LF/CR)
' then pauses 2 seconds and sends the word "pong" (LF/CR)
' and loops.

b_mode   con   32852                          ' Baudmode: 9600 noninverted, open,
8N

again:
  serin 0,b_mode,[wait ("ping",10,13)]
  pause 2000
  serout 0,b_mode,["pong",10,13]
goto again
```

The result of the two programs is that a monitoring PC would see the words “ping” and “pong” appear on the screen at 2-second intervals, showing that the pair of BS2s is sending and receiving on the same lines. This arrangement could be expanded to dozens of BS2s with the right programming.

Demo Program

See the examples above.

Shiftin

SHIFTIN ***dpin,cpin,mode,[result{\bits}{,result{\bits}...}]***

Shift data in from a synchronous-serial device.

- ***Dpin*** is a variable / constant (0–15) that specifies the I / O pin that will be connected to the synchronous-serial device's data output. This pin's I / O direction will be changed to input and will remain in that state after the instruction is completed.

- ***Cpin*** is a variable / constant (0–15) that specifies the I / O pin that will be connected to the synchronous-serial device's clock input. This pin's I / O direction will be changed to output.

- ***Mode*** is a value (0—3) or 4 predefined symbols that tells Shiftin the order in which data bits are to be arranged and the relationship of clock pulses to valid data. Here are the symbols, values, and their meanings:

Symbol	Value	Meaning
MSBPRE	0	Data msb-first; sample bits before clock pulse
LSBPRE	1	Data lsb-first; sample bits before clock pulse
MSBPOST	2	Data msb-first; sample bits after clock pulse
LSBPOST	3	Data lsb-first; sample bits after clock pulse

  (Msb is most-significant bit; the highest or leftmost bit of a nibble, byte, or word. Lsb is the least-significant bit; the lowest or rightmost bit of a nibble, byte, or word.)

- ***Result*** is a bit, nibble, byte, or word variable in which incoming data bits will be stored.

- ***Bits*** is an optional entry specifying how many bits (1—16) are to be input by Shiftin. If no *bits* entry is given, Shiftin defaults to 8 bits.

Explanation

Shiftin provides an easy method of acquiring data from synchronous-serial devices. Synchronous serial differs from asynchronous serial (like Serin and Serout) in that the timing of data bits is specified in relationship to pulses on a clock line. Data bits may be valid after the rising or falling edge of the clock line. This kind of serial protocol is commonly used by controller peripherals like ADCs, DACs, clocks, memory devices, etc. Trade names for synchronous-serial protocols include SPI and Microwire.

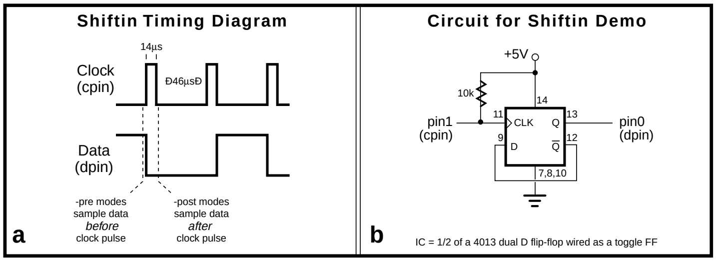
At their heart, synchronous-serial devices are essentially shift-registers—trains of flip-flops that pass data bits along in a bucket-brigade fashion to a single data-output pin. Another bit is output each time the appropriate edge (rising or falling, depending on the device) appears on the clock line. BS2 application note #2 explains shift-register operation in detail.

A single Shiftin instruction causes the following sequence of events:

Makes the clock pin (cpin) output low.
Makes the data pin (dpin) an input.
Copies the state of the data bit into the msb (lsb- modes) or lsb (msb- modes) either before (-pre modes) or after (-post modes) the clock pulse.
Pulses the clock pin high for 14µs.
Shifts the bits of the *result* left (msb- modes) or right (lsb-modes).
Repeats the appropriate sequence of getting data bits, pulsing the clock pin, and shifting the *result* until the specified number of bits is shifted into the variable.

Making Shiftin work with a particular device is a matter of matching the mode and number of bits to that device's protocol. Most manufacturers use a timing diagram to illustrate the relationship of clock and data. Figure I-25a shows Shiftin's timing. For instance, we can use Shiftin to acquire the bits generated by a toggle flip-flop, as shown in figure I-25b. This makes a good example because we know exactly what data this will give us; each bit will be the inverse of the previous one. If the first bit

Figure I-25



is 1, the sequence will be 10101010101... Connect the flip-flop as shown in figure I-25b and run the following program:

```
setup:
 if IN0 = 1 then continue                    ' Force FF to start
 pulsout 1,10                                ' sequence with data=1.

continue:
  SHIFTIN 0,1,msbpre,[b1]                    ' Shiftin msb-first, pre-clock.
  debug "Pre-clock:  ",bin8 b1,cr            ' Show the result in binary.
  SHIFTIN 0,1,msbpost,[b1]                                                  '
Shiftin msb-first, post-clock.
  debug "Post-clock: ",bin8 b1,cr            ' Show the result in binary.
```

You can probably predict what this demonstration will show. Both Shiftin instructions are set up for msb-first operation, so the first bit they acquire ends up in the msb (leftmost bit) of the variable. Look at figure I-25a; the first data bit acquired in the pre-clock case is 1, so the pre-clock Shiftin returns %10101010. The data line is left with a 1 on it because of the final clock pulse.

The post-clock Shiftin acquires its bits after each clock pulse. The initial pulse changes the data line from 1 to 0, so the post-clock Shiftin returns %01010101.

By default, Shiftin acquires eight bits, but you can set it to shift any number of bits from 1 to 16 with an optional entry following the variable name. In the example above, substitute this for the first Shiftin instruction:

```
SHIFTIN  0,1,msbpre,[b1\4]                                                  '
Shiftin 4 bits.
```

The debug window will display %00001010.

Some devices return more than 16 bits. For example, most 8-bit shift registers can be daisy-chained together to form any multiple of 8 bits; 16, 24, 32, 40... You can use a single Shiftin instruction with multiple variables. Each variable can be assigned a particular number of bits with the backslash (\) option. Modify the previous example:

```
SHIFTIN  0,1,msbpre,[b1\5,b2]                    ' 5 bits into b1; 8 bits into b2.
debug "1st variable:  ",bin8 b1,cr
debug "2nd variable:  ",bin8 b2,cr
```

Demo Program

See listing 2 of BS2 application note #2 Using Shiftin and Shiftout, or try the example shown in the explanation above.

Shiftout

SHIFTOUT ***dpin,cpin,mode,[data{\bits}{,data{\bits}...}]***

Shift data out to a synchronous-serial device.

- ***Dpin*** is a variable/constant (0–15) that specifies the I/O pin that will be connected to the synchronous-serial device's data input. This pin's I/O direction will be changed to output and will remain in that sate after the instruction is completed.
- ***Cpin*** is a variable/constant (0–15) that specifies the I/O pin that will be connected to the synchronous-serial device's clock input. This pin's I/O direction will be changed to outputand will remain in that sate after the instruction is completed.
- ***Mode*** is a value (0 or 1) or a predefined symbol that tells Shiftout the order in which data bits are to be arranged. Here are the symbols, values, and their meanings:

Symbol	Value	Meaning
LSBFIRST	0	Data shifted out lsb-first.
MSBFIRST	1	Data shifted out msb-first.

(Msb is most-significant bit; the highest or leftmost bit of a nibble, byte, or word. Lsb is the least-significant bit; the lowest or rightmost bit of a nibble, byte, or word.)

- ***Data*** is a variable or constant containing the data to be sent.
- ***Bits*** is an optional entry specifying how many bits (1—16) are to be ouput. If no bits entry is given, Shiftout defaults to 8 bits.

Explanation

Shiftout provides an easy method of transferring data to synchronous-serial devices. Synchronous serial differs from asynchronous serial (like Serin and Serout) in that the timing of data bits is specified in relationship to pulses on a clock line. Data bits may be valid after the rising or falling edge of the clock line. This kind of serial protocol is commonly used by controller peripherals like ADCs, DACs, clocks, memory devices, etc. Trade names for synchronous-serial protocols include SPI and Microwire.

At their heart, synchronous-serial devices are essentially shift-registers—

trains of flip-flops that pass data bits along in a bucket-brigade fashion to a single data-output pin. Another bit is input each time the appropriate edge (rising or falling, depending on the device) appears on the clock line. BS2 application note #2 explains shift-register operation in detail.

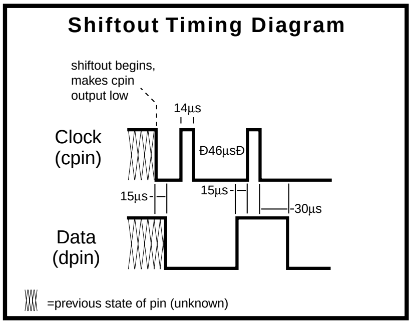
A single Shiftout instruction causes the following sequence of events:

Makes the clock pin (cpin) output low.
Copies the state of the next data bit to be output (working from one end of the data to the other) to the dpin output latch (corresponding bit of the OUTS variable).
Makes the data pin (dpin) an output.
Pulses the clock pin high for 14µs.
Repeats the sequence of outputting data bits and pulsing the clock pin until the specified number of bits is shifted into the variable.

2

Making Shiftout work with a particular device is a matter of matching the mode and number of bits to that device's protocol. Most manufacturers use a timing diagram to illustrate the relationship of clock and data. Figure I-26 shows Shiftout's timing, beginning at the moment the Shiftout instruction first executes. Timing values in the figure are rounded to the nearest microsecond.

Figure I-26



Demo Program

See listing 1 of BS2 application note #2 Using Shiftin and Shiftout.

Sleep

SLEEP seconds

Put the BS2 into low-power sleep mode for a specified number of seconds.

- ***Seconds*** is a variable/constant (1-65535) that specifies the duration of sleep in seconds.

Explanation

Sleep allows the BS2 to turn itself off, then turn back on after a programmed period of time. The length of Sleep can range from 2.3 seconds to slightly over 18 hours. Power consumption is reduced to about 50 µA, assuming no loads are being driven.The resolution of the Sleep instruction is 2.304 seconds. Sleep rounds the specified number of seconds up to the nearest multiple of 2.304. For example, Sleep 1 causes 2.3 seconds of sleep, while Sleep 10 causes 11.52 seconds (5 x 2.304) of sleep.

Pins retain their previous I/O directions during Sleep. However, outputs are interrupted every 2.3 seconds during Sleep due to the way the chip keeps time.

The alarm clock that wakes the BS2 up is called the watchdog timer. The watchdog is a resistor/capacitor oscillator built into the PBASIC2 interpreter chip. During Sleep, the chip periodically wakes up and adjusts a counter to determine how long it has been asleep. If it isn't time to wake up, the chip "hits the snooze bar" and goes back to sleep.

To ensure accuracy of Sleep intervals, PBASIC2 periodically compares the watchdog timer to the more-accurate resonator timebase. It calculates a correction factor that it uses during Sleep. As a result, longer Sleep intervals are accurate to approximately ±1 percent.

If your application is driving loads (sourcing or sinking current through output-high or output-low pins) during Sleep, current will be interrupted for about 18 ms when the BS2 wakes up every 2.3 seconds. The reason is that the watchdog-timer reset that awakens the BS2 also causes all of the pins to switch to input mode for approximately 18 ms. When the PBASIC2 interpreter firmware regains control of the processor, it restores the I/O directions dictated by your program.

If you plan to use End, Nap, or Sleep in your programs, make sure that your loads can tolerate these periodic power outages. The simplest solution is often to connect resistors high or low (to +5V or ground) as appropriate to ensure a continuing supply of current during the reset glitch.

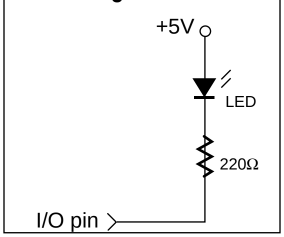
Demo Program

This program demonstrates both Sleep's timing characteristics and the periodic glitch discussed above. Connect an LED to pin 0 as shown in figure I-27 and run the program. The LED will blink, then the BS2 will go to Sleep. During Sleep, the LED will remain on, but will wink out at intervals of approximately 2.3 seconds.

```
low 0                        ' Turn LED on.
pause 1000                   ' Wait 1 second.

again:
  high 0                     ' LED off.
  pause 1000                 ' Wait 1 second.
  low 0                      ' LED back on.
  SLEEP 10                   ' Sleep for 10 seconds.
goto again
```

Figure I-27



Stop

STOP

Stop program execution.

Explanation

Stop prevents the BS2 from executing any further instructions until it is reset. The following actions will reset the BS2: pressing and releasing the RESET button on the carrier board, taking the RES pin low then high, by downloading a new program, or turning the power off then on.

Stop differs from End in two respects:

- Stop does not put the BS2 into low-power mode. The BS2 draws just as much current as if it were actively running program instructions.
- The output glitch that occurs after a program has Ended does not occur after a program has Stopped.

Toggle

TOGGLE pin

Invert the state of a pin.

- ***Pin*** is a variable / constant (0–15) that specifies the I / O pin to use. The state of the corresponding bit of the OUTS register is inverted and the pin is put into output mode by writing a 1 the corresponding bit of the DIRS register.

Explanation

Toggle inverts the state of an I / O pin, changing 0 to 1 and 1 to 0. When the pin is intially in the output mode, Toggle has exactly the same effect as complementing the corresponding bit of the OUTS register. That is, Toggle 7 is the same as OUT7 = ~OUT7 (where ~ is the logical NOT operator).

2

When a pin is initially in the input mode, Toggle has two effects; it inverts the output driver (OUTS bit) and changes the pin to output mode by writing a 1 to the pin's input / output direction bit (the corresponding bit of the DIRS register).

In some situations Toggle may appear to have no effect on a pin's state. For example, suppose pin 2 is in input mode and pulled to +5V by a 10k resistor. Then the following code executes:

```
DIR2 = 0                  ' Pin 2 in input mode.
OUT2 = 0                  ' Pin 2 output driver low.
debug ? IN2               ' Show state of pin 2 (1 due to pullup).
TOGGLE  2                 ' Toggle pin 2 (invert OUT2, put 1 in DIR2).
debug ? IN2               ' Show state of pin 2 (1 again).
```

The state of pin 2 doesn't change—it's high (due to the resistor) before Toggle, and it's high (due to the pin being output high) afterward. The point of presenting this puzzle is to emphasize that Toggle works on the OUTS register, which may not match the pin's state when the pin is initially an input.

If you want to guarantee that the state of the pin actually changes, regardless of whether that pin starts as an input or output, just do this:

```
OUT2 = IN2          ' Make output driver match pin state.
TOGGLE 2            ' Then toggle.
```

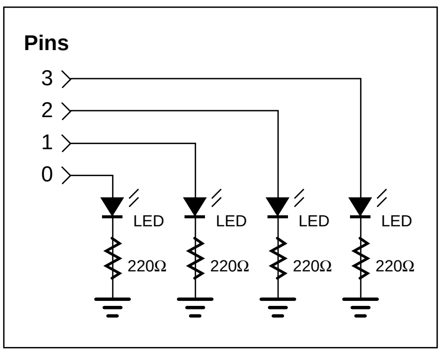
If you change the previous example to copy IN2 to OUT2 before Toggling, you'll see that the state of the pin does change.

Demo Program

Connect LEDs to pins 0 through 3 as shown in figure I-28 and run the program below. The Toggle instruction will treat you to a light show. You may also run the demo without LEDs. The debug window will show you the states of pins 0 through 3.

```
thePin        var       nib                  ' Variable to count 0-3.
again:
  for thePin = 0 to 3                        ' Pins 0 to 3 driving LEDs.
    TOGGLE thePin                            ' Toggle each pin.
    debug cls,bin4 INA                       ' No LEDs? Watch debug screen.
    pause 200                                ' Brief delay.
  next                                       ' Next pin
goto again                                   ' Repeat endlessly.
```

Figure I-28



Write

WRITE *address,byte*

Write a byte of data to the EEPROM.

- ***Address*** is a variable / constant specifying the EEPROM address (0—2047) to write to.
- ***Byte*** is a data byte to be written into EEPROM.

Explanation

The EEPROM is used for both program storage (which builds downward from address 2047) and data storage (which may use any EEPROM byte not used for program storage). Data may either be downloaded to the BS2 along with the program via the Data directive, or a running program may store data in EEPROM using the Write instruction.

EEPROM differs from RAM, the memory in which variables are stored, in several respects:

(1) Writing to EEPROM takes more time than storing a value in a variable. Depending on many factors, it may take several milliseconds for the EEPROM to complete a write. RAM storage is nearly instantaneous.

(2) The EEPROM can accept a finite number of Write cycles per byte before it wears out. At the time of this writing, each byte of the EEPROM used in the BS2 was good for 10 million Write cycles, and an unlimited number of Reads. If a program frequently writes to the same EEPROM location, it makes sense to estimate how long it might take to exceed 10 million writes. For example, at one write per second (86,400 writes / day) it would take nearly 116 days of continuous operation to exceed 10 million.

(3) The primary function of the EEPROM is to store programs; data is stored in leftover space. If data overwrites a portion of your program, the program will most likely crash. Check the program's memory map to determine what portion of memory is occupied by your program and make sure that EEPROM Writes cannot stray into this area. You may also use the Data directive to set aside EEPROM space. For instance:

name DATA (n)

This directive allocates n bytes of EEPROM starting at the address name and extending to address *name* + (n-1). If you restrict Writes to this range of addresses, you'll be fine. If your program grows to the point that it overlaps the addresses allocated, the STAMP2 host program will generate an error message and refuse to download it. See the section BS2 EEPROM Data Storage for more information on the Data directive.

Demo Program

This program is the bare framework of a data logger—an application that gathers data and stores it in memory for later retrieval. To provide sample data, connect the circuit of figure I-14a (see RCtime) to pin 7. Use a 10k resistor and 0.1µF capacitor. Run the program and twiddle the pot to vary the input data. The program writes the data to EEPROM at 1-second intervals, then reads it back from the EEPROM. If you plan to use Write in a similar application, pay close attention to the way the program allocates the EEPROM with Data and uses constants to keep track of the beginning and ending addresses of the EEPROM space. Note that this program uses an unnecessarily large variable (a word) for the EEPROM address. With only 10 samples and with EEPROM addresses that start at 0, we could have gotten away with just a nibble. However, real-world applications could expand to hundreds of samples, or be located much higher in EEPROM, so we used a word variable to set a good example.

```
result      var     word                ' Word variable for RCtime result.
EEaddr      var     word                ' Address of EEPROM storage
locations.

samples     con     10                  ' Number of samples to get.
log         data    (samples)           ' Set aside EEPROM for samples.
endLog      con     log+samples-1       ' End of allocated EEPROM.

for EEaddr = log to endLog              ' Store each sample in EEPROM.
  high 7: pause 1                       ' Charge the cap.
  rctime 7,1,result                     ' Measure resistance.
  result = result*42/100                ' Scale to fit one byte (0-255)
  debug "Storing ", dec result,tab," at ", dec EEaddr,cr
  WRITE EEaddr,result                   ' Store it in EEPROM
  pause 1000                            ' Wait a second.
```

```
next                                    ' Do until all samples done.
pause 2000: debug cls                   ' Wait 2 seconds, then clear screen.

for EEaddr = log to endLog              ' Retrieve each sample from
EEPROM.
  read EEaddr,result                    ' Read back a byte
  debug "Reading ", dec result,tab," at ", dec EEaddr,cr
next                                    ' Do until all samples retrieved.
stop
```

Xout

XOUT

mpin,zpin,[house\keyOrCommand{\cycles}{,house\keyOrCommand{\cycles}...}]

Send an X-10 powerline control command (through the appropriate powerline interface).

- ***Mpin*** is the I/O pin (0-15) that outputs X-10 signals (modulation) to the powerline-interface device. This pin is placed into output mode.
- ***Zpin*** is the I/O pin (0-15) that inputs the zero-crossing signal from the powerline-interface device. This pin will be placed into input mode.
- ***House*** is the X-10 house code (values 0-15 representing letters A through P).
- ***KeyOrCommand*** is a key on a manual X-10 controller (values 0-15 representing keys 1 through 16) or an X-10 control command listed in the table below. In Xout instructions you can use either the command value or the built-in Command constant.
- ***Cycles*** is an optional number of times to transmit a given key or command. If no cycles entry is used, Xout defaults to two. The cycles entry should be used only with the DIM and BRIGHT command codes.

Explanation

Xout lets you control appliances via signals sent through household AC wiring to X-10 modules. The appliances plugged into these modules can be switched on or off; lights may also be dimmed. Each module is assigned a house code and unit code by setting dials or switches on the module. To talk to a particular module, Xout sends the appropriate house code and unit code (key). The module with the corresponding codes then listens for its house code again and a command (on, off, dim, or bright).

Xout interfaces to the AC powerline through an approved interface device such as a PL-513 or TW-523, available from Parallax or X-10 dealers. The hookup requires a length of four-conductor phone cable and a standard modular phone-base connector (6P4C type). Connections are as follows:

PL-513 or TW-523	BS2
1	zPin*
2	GND
3	GND
4	mPin

* This pin should also be connected to +5V through a 10k resistor.

Here are the Xout command codes and their functions:

Command	*Code	Function
unitOn	%10010	Turn on the currently selected unit.
unitOff	%11010	Turn off the currently selected unit.
unitsOff	%11100	Turn off all modules w/ this house code.
lightsOn	%10100	Turn on all lamp modules w/ this house code.
dim	%11110	Reduce brightness of currently selected lamp.
bright	%10110	Increase brightness of currently selected lamp.

*In most applications, it's not necessary to know the code for a given X-10 instruction. Just use the command constant (unitOn, dim, etc.) instead. But knowing the codes leads to some interesting possibilities. For example, XORing a unitOn command with the value %1000 turns it into a unitOff command, and vice-versa. This makes it possible to write the equivalent of an X-10 "toggle" instruction.

Here is an example of the Xout instruction:

```
zPin      con     0                         ' Zpin is P0.
mPin      con     1                         ' Mpin is P1.
houseA    con     0                         ' House code A = 0.
unit1     con     0                         ' Unit code 1 = 0.

XOUT  mPin,zPin,[houseA\unit1]              ' Get unit 1's attention..
XOUT  mPin,zPin,[houseA\unitOn]             ' ..and tell it to turn on.
```

You can combine those two Xout instructions into one like so:

```
XOUT  mPin,zPin,[houseA\unit1\2,houseA\unitOn]   ' Unit 1 on.
```

Note that to complete the attention-getting code houseA \ unit1 we tacked on the normally optional cycles entry \2 to complete the command before beginning the next one. Always specify two cycles in multiple commands unless you're adjusting the brightness of a lamp module.

Here is an example of a lamp-dimming instruction:

```
zPin      con    0                                 ' Zpin is P0.
mPin      con    1                                 ' Mpin is P1.
houseA    con    0                                 ' House code A = 0.
unit1     con    0                                 ' Unit code 1 = 0.

XOUT  mPin,zPin,[houseA\unit1]                     ' Get unit 1's attention..
XOUT  mPin,zPin,[houseA\unitOff\2,houseA\dim\10]   ' Dim halfway.
```

The dim / bright commands support 19 brightness levels. Lamp modules may also be turned on and off using the standard unitOn and unitOff commands. In the example instruction above, we dimmed the lamp by first turning it comletely off, then sending 10 cycles of the dim command. This may seem odd, but it follows the peculiar logic of the X-10 system. See the table in BS2 app note #1, X-10 Control, for complete details.

Demo Program

See the program listing accompanying BS2 app note #1, X-10 Control.

Introduction. This application note shows how to use the new Xout command to remotely control X-10® lamp and appliance modules.

Background. Home automation—the management of lights and appliances with a computer—promises to increase security, energy efficiency, and convenience around the house. So why aren't home-control systems more common? The answer is probably the wiring; it's hard to think of a nastier job than stringing control wiring through the walls and crawlspaces of an existing home.

Fortunately, there's a wireless solution for home control called X-10, a family of control modules that respond to signals sent through existing AC wiring. The BASIC Stamp II has the built-in ability to generate X-10 control signals with the new Xout instruction.

How it works. From the user's standpoint, an X-10 system consists of a control box plugged into a wall outlet, and a bunch of modules plugged into outlets around the house. The appliances and lights to be controlled are plugged into the modules.

During the installation of the system, the user assigns two codes to each of the modules; a house code and a unit code. As the name suggests, the house code is usually common to all modules in a particular house. There are 16 house codes, assigned letters A through P. The idea of the house code is to avoid interference between adjacent homes equipped with X-10 by allowing the owners to assign different codes to their modules. The control box must be assigned the same house codes as the modules it will control.

There are also 16 unit codes (numbered 1 through 16) that identify the modules within a particular house. If your needs expand beyond 16 modules, it's generally safe to use another house code for the next group of 16, since few if any neighborhoods are so infested with X-10 controllers that all available house codes are taken. X-10 signals don't propagate beyond the nearest utility transformer.

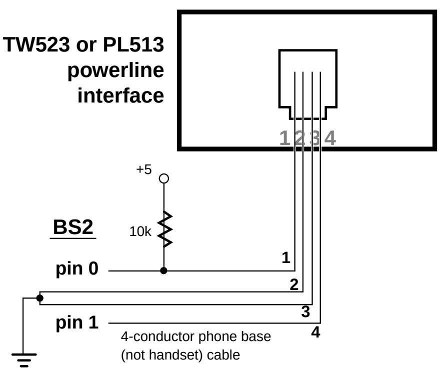
Once this simple setup is complete, the user controls the modules by pressing keys on the control box. Pressing "1 ON" turns module 1 on.

From a more technical standpoint, X-10 signals are digital codes imposed on a 120-kHz carrier that is transmitted during zero crossings of the AC line. To send X-10 commands, a controller must synchronize to the AC line frequency with 50-microsecond precision, and transmit an 11-bit code sequence representing the button pressed.

A company named X-10 owns a patent on this system. To encourage others to use their technology without infringing their patent, X-10 sells a pair of modules that provide a relatively simple, safe, UL- and CSA-approved interface with the AC power line. These interfaces are the PL-513 and TW-523. The PL-513 is a transmit-only unit; the TW-523 can be used to transmit and receive X-10 codes. The Stamp II presently supports only transmission of X-10 codes, but either of the interfaces may be used. The figure shows how they connect to the Stamp II.

A word of caution: The PL-513 or TW-523 provide a safe, opto-isolated interface through their four-pin modular connector. However, they derive power directly from the AC power line. Never open the cases of these devices to make connections or measurements. You'll be exposing yourself to a severe—even deadly—shock hazard.

That said, connecting to the PL-513 or TW-523 is easy. They use a standard four-conductor modular phone base (not handset) connector. Cutting a 12-foot phone cord in half yields two 6-foot X-10 cables. The



Schematic to accompany X10_DEMO.BS2

color codes can vary in phone cables, so be sure to follow the numbers imprinted next to the modular jack on the PL-513 or TW-523 unit.

The program listing shows how to send X-10 commands through this hookup. The listing is self-explanatory, and the procedures are simple, as long as you keep some ground rules in mind:

- House codes A through P are represented as values from 0 to 15 in the Xout command.
- Unit codes 1 through 16 are represented as values from 0 to 15 in the Xout command.
- Every X-10 transmission must include a house code.
- Except for Dim and Bright, all codes are sent for a default of two cycles. You don't have to specify the number of cycles for commands other than Dim and Bright, unless you are sending multiple codes in a single instruction. See the listing for examples.
- It takes 19 cycles for a lamp to go from fully bright to fully dim and vice versa. There's also a peculiar logic to the operation of the Dim and Bright commands (see the table). To set a specific level of brightness, you should first reset the dimmer module by turning it off, then back on.
- In some homes, X-10 signals may not be able to reach all outlets without a little help. A device called an ACT CP000 Phase Coupler (about $40 retail from the source below) installed on the electrical breaker box helps X-10 signals propagate across the phases of the AC line. For larger installations, there are also amplifiers, repeaters, etc.

Sources. X-10 compatible modules are available from many home centers, electrical suppliers, and electronics retailers, including Radio

Operation of the Dim and Bright Commands

Lamp is...	And you send... OFF	ON	DIM	BRIGHT
OFF/FULL	no effect	turns ON/FULL	turns ON/FULL	turns ON/FULL
ON/FULL	turns OFF/FULL	no effect	dims	no effect
OFF/DIM	turns OFF/FULL	no effect	no effect	brightens
ON/DIM	turns OFF/FULL	no effect	dims	brightens

Shack. However, relatively few of these carry the PL-513 and TW-523. Advanced Services Inc., a home-automation outlet, sells every conceivable sort of X-10 hardware, including the PL-513 and TW-523 (starting at around $20 at the time of this writing). You may contact them at 800-263-8608 or 508-747-5598.

Program listing. This program may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' Program: X10_DEMO.BS2 (Demonstration of X-10 control using Xout)
' This program--really two program fragments--demonstrates the
' syntax and use of the new XOUT command. Basically, the command
' works like pressing the buttons on an X-10 control box; first you
' press one of 16 keys to identify the unit you want to control,
' then you press the key for the action you want that unit to
' take (turn ON, OFF, Bright, or Dim). There are also two group-action
' keys, Lights ON and All OFF. Lights ON turns all lamp modules on
' without affecting appliance modules. All OFF turns off all modules,
' both lamp and appliance types.

' Using  XOUT requires a 4-wire (2-I/O pin) connection to a PL-513 or
' TW-523 X-10 module. See the application note for sources.
zPin      con      0              ' Zero-crossing-detect pin from TW523 or PL513.
mPin      con      1              ' Modulation-control pin to TW523 or PL513.

' X-10 identifies modules by two codes: a House code and a Unit code.
' By X-10 convention, House codes are A through P and Unit codes are
' 1 through 16. For programming efficiency, the Stamp II treats both
' of these as numbers from 0 through 15.
houseA    con      0              ' House code: 0=A, 1=B... 15=P
Unit1     con      0              ' Unit code: 0=1, 1=2... 15=16
Unit2     con      1              ' Unit code 1=2.

' This first example turns a standard (appliance or non-dimmer lamp)
' module ON, then OFF. Note that once the Unit code is sent, it
' need not be repeated--subsequent instructions are understood to
' be addressed to that unit.

xout mPin,zPin,[houseA\Unit1]     ' Talk to Unit 1.
xout mPin,zPin,[houseA\uniton]    ' Tell it to turn ON.
pause 1000                        ' Wait a second.
xout mPin,zPin,[houseA\unitoff]   ' Tell it to turn OFF.

' The next example talks to a dimmer module. Dimmers go from full
```

```
' ON to dimmed OFF in 19 steps. Because dimming is relative to
' the current state of the lamp, the only guaranteed way to set a
' predefined brightness level is to turn the dimmer fully OFF, then
' ON, then dim to the desired level. Otherwise, the final setting of
' the module will depend on its initial brightness level.

xout mPin,zPin,[houseA\Unit2]                   ' Talk to Unit 2.
' This example shows how to combine X-10 instructions into a
' single line. We send OFF to the previously identified unit (Unit2)
' for 2 cycles (the default for non-dimmer commands). Then a comma
' introduces a second instruction that dims for 10 cycles. When you
' combine instructions, don't leave out the number of cycles. The
' Stamp may accept your instruction without complaint, but it
' won't work correctly--it may see the house code as the number of
' cycles, the instruction as the house code, etc.

xout mPin,zPin,[houseA\unitoff\2,houseA\dim\10]

' Just to reinforce the idea of combining commands, here's the
' first example again:

xout mPin,zPin,[houseA\Unit1\2,houseA\uniton]   ' Turn Unit 1 ON.
pause 1000                                      ' Wait a second.
xout mPin,zPin,[houseA\Unit1\2,houseA\unitoff]  ' Turn Unit 1 OFF.

' End of program.
stop
```

2

Introduction. This application note shows how to use the new Shiftin and Shiftout instructions to efficiently interface the BASIC Stamp II to synchronous serial peripheral chips.

Background. Many of the most exciting peripheral chips for microcontrollers are available only with synchronous-serial interfaces. These go by various names, like SPI, Microwire, three- or four-wire interface, but they are essentially the same in operation. The BASIC Stamp II takes advantage of these similarities to offer built-in instructions—Shiftout and Shiftin—that take most of the work out of communicating with synchronous-serial peripherals.

Before plunging into the nuts and bolts of using the new instructions, let's discuss some fundamentals. First of all, how does a synchronous-serial interface differ from a parallel one? Good question, since most synchronous-serial devices incorporate elements of both serial and parallel devices.

The building block of both parallel and serial interfaces is called a flip-flop. There are several types, but we're going to discuss the D-type or Data flip-flop. A D-type flip-flop has two inputs (Data and Clock) and one output (typically called Q). When the logic level on the Clock input rises (changes from 0 to 1), the flip-flop stores a snapshot of the logic level at the Data input to the Q output. It holds that bit on Q until the power is turned off, or until the opposite state is present on Data when Clock receives another 0-to-1 change. (For the sake of conversation, we call a 0-to-1 transition a "rising edge" and 1-to-0 a "falling edge.")

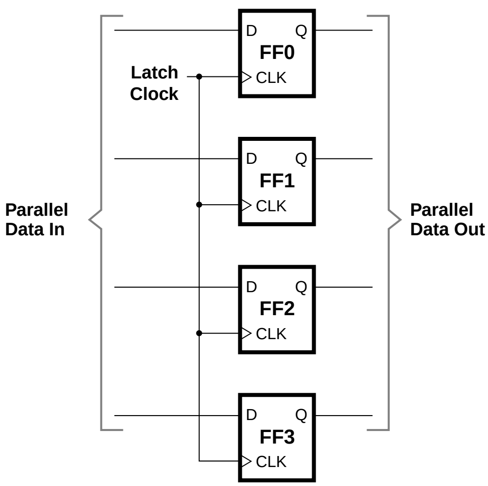


Figure 1. Parallel latch.

The action of a D-type flip-flop is described as "latching" Data onto Q. Parallel latches, like the one shown in figure 1, allow several bits to be simultaneously latched onto a set of outputs. This is one of the ways that a computer addresses multiple devices on a single parallel data bus—it puts the data on the bus, then triggers one device's Clock. The data is latched into the destination device only; other devices ignore the data until *their* Clock lines are triggered.

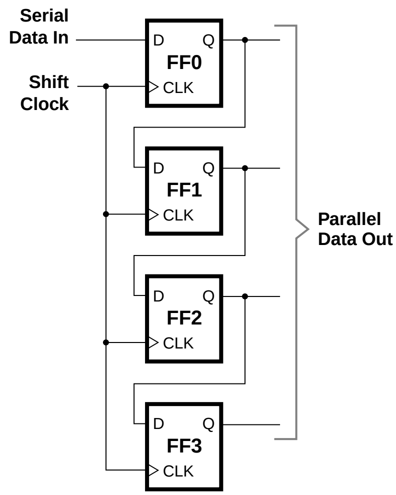


Figure 2. Serial shift register.

With different wiring, the parallel latch becomes a serial one, known as a shift register (figure 2). See how this works: When a rising edge appears on the Clock input, all of the flip-flops latch their Data inputs to their Q outputs. Because they are wired in a chain with each Q output connected to the next flip-flop's Data input, incoming bits ripple down the shift register.

You can picture this process as working like a bucket brigade or a line of people moving sandbags. In perfect coordination, each person hands their burden to the next person in line and accepts a new one from the previous person.

Looking at this from the standpoint of the parallel output, there's a potential problem. When data is being clocked into the shift register, the data at the output isn't stable—it's rippling down the line. The cure for this is to add the previously described parallel latch after the shift register, and clock it only when we're finished shifting data in. That's the arrangement shown in figure 3.

It isn't too much of a stretch to imagine how this kind of circuit could be turned around and used as an input. Data would be grabbed in parallel by a latch, then transferred to a shift register to be moved one bit at a time to a serial data output.

Now you understand the communications hardware used in synchronous serial peripherals; it's basically just a collection of shift registers, latches and other logic. The Stamp II's built-in Shiftout and Shiftin instructions provided general-purpose tools for working with this kind of hardware. Let's look at some examples.

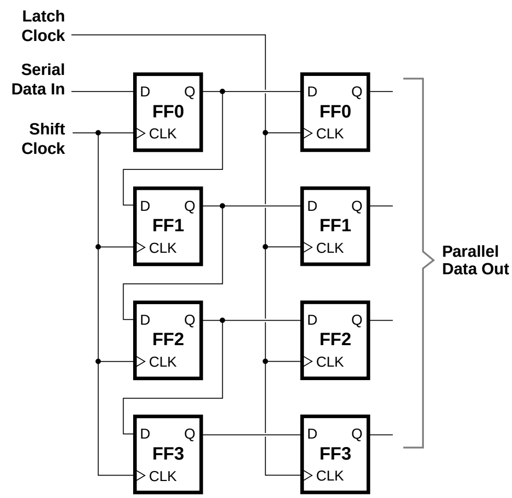


Figure 3. A shift register plus a latch makes a serial-to-parallel converter.

Shift-Register Output with Shiftout. The most basic use for Shiftout is to add an output-only port based on a shift register/latch combination like the 74HC595 shown in figure 4. Listing 1 demonstrates how simple it is to send data to a device like this.

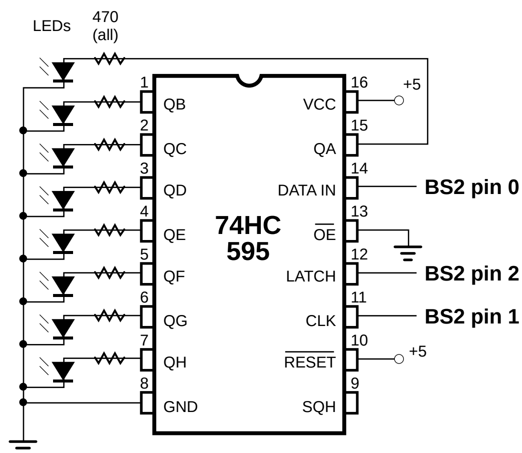


Figure 4. Schematic to accompany 74HC595.BS2.

Shiftout requires just five pieces of information to do its job:

- The pin number of the data connection.
- The pin number of the shift-clock connection.
- The order in which the bits should be sent—least-significant bit (lsb) first or most-significant bit (msb) first. For the '595, we chose msb first, since the msb of the output is farthest down the shift register from the data input. For other devices, the order of bits is prescribed by the manufacturer's spec sheet.
- The variable containing the data to output.
- The number of bits to be sent. (If this entry is omitted, Shiftout will send eight bits).

Note that once the data is shifted into shift register, an additional program step—pulsing the Latch line—is required to move the data to the output lines. That's because the 74HC595 is internally similar to the schematic in figure 3. The two-step transfer process prevents the outputs from rippling as the data is shifted.

The 74HC595 also has two control lines that are not used in our demonstration, but may prove useful in real-world applications. The Reset line, activated by writing a 0 to it, simultaneously clears all of the shift register flip-flops to 0 without affecting the output latch. The Output-enable (OE) line can effectively disconnect the output latch, allowing other devices to drive the same lines. A 0 on OE connects the outputs; a 1 disconnects them.

Serial ADC with Shiftin. Figure 5 and listing 2 demonstrate how to use Shiftin to obtain data from an 8-bit serial analog-to-digital converter, the ADC0831.

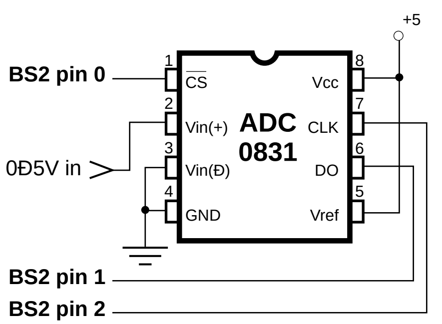


Figure 5. Schematic for ADC0831.BS2.

Shiftin requires the same five pieces of information as

Shiftout, plus one more, the relationship of valid data to clock pulses. Some devices latch bits onto the serial data output on the rising edge of the clock line. Output bits remain valid until the next rising edge. In these cases, your program must specify *post*-clock input for the Shiftin mode. When bits are latched on the falling edge of the clock, specify *pre*-clock input.

With pre-clock input, we sometimes encounter a chicken-and-egg problem. How can the first bit be clocked out *before* the first clock pulse? It can't, of course. The simple solution is to specify one additional bit in the Shiftin instruction.

However, most serial peripherals require that some instructions be sent to them before they return any data. In this case, the falling edge of the last Shiftout clock cycle clocks the first bit of the following pre-clock Shiftin instruction.

Serial ADC with Shiftout and Shiftin. The third example (figure 6, listing 3) uses Shiftout and Shiftin to hold a two-way conversation with an LTC1298 ADC. An initial Shiftout sends configuration bits to the LTC1298 to select channel and mode, then a Shiftin gets the 12-bit result of the conversion. The program listing concentrates on the mechanics of the Shift instructions; for more detailed information on the ADC itself, see Stamp Application Note #22 or the manufacturer's spec sheet.

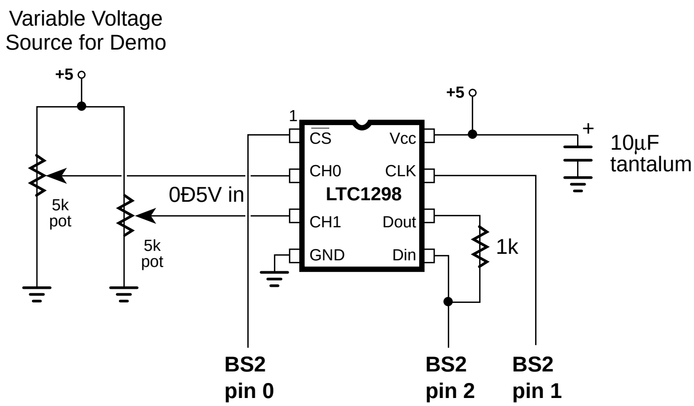


Figure 6. Schematic for LTC1298.BS2.

Custom Shift Routines. The key to successful use of the Shift instructions is obtaining, reading, and understanding the manufacturer's specification sheets. In addition to providing the data required to fill in the parameters for the Shift instructions, the data sheets document configuration bits, operating modes, internal register arrangements, and lots of other valuable data.

Sources. The components used in the example applications are available from Digi-Key, 710 Brooks Avenue South, P. O. Box 677, Thief River Falls, MN 56701-0677; phone 1-800-344-4539. Packages of components, documentation, and source code listings for the Stamp I, Stamp II and PIC microcontrollers are available from Scott Edwards Electronics; phone 520-459-4802, fax 520-459-0623. These packages, known as AppKits, are available for the LTC1298 ADC, DS1620 digital thermometer, Xicor X25640 8-kB EEPROM, and others.

Program listings. These programs may be downloaded from our Internet ftp site at ftp.parallaxinc.com. The ftp site may be reached directly or through our web site at http://www.parallaxinc.com.

```
' LISTING 1. SHIFTOUT TO 74HC595
' Program: 74HC595.BS2 (Demonstrate 74HC595 shift register with Shiftout)
' This program demonstrates the use of the 74HC595 shift register as an
' 8-bit output port accessed via the Shiftout instruction. The '595
' requires a minimum of three inputs: data, shift clock, and latch
' clock. Shiftout automatically handles the data and shift clock,
' presenting data bits one at a time on the data pin, then pulsing the
' clock to shift them into the '595's shift register. An additional
' step—pulsing the latch-clock input—is required to move the shifted
' bits in parallel onto the output pins of the '595.

' Note that this application does not control the output-enable or
' reset lines of the '595. This means that before the Stamp first
' sends data to the '595, the '595's output latches are turned on and
' may contain random data. In critical applications, you may want to
' hold output-enable high (disabled) until the Stamp can take control.

DataP    con    0       ' Data pin to 74HC595.
Clock    con    1       ' Shift clock to '595.
Latch    con    2       ' Moves data from shift register to output latch.
counter  var    byte    ' Counter for demo program.

' The loop below moves the 8-bit value of 'counter' onto the output
```

```
' lines of the '595, pauses, then increments counter and repeats.
' The data is shifted msb first so that the most-significant bit is
' shifted to the end of the shift register, pin QH, and the least-
' significant bit is shifted to QA. Changing 'msbfirst' to 'lsbfirst'
' causes the data to appear backwards on the outputs of the '595.
' Note that the number of bits is _not_ specified after the variable
' in the instruction, since it's eight, the default.
Again:
  Shiftout DataP,Clock,msbfirst,[counter]  ' Send the bits.
  pulsout Latch,1                          ' Transfer to outputs.
  pause 50                                 ' Wait briefly.
  counter = counter+1                      ' Increment counter.
goto Again                                 ' Do it again.
```

```
' LISTING 2. SHIFTIN FROM ADC0831
' Program: ADC0831.BS2
' This program demonstrates the use of the BS2's new Shiftin instruction
' for interfacing with the Microwire interface of the Nat'l Semiconductor
' ADC0831 8-bit analog-to-digital converter. It uses the same connections
' shown in the BS1 app note.

ADres    var    byte         ' A-to-D result: one byte.
CS       con    0            ' Chip select is pin 0.
AData    con    1            ' ADC data output is pin 1.
CLK      con    2            ' Clock is pin 2.

high CS                      ' Deselect ADC to start.

' In the loop below, just three lines of code are required to read
' the ADC0831. The Shiftin instruction does most of the work. Shiftin
' requires you to specify a data pin and clock pin (AData, CLK), a
' mode (msbpost), a variable (ADres), and a number of bits (9). The
' mode specifies msb or lsb-first and whether to sample data before
' or after the clock. In this case, we chose msb-first, post-clock.
' The ADC0831 precedes its data output with a dummy bit, which we
' take care of by specifying 9 bits of data instead of 8.

again:
  low CS                                  ' Activate the ADC0831.
  shiftin AData,CLK,msbpost,[ADres\9]  ' Shift in the data.
  high CS                                 ' Deactivate '0831.
  debug ? ADres                           ' Show us the conversion result.
  pause 1000                              ' Wait a second.
goto again                                ' Do it again.
```

```
' LISTING 3. BIDIRECTIONAL COMMUNICATION WITH LTC1298
' Program: LTC1298.BS2 (LTC1298 analog-to-digital converter)
' This program demonstrates use of the Shiftout and Shiftin instructions
' to communicate with an LTC1298 serial ADC. Shiftout is used to
' send setup data to the ADC; Shiftin to capture the results of the
' conversion. The comments in this program concentrate on explaining
' the operation of the Shift instructions. for more information on
' the ADC, see Stamp app note #22 or the Linear Tech spec sheets.

CS        con    0             ' Chip select; 0 = active
CLK       con    1             ' Clock to ADC; out on rising, in on falling edge.
DIO_n     con    2             ' Data I/O pin _number_.
config    var    nib           ' Configuration bits for ADC.
AD        var    word          ' Variable to hold 12-bit AD result.

startB    var    config.bit0   ' Start bit for comm with ADC.
sglDif    var    config.bit1   ' Single-ended or differential mode.
oddSign   var    config.bit2   ' Channel selection.
msbf      var    config.bit3   ' Output 0s after data xfer complete.

' This program demonstrates the LTC1298 by alternately sampling the two
' input channels and presenting the results on the PC screen using Debug.

high CS                        ' Deactivate ADC to begin.
high DIO_n                     ' Set data pin for first start bit.
again:                         ' Main loop.
  for oddSign = 0 to 1         ' Toggle between input channels.
    gosub convert              ' Get data from ADC.
    debug "channel ",DEC oddSign, ": ",DEC AD,cr    ' Display data.
    pause 500                  ' Wait a half second.
  next                         ' Change channels.
goto again                     ' Endless loop.

' Here's where the conversion occurs. The Stamp first sends the config
' bits to the 1298, then clocks in the conversion data. Note the use of
' the new BS2 instructions Shiftout and Shiftin. Their use is pretty
' straightforward here: Shiftout sends data bits to pin DIO and clock
' the CLK pin. Sending the least-significant bit first, it shifts out
' the four bits of the variable config. Then Shiftin changes DIO to
' input and clocks in the data bits—most-significant bit first, post
' clock (valid after clock pulse). It shifts in 12 bits to the variable AD.

convert:
  config = config | %1011      ' Set all bits except oddSign.
  low CS                       ' Activate the ADC.
  shiftout DIO_n,CLK,lsbfirst,[config\4]' Send config bits.
  shiftin DIO_n,CLK,msbpost,[AD\12] ' Get data bits.
  high CS                      ' Deactivate the ADC.
return                         ' Return to program.
```

Introduction. This application note shows how to interface the BS2 to the phone line in applications that use the DTMFout instruction.

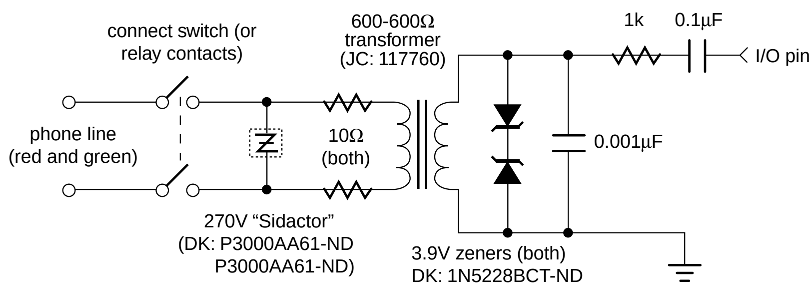
Background. The BS2 instruction DTMFout generates dual-tone, multifrequency signals—the same musical beeps used to dial the phone, activate pagers, and access repeaters in ham-radio applications.

Commercial designs that interface electronic devices to the phone line normally require the approval of the Federal Communications Commission (FCC) to ensure the quality and reliability of telephone service. Manufacturers of phone accessories often take the shortcut of using an off-the-shelf interface, known as a Data Access Arrangement (DAA). Since the DAA has already been checked out by the FCC, it's generally much easier to get a DAA-based design approved than a from-scratch circuit. Unfortunately, DAAs tend to be somewhat expensive in small quantities ($25+ each), and are sold primarily through high-volume distributors geared toward serving manufacturers.

2

Where does this leave experimenters, hobbyists, and one-off instrument makers? Pretty much on their own. For them, we present the circuit below. It's not a full-blown DAA suitable for production designs, but it is a good starting point for prototype DTMF-transmit

Interfacing to the Telephone Line



Parts Sources

Digi-Key (DK), 1-800-344-4539 or 218-681-6674	Jameco (JC), 1-800-831-4242 or 415-592-8097

Schematic of the phone-line interface.

applications using the BS2. It's based on a circuit presented in *Encyclopedia of Electronic Circuits, Volume 5,* by Graf and Sheets (TAB / McGraw Hill, 1995; ISBN 0-07-011077-8). We've filled in specific component values and sources, added parts for coupling the BS2, and tested the circuit's ability to dial the phone.

How it works. Starting at the phone-line end of the circuit, a double-pole single-throw (DPST) switch or set of relay contacts isolates the circuit from the phone line when the circuit is not in use. Closing the switch puts the phone into the "off-hook" condition, which causes the phone company to generate a dialtone. Although a single set of contacts would be sufficient to break the circuit, a tradition of robust design in phone circuits makes it normal for a hook switch to break both sides of the circuit.

After the switch, a Sidactor surge-protection device clips large voltage spikes that might result from nearby lightning strikes. Its voltage rating is selected to let it do its surge-protection job without interfering with relatively high ringing voltages or phone-company test voltages. Note that nothing can provide 100-percent lightning immunity, but the Sidactor is cheap insurance against most routine surges.

A 600-to-600-ohm transformer isolates the BS2 from the line's DC voltages. On the other side of the transformer, a pair of zener diodes clips any voltage over approximately 4.6 volts. The remaining resistors and capacitors couple the DTMF tones from the BS2 into the transformer. They also work together to smooth the ragged edges of the DTMF tones, which are generated using fast pulse-width modulation (PWM). Before filtering, these tones contain high-frequency components that can make them sound distorted or fuzzy. With the circuit shown, the tones come through crystal clear.

Programming. You'll be amazed at how easy it is to dial the phone with the DTMFout instruction. Suppose you want to dial 624-8333—one line will do the trick:

```
DTMFout 0,[6,2,4,8,3,3,3]
```

where 0 is the pin number (0-15) connected to the interface and the numbers inside the square brackets are the numbers to dial. Values of 0-9 represent those same buttons on the phone keypad; 10 is the star (*) key; 11 is the pound sign (#); and 12 through 15 are additional tones that aren't meant for phone-subscriber use. They're included primarily for non-phone DTMF applications like remote controls and ham-radio purposes. You may specify values as literal numbers, as we did above, or as variables. Nibble-sized variables are perfect for holding DTMF digits.

For each digit in square brackets, DTMFout sends the corresponding tone for 200 milliseconds (ms), followed by a silent pause of 50 ms. This timing gives the phone company equipment plenty of time to recognize and respond to the tones. If you want some other timing scheme, you can place on and off times between the pin numbers and the tone list, like so:


```
DTMFout 0,1000,500,[6,2,4,8,3,3,3]
```

That instruction would transmit each tone for a full second (1000 ms), and pause in silence for a half second (500 ms) after each tone.

Sources. Components needed for the simple phone-line interface are available from Digi-Key and Jameco; see the contact information in the schematic. For commercial applications, one manufacturer of DAAs is Cermetek Microelectronics, 406 Pasman Drive, Sunnyvale, CA 94089; phone 800-882-6271; fax 408-752-5004.

ASCII Chart

Control Codes			Printing Characters					
Name/Function	***Char**	**Code**	**Char**	**Code**	**Char**	**Code**	**Char**	**Code**
null	NUL	0	<space>	32	@	64	‘	96
start of heading	SOH	1	!	33	A	65	a	97
start of text	STX	2	"	34	B	66	b	98
end of text	ETX	3	#	35	C	67	c	99
end of xmit	EOT	4	$	36	D	68	d	100
enquiry	ENQ	5	%	37	E	69	e	101
acknowledge	ACK	6	&	38	F	70	f	102
bell	BEL	7	’	39	G	71	g	103
backspace	BS	8	(	40	H	72	h	104
horizontal tab	HT	9	)	41	I	73	i	105
line feed	LF	10	*	42	J	74	j	106
vertical tab	VT	11	+	43	K	75	k	107
form feed	FF	12	’	44	L	76	l	108
carriage return	CR	13	-	45	M	77	m	109
shift out	SO	14	.	46	N	78	n	110
shift in	SI	15	/	47	O	79	o	111
data line escape	DLE	16	0	48	P	80	p	112
device control 1	DC1	17	1	49	Q	81	q	113
device control 2	DC2	18	2	50	R	82	r	114
device control 3	DC3	19	3	51	S	83	s	115
device control 4	DC4	20	4	52	T	84	t	116
non acknowledge	NAK	21	5	53	U	85	u	117
synchronous idle	SYN	22	6	54	V	86	v	118
end of xmit block	ETB	23	7	55	W	87	w	119
cancel	CAN	24	8	56	X	88	x	120
end of medium	EM	25	9	57	Y	89	y	121
substitute	SUB	26	:	58	Z	90	z	123
escape	ESC	27	;	59	[	91	{	124
file separator	FS	28	<	60	\	92	|	125
group separator	GS	29	=	61	]	93	}	126
record separator	RS	30	>	62	^	94	~	127
unit separator	US	31	?	63	-	95	<delete>	128

* Note that the control codes have no standardized screen symbols. The characters listed for them are just names used in referring to these codes. For example, to move the cursor to the beginning of the next line of a printer or terminal often requires sending linefeed and carriage return codes. This common pair is referred to as “LF/CR.”

The following table shows the reserved words for each stamp module.

BASIC STAMP I		BASIC STAMP II		
AND	ON2400	ABS	HOME	OUTL
B0..B13	OR	AND	IHEX	OUTPUT
BIT0..BIT15	OT300	ASC	IHEX1..IHEX4	OUTS
BRANCH	OT600	BELL	IF	PAUSE
BSAVE	OT1200	BKSP	IN0..IN15	RCTIME
BUTTON	OT2400	BIN	INA	REV
DEBUG	OUTPUT	BIN1..BIN4	INB	PULSIN
DIR0..DIR7	PAUSE	BIT	INC	PULSOUT
DIRS	PIN0..PIN7	BIT0..BIT15	IND	PWM
EEPROM	PINS	BRANCH	INH	RANDOM
END	PORT	BRIGHT	INL	READ
FOR	POT	BUTTON	INPUT	REP
GOSUB	PULSIN	BYTE	INS	REVERSE
GOTO	PULSOUT	CLS	ISBIN	SBIN
HIGH	PWM	CON	ISBIN1..ISBIN16	SBIN1..SBIN16
IF	RANDOM	COS	ISHEX	SDEC
INPUT	READ	COUNT	ISHEX1..ISHEX4	SDEC1..SDEC5
LET	REVERSE	CR	LIGHTSON	SERIN
LOOKDOWN	SERIN	DATA	LOOKDOWN	SEROUT
LOOKUP	SEROUT	DCD	LOOKUP	SHEX
LOW	SLEEP	DEBUG	LOW	SHEX1..SHEX4
MAX	SOUND	DEC	LOWBIT	SHIFTIN
MIN	STEP	DEC1..DEC5	LOWNIB	SHIFTOUT
N300	SYMBOL	DIG	LSBFIRST	SIN
N600	T300	DIM	LSBPOST	SKIP
N1200	T600	DIR0..DIR15	LSBPRE	SLEEP
N2400	T1200	DIRA	MAX	STEP
NAP	T2400	DIRB	MIN	STOP
NEXT	THEN	DIRC	MSBFIRST	STR
ON300	TOGGLE	DIRD	MSBPOST	SQR
ON600	W0..W6	DIRH	MSBPRE	TAB
ON1200	WRITE	DIRL	NAP	THEN
		DIRS	NCD	TO
		DTMFOUT	NEXT	TOGGLE
		END	NIB	UNITOFF
		FOR	NIB0..NIB3	UNITON
		FREQOUT	NOT	UNITSOFF
		GOSUB	OR	VAR
		GOTO	OUT0..OUT15	WAIT
		HEX	OUTA	WAITSTR
		HEX1..HEX4	OUTB	WORD
		HIGH	OUTC	WRITE
		HIGHBIT	OUTD	XOR
		HIGHNIB	OUTH	XOUT

B

BASIC Stamp I and Stamp II Conversions

INTRODUCTION

The BASIC Stamp I and BASIC Stamp II have many differences in both hardware and software. While it is trivial to recognize the differences in the Stamp hardware, the modifications to the PBASIC command structure are intricate and not always obvious. This appendix describes the Stamp I and Stamp II PBASIC differences in a detailed manner to aid in the conversion of programs between the two modules. This document may also serve to give a better understanding of how certain features of the two versions can be helpful in problem solving.

TYPOGRAPHICAL CONVENTIONS

This Appendix will use a number of symbols to deliver the needed information in a clear and concise manner. Unless otherwise noted the following symbols will have consistent meanings throughout this document.

TOPIC HEADING

Each discussion of a topic or PBASIC command will begin with a topic heading such as the one above.

MODULE HEADING

When separate discussion of a Stamp I or Stamp II module is necessary it will begin with a module heading such as this one.

-
-

Inside the module section bulleted items will precede information on the properties of various arguments for the indicated command.

CONVERSION:

When conversion between the two versions of PBASIC are necessary, each set of steps will begin under the conversion heading as shown above. This header will always begin with the word "Conversion" and will indicate in which direction the conversion is taking place; i.e. from BS1 to BS2 or from BS2 to BS1.

1. First do this...
2. Next do this...

The most important steps in conversion will be listed in a numeric sequence within the conversion section. The order of the numbered steps may be important in some situations and unimportant in others; it is best to follow the order as closely as possible.

Tips which are not vital to the conversion are listed within the conversion section and are preceded by bullets as shown above. These tips include additional information on valid argument types, properties of the command, etc. and may be used for further optimization of the code if desired.

As an example, using the above conventions, a typical section within this document will look like this:

SAMPLE COMMAND

BASIC Stamp I

Command syntax line shown here

- Argument one is…
- Argument two is…

BASIC Stamp II

Command syntax line shown here

- Argument one is...
- Argument two is...

Conversion: BS1 ⇨ BS2

1. First do this...
2. Next do this...

- You might like to know this...
- You might want to try this...

CONVERSION: BS1 ⇦ BS2

1. First do this...
2. Next do this...

- You might like to know this...
- You might want to try this...

The following symbols appear within command syntax listings or within the text describing them.

UPPER CASE	All command names will be shown is upper case lettering within the command syntax line. Argument names will be in upper case lettering outside of the command syntax line.
lower case	All arguments within the command syntax line will be in lower case lettering.
( )	Parentheses may appear inside a command syntax line and indicate that an actual parenthesis character is required at that location.
[ ]	Brackets may appear inside a command syntax line and indicate that an actual bracket character is required at that location.
[|]	Brackets with an internal separator may appear in the text following a command syntax line and indicate that one, and only one, of the items between the separators may be specified.
{ }	Wavy brackets may appear inside a command syntax line and indicate that the items they surround are optional and may be left out of the command. The wavy bracket characters themselves should not be used within the command, however.

#..# Double periods between numbers indicate that a contiguous range of numbers are allowed for the given argument. Wherever a range of numbers are shown it usually indicates the valid range which a command expects to see. If a number is given which is outside of this range the Stamp will only use the lowest bits of the value which correspond to the indicated range. For example, if the range 0..7 is required (a 3 bit value) and the number 12 is provided, the Stamp will only use the lowest 3 bits which would correspond to a value of 4.

HOW TO USE THIS APPENDIX

This appendix should be used as a reference for converting specific commands, or other PBASIC entities, from one version of the Stamp to another. While this document will help to convert most of the programs available for the Stamp I and Stamp II, some programs may require logic changes to achieve correct results. The required logic changes are beyond the scope of this document.

In an effort to lessen the time spent in performing a code conversion the following routine should be followed in the order listed for each program.

1. Review the entire code briefly to familiarize yourself with how it functions and the types of commands and expressions which are used.
2. Consult the RAM SPACE AND REGISTER ALLOCATION section in this manual and go through the entire program carefully converting symbols, variables and expressions to the proper format.
3. Go through the code instruction by instruction, consulting the appropriate section in this document, and convert each one to the appropriate form.
4. Make any necessary circuit changes as required by the new stamp code.

COMMAND AND DIRECTIVE DIFFERENCES

Many enhancements to the Stamp I command structure were made in the Stamp II. Commands have also been added, replaced or removed. The following table shows the differences between the two modules.

BASIC Stamp I	BASIC Stamp II	Comments
BRANCH	BRANCH	Syntax Modifications
BSAVE		Removed
BUTTON	BUTTON	
	COUNT	New Command
DEBUG	DEBUG	Enhanced
EEPROM	DATA	Enhanced
	DTMFOUT	New Command
END	END	
(Expressions)	(Expressions)	Enhanced
FOR...NEXT	FOR...NEXT	Enhanced
GOSUB	GOSUB	Enhanced
GOTO	GOTO	
HIGH	HIGH	
IF...THEN	IF...THEN	Enhanced
INPUT	INPUT	
LET	(Expression)	Enhanced
LOOKDOWN	LOOKDOWN	Enhanced
LOOKUP	LOOKUP	Syntax Modifications
LOW	LOW	
NAP	NAP	
OUTPUT	OUTPUT	
PAUSE	PAUSE	
POT	RCTIME	Enhanced
PULSIN	PULSIN	Enhanced
PULSOUT	PULSOUT	Enhanced
PWM	PWM	Enhanced
RANDOM	RANDOM	
READ	READ	
(Register Allocation)	(Register Allocation)	Enhanced
REVERSE	REVERSE	
SERIN	SERIN	Enhanced
SEROUT	SEROUT	Enhanced
	SHIFTIN	New Command
	SHIFTOUT	New Command
SLEEP	SLEEP	
SOUND	FREQOUT	Enhanced
	STOP	New Command
TOGGLE	TOGGLE	
WRITE	WRITE	
	XOUT	New Command

RAM SPACE AND REGISTER ALLOCATION

BASIC STAMP I

The RAM space in the BASIC Stamp I consists of eight 16-bit words. Each word has a unique, predefined name as shown in the table below. Each word consists of two 8-bit bytes which have unique, predefined names. Additionally the first two words, PORT and W0, can be accessed as individual bits.

The first word, named PORT, is reserved to allow access and control over the 8 I/O pins on the Stamp I. This word consists of two bytes, PINS and DIRS, which represent the status and the data direction of the pins.

The other seven words are general purpose registers for use by the PBASIC program. They may be used via their direct name or by assigning symbols as aliases to specific registers.

To assign a symbol to a specific register, use the following format:

SYMBOL symbolname = registername

Example: SYMBOL LoopCounter = W0

- SYMBOLNAME is a series of characters (letters, numbers and underscores but not starting with a number) up to 32 characters in length.
- REGISTERNAME is a valid bit, byte or word register name as shown in the table below.

You may assign a symbol to a constant value by using a similar format:

SYMBOL symbolname = constantvalue

Example: SYMBOL MaxLoops = 100

- SYMBOLNAME is a series of characters (letters, numbers and underscores but not starting with a number) up to 32 characters in length.

- CONSTANTVALUE is a valid number in decimal, hexidecimal, binary or ascii.

Stamp I I/O and Variable Space			
Word Name	**Byte Name**	**Bit Names**	**Special Notes**
PORT	PINS DIRS	PIN0 - PIN7 DIR0 - DIR7	I/O pins; bit addressable. I/O pin direction control; bit addressable.
W0	B0 B1	BIT0 - BIT7 BIT8 - BIT15	Bit addressable. Bit addressable.
W1	B2 B3		
W2	B4 B5		
W3	B6 B7		
W4	B8 B9		
W5	B10 B11		
W6	B12 B13		Used by GOSUB instruction. Used by GOSUB instruction.

BASIC STAMP II

The RAM space of the BASIC Stamp II consists of sixteen words of 16 bits each. Each word and each byte within the word has a unique, predefined name similar to the Stamp I and shown in the table below.

The first three words, named INS, OUTS and DIRS, are reserved to allow access and control over the 16 I/O pins on the Stamp II. These reserved words represent the input states, output states and directions of the pins respectively and are the Stamp II version of the single control word, PORT, on the Stamp I. In comparison to the Stamp I, the control registers' size has been doubled and the I/O register PINS has been split into two words, INS and OUTS, for flexibility. Each word consists of a predefined name for its byte, nibble and bit parts.

The other thirteen words are general purpose registers for use by the PBASIC program. There are two methods of referencing these registers within the Stamp II as follows:

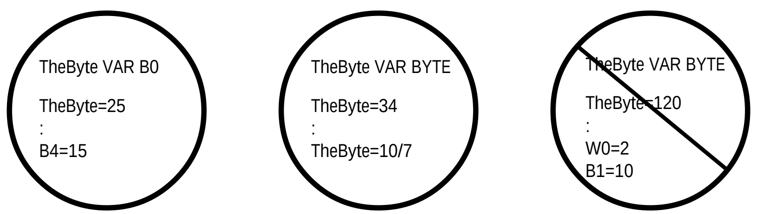
1. They may be referenced via their direct name or by defining symbols as aliases.

   - OR -

2. They may be referenced by defining variables of specific types (byte, word, etc.). The software will automatically assign variables to registers in an efficient manner.

The first method is used in the Stamp I, and supported in the Stamp II, as a means of directly allocating register space. The second method was introduced with the Stamp II as a means of indirectly allocating register space and is the *recommended method.*

It is important to note that defining variables of specific types in the Stamp II is not directly equivalent to assigning symbols to registers in the Stamp I. Defining variables of specific types on the Stamp II allows the software to efficiently and automatically organize variable space within the general purpose registers while assigning symbols to registers allows you to organize variable space yourself. While both methods of register allocation are legal in the Stamp II, care should be taken to implement only one method of register use within each program. Each PBASIC program should either reference all registers by their predefined names (or symbols assigned to them) or reference all registers by defining variables of specific types and let the software do the organization for you. If you use both methods within the same program, it is likely that variables will *overlap* and your program will behave erratically. The following diagram may serve to clarify the use of the register allocation methods within a single Stamp II program:



Using only method 1 within a program is safe. | Using only method 2 within a program is safe. | Using both methods within a program leads to erratic execution.

To define a variable of a specific type, use the following format.

```
variablename  VAR  [ type{(arraysize)} | previousvariable{.modifier{.modifier...}} ]
```

Example:

```
LoopCounter     VAR  WORD                'defines LoopCounter as a word.
LoopCounter2    VAR  BYTE(2)             'defines LoopCounter2 as an array of
                                         'two bytes.
FirstBit        VAR  LoopCounter.LOWBIT  'defines FirstBit as the lowest bit
                                         'within the variable LoopCounter.
```

- VARIABLENAME is a series of characters (letters, numbers and underscores but not starting with a number) up to 32 characters in length.
- TYPE is a valid variable type of BIT, NIB, BYTE or WORD.
- ARRAYSIZE is an optional constant value, in parentheses, specifying the number of elements of TYPE to define for the variable VARIABLENAME.
- PREVIOUSVARIABLE is the name of a previously defined variable. This can be used to assign alias names to the same variable space.
- MODIFIER is an optional offset, preceded by a period '.', which indicates which part of a previously defined variable to set VARIABLENAME to. Valid modifiers are: LOWBYTE, HIGHBYTE, BYTE0..1, LOWNIB, HIGHNIB, NIB0..3, LOWBIT, HIGHBIT and BIT0..15.

You may define a constant by using a similar format:

```
constantname  CON  constantexpression
```

Example:

```
MaxLoops     CON  100          'defines MaxLoops as a constant
                               'equivalent to the number 100.
MaxLoops2    CON  50 * 4 / 2   'also defines MaxLoops as a
                               'constant equivalent to the number 100.
```

C

- CONSTANTNAME is a series of characters (letters, numbers and underscores but not starting with a number) up to 32 characters in length.
- CONSTANTEXPRESSION is a numerical expression in decimal, hexidecimal, binary or ascii using only numbers and the +, -, *, /, &, |, ^, << or >> operators. NOTE: Parentheses are not allowed and expressions are always computed using 16-bits.

Stamp II I/O and Variable Space				
Word Name	**Byte Name**	**Nibble Names**	**Bit Names**	**Special Notes**
INS	INL INH	INA, INB, INC, IND	IN0 - IN7, IN8 - IN15	Input pins; word, byte, nibble and bit addressable.
OUTS	OUTL OUTH	OUTA, OUTB, OUTC, OUTD	OUT0 - OUT7, OUT8 - OUT15	Output pins; word, byte, nibble and bit addressable.
DIRS	DIRL DIRH	DIRA, DIRB, DIRC, DIRD	DIR0 - DIR7, DIR8 - DIR15	I/O pin direction control; word, byte, nibble and bit addressable.
W0	B0 B1			General Purpose; word, byte, nibble and bit addressable.
W1	B2 B3			General Purpose; word, byte, nibble and bit addressable.
W2	B4 B5			General Purpose; word, byte, nibble and bit addressable.
W3	B6 B7			General Purpose; word, byte, nibble and bit addressable.
W4	B8 B9			General Purpose; word, byte, nibble and bit addressable.
W5	B10 B11			General Purpose; word, byte, nibble and bit addressable.
W6	B12 B13			General Purpose; word, byte, nibble and bit addressable.
W7	B14 B15			General Purpose; word, byte, nibble and bit addressable.
W8	B16 B17			General Purpose; word, byte, nibble and bit addressable.
W9	B18 B19			General Purpose; word, byte, nibble and bit addressable.
W10	B20 B21			General Purpose; word, byte, nibble and bit addressable.
W11	B22 B23			General Purpose; word, byte, nibble and bit addressable.
W12	B24 B25			General Purpose; word, byte, nibble and bit addressable.

Symbol Conversion: BS1 ⇨ BS2

1. Remove the 'SYMBOL' directive from variable or constant declarations.

2. On all variable declarations, replace the predefined register name, to the right of the '=', with the corresponding variable type or register name according to the following table:

BS1 to BS2 Register Allocation Conversion	
Stamp I Register Name	**Stamp II Variable Type / Register Name**
PORT	NO EQUIVALENT*
PINS or PIN0..PIN7	INS / OUTS or IN0..IN7 / OUT0..OUT7**
DIRS or DIR0..DIR7	DIRS or DIR0..DIR7
W0..W6	WORD
B0..B13	BYTE
BIT0..BIT15	BIT

* The PORT control register has been split into three registers, INS, OUTS and DIRS, on the Stamp II. There is no predefined name representing all registers as a group as in the Stamp I. Additional symbol and / or program structure and logic changes are necessary to access all three registers properly.

** The Stamp I PINS register has been split into two registers, INS and OUTS, in the Stamp II. Each register now has a specific task, input or output, rather than a dual task, both input and output, as in the Stamp I. If the Stamp I program used the symbol assigned to PINS for both input and output, an additional symbol is necessary to access both functions. This may also require further changes in program structure and logic.

1. On all variable declarations, replace the equal sign, '=', with 'VAR'.

2. On all constant declarations, replace the equal sign, '=', with 'CON'.

Variable or Constant Conversion: BS1 ⇦ BS2

1. Insert the 'SYMBOL' directive before the variable's name or constant's name in the declaration.

2. On all variable declarations, replace the variable type or register name, to the right of the '=', with the corresponding, predefined register name according to the following table:

C

BS2 to BS1 Register Allocation Conversion	
Stamp II Variable Type / Register Name	**Stamp I Register Name**
INS	PINS
OUTS	PINS
DIRS	DIRS
WORD	W0..W6
BYTE	B0..B13
NIB	B0..B13*
BIT	BIT0..BIT15**

* There are no registers on the Stamp I which are nibble addressable. The best possible solution is to place one or two nibble variables within a byte register and modify the code accordingly.

** The only general purpose registers on the Stamp I which are bit addressable are B0 and B1. BIT0..BIT7 correspond to the bits within B0 and BIT8..BIT15 correspond to the bits within B1. If you have a set of bit registers in the Stamp II program, you should reserve B0 and B1 for this bit usage; i.e.: do not assign any other symbols to B0 or B1.

3. On all variable and constant declarations, replace the variable or constant directive, ‘VAR’ or ‘CON’, with an equal sign, ‘=’.

Assignment Conversion: BS1 ⇦ BS2

1. Remove the ‘LET’ command if it is specified.
2. If PINS or PIN0..PIN7 appears to the left, or to the left and right, of the equal sign, ‘=’, replace PINS with OUTS and PIN0..PIN7 with OUT0..OUT7.
3. If PINS or PIN0..PIN7 appears to the right of the equal sign, ‘=’, replace PINS with INS and PIN0..PIN7 with IN0..IN7.
4. If PORT appears in an assignment, determine which byte (PINS or DIRS) is affected and replace PORT with the corresponding Stamp II symbol (INS, OUTS or DIRS). If both bytes are affected, separate assignment statements may be needed to accomplish the equivalent effect in the Stamp II.

BRANCH

BASIC STAMP I

BRANCH **index,(label0, label1,... labeln)**

- INDEX is a constant or a bit, byte or word variable.
- LABEL0..LABELN are valid labels to jump to according to the value of INDEX.

BASIC STAMP II

BRANCH **index,[label0, label1,... labeln]**

- INDEX is a constant, expression or a bit, nibble, byte or word variable.
- LABEL0..LABELN are valid labels to jump to according to the value of INDEX.

CONVERSION: BS1 ⇨ BS2

1. Change open and close parentheses, “(“ and “)”, to open and close brackets, “[“ and “]”.

Example:

```
BS1:     BRANCH  B0, ( Loop1, Loop2, Finish )

BS2:     BRANCH  BranchIdx, [ Loop1, Loop2, Finish ]
```

CONVERSION: BS1 ⇦ BS2

1. Change open and close brackets, “[” and “]”, to open and close parentheses, “(“ and “)”.

Example:

```
BS2:     BRANCH BranchIdx, [ Loop1, Loop2, Finish ]

BS1:     BRANCH  B0, ( Loop1, Loop2, Finish )
```

C

BSAVE

BASIC STAMP I

BSAVE

- This is a compiler directive which causes the Stamp I software to create a file containing the tokenized form or the associated source code.

BASIC STAMP II

NO EQUIVELANT COMMAND

CONVERSION:

No conversion possible.

BUTTON

BASIC STAMP I

BUTTON pin, downstate, delay, rate, workspace, targetstate, label

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- DOWNSTATE is a constant or a bit, byte or word variable in the range 0..1.
- DELAY is a constant or a bit, byte or word variable in the range 0..255.
- RATE is a constant or a bit, byte or word variable in the range 0..255.
- WORKSPACE is a byte or word variable.
- TARGETSTATE is a constant or a bit, byte or word variable in the range 0..1.
- LABEL is a valid label to jump to in the event of a button press.

BASIC STAMP II

BUTTON pin, downstate, delay, rate, workspace, targetstate, label

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- DOWNSTATE is a constant, expression or a bit, nibble, byte or word variable in the range 0..1.
- DELAY is a constant, expression or a bit, nibble, byte or word variable in the range 0..255.
- RATE is a constant, expression or a bit, nibble, byte or word variable in the range 0..255.
- WORKSPACE is a byte or word variable.
- TARGETSTATE is a constant, expression or a bit, nibble, byte or word variable in the range 0..1.

BASIC Stamp I and Stamp II Conversions

- LABEL is a valid label to jump to in the event of a button press.

CONVERSION: BS1 ⇨ BS2

1. PIN may be a constant or a bit, nibble, byte or word variable in the range 0..15.
2. Any or all arguments other than LABEL may be nibble variables for efficiency.

Example:

```
BS1:        BUTTON  0, 1, 255, 0, B0, 1, ButtonWasPressed

BS2:        BUTTON  0, 1, 255, 0, WkspcByte, 1, ButtonWasPressed
```

CONVERSION: BS1 ⇦ BS2

1. PIN must be a constant or a bit, byte or word variable in the range 0..7.
2. No arguments may be nibble variables.

Example:

```
BS2:        BUTTON  12, 1, 255, 0, WkspcByte, 1, ButtonWasPressed

BS1:        BUTTON  7, 1, 255, 0, B0, 1, ButtonWasPressed
```

COUNT

BASIC STAMP I

NO EQUIVELANT COMMAND

BASIC STAMP II

COUNT **pin, period, result**

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- PERIOD is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535.
- RESULT is a bit, nibble, byte or word variable.

CONVERSION:

No conversion possible.

DEBUG

BASIC Stamp I

DEBUG outputdata{,outputdata...}

- OUTPUTDATA is a text string, bit, byte or word variable (no constants allowed).
- If no formatters are specified DEBUG defaults to “variablename = value” + carriage return.

FORMATTERS:
(The following formatting characters may precede the variable name)

#	displays value in decimal followed by a space.
$	displays “variablename = $value ” + carriage return; where value is in hexidecimal.
%	displays “variablename = %value ” + carriage return; where value is in binary.
@	displays “variablename = ‘character’ ” + carriage return; where character is an ascii character.

SPECIAL SYMBOLS:
(The following symbols can be included in the output data)

CLS causes the debug window to be cleared.
CR causes a carriage return in the debug window.

BASIC Stamp II

DEBUG outputdata{,outputdata...}

- OUTPUTDATA is a text string, constant or a bit, nibble, byte or word variable.
- If no formatters are specified DEBUG defaults to ascii character display without spaces or carriage returns following the value.

FORMATTERS:
(The following formatting tokens may precede the data elements as indicated below)

ASC?	value	Displays "variablename = 'character' " + carriage return; where character is an ascii character.
STR	bytearray	Displays values as an ascii string until a value of 0 is reached.
STR	bytearray\n	Displays values as an ascii string for n bytes.
REP	value\n	Displays value n times.
DEC{1..5}	value	Displays value in decimal, optionally limited or padded for 1 to 5 digits.
SDEC{1..5}	value	Displays value in *signed* decimal, optionally limited or padded for 1 to 5 digits. Value must not be less than a word variable.
HEX{1..4}	value	Displays value in hexidecimal, optionally limited or padded for 1 to 4 digits.
SHEX{1..4}	value	Displays value in *signed* hexidecimal, optionally limited or padded for 1 to 4 digits. Value must not be less than a word variable.
IHEX{1..4}	value	Displays value in hexidecimal preceded by a "$" and optionally limited or padded for 1 to 4 digits.
ISHEX{1..4}	value	Displays value in *signed* hexidecimal preceded by a "$" and optionally limited or padded for 1 to 4 digits. Value must not be less than a word variable.
BIN{1..16}	value	Displays value in binary, optionally limited or padded for 1 to 16 digits.
SBIN{1..16}	value	Displays value in *signed* binary, optionally limited or padded for 1 to 16 digits. Value must not be less than a word variable.

IBIN{1..16}	value	Displays value in binary preceded by a "%" and optionally limited or padded for 1 to 16 digits.
ISBIN{1..16}	value	Displays value in *signed* binary preceded by a "%" and optionally limited or padded for 1 to 16 digits. Value must not be less than a word variable.

SPECIAL SYMBOLS:
(The following symbols can be included in the output data)

BELL	Causes the computer to beep.
BKSP	Causes the cursor to backup one space.
CLS	Causes the debug window to be cleared.
CR	Causes a carriage return to occur in debug window.
HOME	Causes the cursor in the debug window to return to home position.
TAB	Causes the cursor to move to next tab position.

CONVERSION: BS1 ⇨ BS2

1. Replace all '#' formatters with 'DEC'.
2. Replace all '$' formatters with 'HEX?'.
3. Replace all '%' formatters with 'BIN?'.
4. Replace all '@' formatters with 'ASC?'.
5. If variable has no formatters preceding it, add the 'DEC?' formatter before variable.

- Signs, type indicators, strings and digit limitation formatting options are available for more flexibility.

Example:

```
BS1:    DEBUG #B0, $B1, %B2

BS2:    DEBUG DEC AByte, HEX? AWord, BIN? ANibble
```

CONVERSION: BS1 ⇦ BS2

1. Remove any ‘DEC?’ formatters preceding variables.
2. Replace all ‘DEC’ formatters with ‘#’.
3. Replace all ‘HEX?’ formatters with ‘$’.
4. Replace all ‘BIN?’ formatters with ‘%’.
5. Replace all ‘ASC?’ formatters with ‘@’.
6. Delete any ‘?’ formatting characters.
7. Signs, type indicators, strings and digit limitation formatters are not available in the Stamp I. Manual formatting will have to be done (possibly multiple DEBUG statements) to accomplish the same formatting.

Example:

```
BS2:    DEBUG DEC AByte, HEX? AWord, BIN? ANibble, CR

BS1:    DEBUG #B0, $B1, %B2, CR
```

DATA

BASIC STAMP I

EEPROM {location,}(data{,data...})

- LOCATION is in the range 0..255.
- DATA is a constant in the range 0..255. No variables are allowed.

BASIC STAMP II

{pointer} DATA {@location,} {WORD} {data}{(size)} {, { WORD} {data}{(size)}...}

- POINTER is an optional undefined constant name or a bit, nibble, byte or word variable which is assigned the value of the first memory location in which data is written.
- @LOCATION is an optional constant, expression or a bit, nibble, byte or word variable which designates the first memory location in which data is to be written.
- WORD is an optional switch which causes DATA to be stored as two separate bytes in memory.
- DATA is an optional constant or expression to be written to memory.
- SIZE is an optional constant or expression which designates the number of bytes of defined or undefined data to write / reserve in memory. If DATA is not specified then undefined data space is reserved and if DATA is specified then SIZE bytes of data equal to DATA are written to memory.

CONVERSION: BS1 ⇨ BS2

1. Replace the EEPROM directive with the DATA directive.
2. If LOCATION is specified, insert an at sign, ‘@’, immediately before it.
3. Remove the open and close parentheses, ‘(‘ and ‘)’.

- The POINTER constant and WORD and (SIZE) directives may be used for added flexibility.

Example:

BS1: EEPROM 100, (255, 128, 64, 92)

BS2: DATA @100, 255, 128, 64, 92

CONVERSION: BS1 ⇦ BS2

1. If a POINTER constant is specified, remove it and set it equal to the value of the first location using a Stamp I assign statement.
2. Replace the DATA directive with the EEPROM directive.
3. If LOCATION is specified, remove the at sign, '@', immediately before it.
4. If the WORD directive is given, remove it and convert the data element immediately following it, if one exists, into two bytes of low-byte, high-byte format. If no data element exists immediately following the WORD directive, (the (SIZE) directive must exist) insert zero data element pairs, '0, 0,' for the number of elements given in (SIZE).
5. Add an open parenthesis, '(', just before the first data element and a close parenthesis, ')', after the last data element.
6. If the (SIZE) directive is given, remove it and copy the preceding data element, if available, into the number of SIZE data elements. If data was not given, insert SIZE data elements of zero, '0', separated by commas.

Example:

BS2: MyDataPtr DATA @100, 255, 128(2), 64, WORD 920, (10)

BS1: SYMBOL MyDataPtr = 100
EEPROM MyDataPtr, (255, 128, 128, 64, 152, 3, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)

DTMFOUT

BASIC STAMP I

NO EQUILEVANT COMMAND

BASIC STAMP II

DTMFOUT pin, {ontime, offtime,}[key{,key...}]

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- ONTIME and OFFTIME are constants, expressions or bit, nibble, byte or word variables in the range 0..65535.
- KEY is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION:

No conversion possible.

EEPROM (See DATA)

C

END

BASIC STAMP I

END

- 20uA reduced current (no loads).

BASIC STAMP II

END

- 50uA reduced current (no loads).

CONVERSION:

No conversion necessary.

EXPRESSIONS

BASIC STAMP I

{-} value ?? value {?? value...}

- Stamp I expressions are only allowed within an assignment statement. See the LET command for more detail.
- VALUE is a constant or a bit, byte or word variable.
- ?? is +,-,*,**,/,//,MIN,MAX,&,1,^,&/,|/,^/.

BASIC STAMP II

{?} value ?? value {?? {?} value}

- Stamp II expressions are allowed in place of almost any argument in any command as well as within an assignment statement.
- ? is SQR, ABS, ~, -, DCD, NCD, COS, SIN.
- VALUE is a constant or a bit, nibble, byte or word variable.
- ?? is +,-,*,**,*/,/,//,MIN,MAX,&,|,^,DIG,<<,>>,REV.
- Parentheses may be used to modify the order of expression evaluation.

CONVERSION: BS1 ⇨ BS2

1. Remove the LET command. This is not allowed in the Stamp II.

- VARIABLE and VALUE may be nibble variables for efficiency.
- The optional unary operator {-} may now also include SQR, ABS, ~, DCD, NCD, COS and SIN.
- The binary operators can now include */, DIG, <<, >> and REV.

Example:

```
BS1:        LET  b0 = -10 + 16

BS2:        Result = -10 + 16
```

BASIC Stamp I and Stamp II Conversions

CONVERSION: BS1 ⇦ BS2

1. Remove any unary operator other than minus (-) and modify the equation as appropriate, if possible.
2. The binary operator can not be */, DIG, <<, >> or REV.
3. VARIABLE and VALUE must not be a nibble variable.

Example:

```
BS2:        Result =  ~%0001 + 16

BS1:        b0 = %1110 + 16
```

FOR...NEXT

BASIC STAMP I

FOR variable = start TO end {STEP {-} stepval}...NEXT {variable}

- Up to 8 nested FOR...NEXT loops are allowed.
- VARIABLE is a bit, byte or word variable.
- START is a constant or a bit, byte or word variable.
- END is a constant or a bit, byte or word variable.
- STEPVAL is a constant or a bit, byte or word variable.
- VARIABLE (after NEXT) must be the same as VARIABLE (after FOR).

BASIC STAMP II

FOR variable = start TO end {STEP stepval}...NEXT

- Up to 16 nested FOR...NEXT loops are allowed.
- VARIABLE is a bit, nibble, byte or word variable.
- START is a constant, expression or a bit, nibble, byte or word variable.
- END is a constant, expression or a bit, nibble, byte or word variable.
- STEPVAL is an optional constant, expression or a bit, nibble, byte or word variable and must be positive.

CONVERSION: BS1 ⇨ BS2

1. Remove the minus sign "-" from the step value if given. The Stamp II dynamically determines the direction at run-time depending on the order of START and END. This allows for great flexibility in programming.

2. Remove the VARIABLE name after the NEXT statement if given. The variable is always assumed to be from the most recent FOR statement and is not allowed in the Stamp II.

- VARIABLE, START, END and STEPVAL may be a nibble variable for efficiency.

- Up to 16 nested FOR...NEXT statements may be used.

Example:

```
BS1:        FOR  B0 = 10 TO 1 STEP -1
  {code inside loop}
  NEXT B0

BS2:        FOR  LoopCount = 10 TO 1 STEP 1
  {code inside loop}
  NEXT
```

CONVERSION: BS1 ⇦ BS2

1. VARIABLE, START, END and STEPVAL must not be a nibble.
2. If negative stepping is to be done, a negative STEPVAL must be specified.
3. Must have no more than 8 nested FOR...NEXT loops.

Example:

```
BS2:        FOR  LoopCount = 100 TO 10 STEP 2
  {code inside loop}
  NEXT

BS1:        FOR  B0 = 100 TO 10 STEP -2
  {code inside loop}
  NEXT
```

FREQOUT

BASIC STAMP I

SOUND pin, (note, duration {,note, duration...})

- PIN is a constant or a bit, byte or word variable in the range of 0..7.
- NOTE is a constant or a bit, byte or word variable in the range of 0..255 representing frequencies in the range 94.8 Hz to 10,550 Hz.
- DURATION is a constant or a bit, byte or word variable in the range of 1..255 specifying the duration in 12 ms units.

BASIC STAMP II

FREQOUT pin, milliseconds, freq1 {,freq2}

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range of 0..15.
- MILLISECONDS is a constant, expression or a bit, nibble, byte or word variable.
- FREQ1 and FREQ2 are constant, expression or bit, nibble, byte or word variables in the range 0..32767 representing the corresponding frequencies. FREQ2 may be used to output 2 sine waves on the same pin simultaneously.

CONVERSION: BS1 ⇨ BS2

1. Change command name ‘SOUND’ to ‘FREQOUT’.
2. Remove the parentheses, ‘(‘ and ‘)’.
3. Swap the orientation of DURATION with NOTE and multiply DURATION by 12.
4. (MILLISECONDS = DURATION * 12).
5. Calculate FREQ1 using the formula: FREQ1 = 1 / (95 x 10^{-6} + ((127 - NOTE) * 83 x 10^{-6}).
5. Place successive NOTE and DURATION pairs into separate FREQOUT commands.

- PIN may be in the range 0..15.

Example:

```
BS1:     SOUND 1, (92, 128, 75, 25)

BS2:     FREQOUT 1, 1536, 333
         FREQOUT 1, 300, 226
```

CONVERSION: BS1 ⇦ BS2

1. Change command name 'FREQOUT' to 'SOUND'.
2. PIN must be in the range 0..7.
3. Insert an open parenthesis just before the MILLISECONDS argument.
4. Swap the orientation of MILLISECONDS with FREQ1 and divide MILLISECONDS by 12. (DURATION = MILLISECONDS / 12).
5. Calculate NOTE using the formula: NOTE = 127 - ((1 / FREQ1) - 95 x 10^{-6}) / 83 x 10^{-6}.
6. Successive FREQOUT commands may be combined into one SOUND command by separating NOTE and DURATION pairs with commas.
7. Insert a close parenthesis, ')', after the last DURATION argument.

- Notes can not be mixed as in the Stamp II

Example:

```
BS2:     FREQOUT 15, 2000, 400
         FREQOUT 15, 500, 600

BS1:     SOUND 7, (98, 167, 108, 42)
```

GOSUB

BASIC STAMP I

GOSUB label

- Up to 16 GOSUBs allowed per program.
- Up to 4 nested GOSUBs allowed.
- Word W6 is modified with every occurrence of GOSUB.

BASIC STAMP II

GOSUB label

- Up to 255 GOSUBs allowed per program.
- Up to 4 nested GOSUBs allowed.

CONVERSION: BS1 ⇨ BS2

- Up to 255 GOSUBs can be used in the program.
- No general purpose variables are modified with the occurrence of GOSUB.

CONVERSION: BS1 ⇦ BS2

1. Only 16 GOSUBs can be used in the program.

- Word W6 is modified with every occurrence of GOSUB.

GOTO

BASIC Stamp I

GOTO label

BASIC Stamp II

GOTO label

Conversion:

No conversion necessary.

HIGH

BASIC STAMP I

HIGH pin

- PIN is a constant, expression or a bit, byte or word variable in the range 0..7.

BASIC STAMP II

HIGH pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇨ BS2

- PIN may be a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇦ BS2

- PIN must be a constant or a bit, byte or word variable in the range 0..7.

Example:

```
BS2:        HIGH  15

BS1:        HIGH  7
```

IF...THEN

BASIC Stamp I

IF variable ?? value {AND/OR variable ?? value...} THEN label

- VARIABLE is a bit, byte or word variable. No constants are allowed.
- ?? is =, <>, >, <, >=, <=.
- VALUE is a constant or a bit, byte, or word variable.
- LABEL is a location to branch to if the result is true.

BASIC Stamp II

IF conditionalexpression THEN label

- CONDITIONALEXPRESSION is any valid Boolean expression using the =, <>, >, <, >=, <=, conditional operators and the AND, OR, NOT, and XOR logical operators.
- LABEL is a location to branch to if the result is true.

Conversion: BS1 ⇨ BS2

1. If VARIABLE is PINS or PIN0..PIN7 then replace in with INS or IN0..IN7.

Conversion: BS1 ⇦ BS2

1. If the INS or OUTS symbol is specified to the left of the conditional operator, replace it with PINS.
2. If the logical operator NOT is specified, remove it and switch the conditional operator to negative logic.
3. If one of the values is an expression, you must perform the calculation in a dummy variable outside of the IF...THEN statement.

Example:

```
BS2:    IF NOT FirstValue > LastValue * (2 + NextValue) THEN Loop

BS1:    Temp = 2 + NextValue * LastValue
        IF FirstValue <= Temp THEN Loop
```

INPUT

BASIC STAMP I

INPUT pin

- PIN is a constant, expression or a bit, byte or word variable in the range 0..7.

BASIC STAMP II

INPUT pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇨ BS2

- PIN may be a nibble variable in the range 0..15.

CONVERSION: BS1 ⇦ BS2

- PIN must not be a nibble variable and must be in the range 0..7 only.

Example:

```
BS2:        INPUT  15

BS1:        INPUT  7
```

BASIC Stamp I and Stamp II Conversions

LET

BASIC STAMP I

{LET} variable = {-} value ?? value {?? value...}

- VARIABLE is a bit, byte or word variable.
- VALUE is a constant or a bit, byte or word variable.
- ?? is +,-,*,**,/,//,MIN,MAX,&,1,^,&/,|/,^/.

BASIC STAMP II

variable = {?} value ?? value {?? {?} value}

- VARIABLE is a bit, nibble, byte or word variable.
- ? is SQR, ABS, ~, -, DCD, NCD, COS, SIN.
- VALUE is a constant or a bit, nibble, byte or word variable.
- ?? is +,-,*,**,*/,/,//,MIN,MAX,&,|,^,DIG,<<,>>,REV.
- Parentheses may be used to modify the order of expression evaluation.

CONVERSION: BS1 ⇨ BS2

1. Remove the LET command. This is not allowed in the Stamp II.

- VARIABLE and VALUE may be nibble variables for efficiency.
- The optional unary operator {-} may now also include SQR, ABS, ~, DCD, NCD, COS and SIN.
- The binary operators can now include */, DIG, <<, >> and REV.

Example:

```
BS1:        LET  b0 = -10 + 16

BS2:        Result = -10 + 16
```

CONVERSION: BS1 ⇦ BS2

1. Remove any unary operator other than minus (-) and modify the equation as appropriate, if possible.

2. The binary operator can not be */, DIG, <<, >> or REV.

3. VARIABLE and VALUE must not be a nibble variable.

Example:

```
BS2:        Result =  ~%0001 + 16

BS1:        b0 = %1110 + 16
```

LOOKDOWN

BASIC Stamp I

LOOKDOWN value, (value0, value1,... valueN), variable

- VALUE is a constant or a bit, byte or word variable.
- VALUE0, VALUE1, etc. are constants or a bit, byte or word variables.
- VARIABLE is a bit, byte or word variable.

BASIC Stamp II

LOOKDOWN value, {??,} [value0, value1,... valueN], variable

- VALUE is a constant, expression or a bit, nibble, byte or word variable.
- ?? is =, <>, >, <, <=, =>. (= is the default).
- VALUE0, VALUE1, etc. are constants, expressions or bit, nibble, byte or word variables.
- VARIABLE is a bit, nibble, byte or word variable.

Conversion: BS1 ⇨ BS2

1. Change all parentheses, "(" and ")", to brackets, "[" and "]"

- Any or all arguments may be nibble variables for efficiency.
- The optional ?? operator may be included for flexibility.

Example:

```
BS1:     LOOKDOWN  b0, ("A", "B", "C", "D"), b1

BS2:     LOOKDOWN  ByteValue, ["A", "B", "C", "D"], Result
```

Conversion: BS1 ⇦ BS2

1. Change all brackets, "[" and "]", to parentheses, "(" and ")".
2. Remove the "??," argument if it exists and modify the list if possible. "=" is assumed in the Stamp I.

• None of the arguments may nibble variables.

Example:

```
BS2:        LOOKDOWN  ByteValue, [1, 2, 3, 4], Result

BS1:        LOOKDOWN  b0, (1, 2, 3, 4), b1
```

LOOKUP

BASIC Stamp I

LOOKUP index, (value0, value1,... valueN), variable

- INDEX is a constant or a bit, byte or word variable.
- VALUE0, VALUE1, etc. are constants or a bit, byte or word variables.
- VARIABLE is a bit, byte or word variable.

BASIC Stamp II

LOOKUP index, [value0, value1,... valueN], variable

- INDEX is a constant, expression or a bit, nibble, byte or word variable.
- VALUE0, VALUE1, etc. are constants, expressions or bit, nibble, byte or word variables.
- VARIABLE is a bit, nibble, byte or word variable.

Conversion: BS1 ⇨ BS2

1. Change all parentheses, “(“ and “)”, to brackets, “[“ and “]”

- Any or all arguments may be nibble variables for efficiency.

Example:

```
BS1:        LOOKUP  b0, (1, 2, 3, 4), b1

BS2:        LOOKUP  ByteValue, [1, 2, 3, 4], Result
```

Conversion: BS1 ⇦ BS2

1. Change all brackets, “[“ and “]”, to parentheses, “(“ and “)”

- None of the arguments may nibble variables.

Example:

```
BS2:        LOOKUP  ByteValue, [1, 2, 3, 4], Result

BS1:        LOOKUP  b0, (1, 2, 3, 4), b1
```

LOW

BASIC Stamp I

LOW pin

- PIN is a constant or a bit, byte or word variable in the range 0..7.

BASIC Stamp II

LOW pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 ⇨ BS2

- PIN may be a constant or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 ⇦ BS2

PIN must be a constant or a bit, byte or word variable in the range 0..7.

Example:

```
BS2:        LOW  15

BS1:        LOW  7
```

NAP

BASIC Stamp I

NAP period

- PERIOD is a constant or a bit, byte or word variable in the range 0..7 representing 18ms intervals.
- Current is reduced to 20uA (assuming no loads).

BASIC Stamp II

NAP period

- PERIOD is a constant, expression or a bit, nibble, byte or word variable in the range 0..7 representing 18ms intervals.
- Current is reduced to 50uA (assuming no loads).

Conversion:

No conversion necessary.

OUTPUT

BASIC STAMP I

OUTPUT pin

- PIN is a constant or a bit, byte or word variable in the range 0..7.

BASIC STAMP II

OUTPUT pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇨ BS2

- PIN may be a constant or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇦ BS2

1. PIN must be a constant or a bit, byte or word variable in the range 0..7.

Example:

```
BS2:    OUTPUT 15

BS1:    INPUT 7
```

C

PAUSE

BASIC STAMP I

PAUSE milliseconds

- MILLISECONDS is a constant or a bit, byte or word variable in the range 0..65535.

BASIC STAMP II

PAUSE milliseconds

- MILLISECONDS is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535.

CONVERSION:

No conversion necessary.

POT (See RCTIME)

C

PULSIN

BASIC STAMP I

PULSIN pin, state, variable

- PIN is a constant, expression or a bit, byte or word variable in the range 0..7.
- STATE is a constant, expression or a bit, byte or word variable in the range 0..1.
- VARIABLE is a bit, byte or word variable.
- Measurements are in 10uS intervals and the instruction will time out in 0.65535 seconds.

BASIC STAMP II

PULSIN pin, state, variable

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- STATE is a constant, expression or a bit, nibble, byte or word variable in the range 0..1.
- VARIABLE is a bit, nibble, byte or word variable.
- Measurements are in 2uS intervals and the instruction will time out in 0.13107 seconds.

CONVERSION: BS1 ⇨ BS2

- Any or all arguments may be a nibble variable for efficiency.
- PIN may be in the range 0..15.
- Returned value is 5 times less than in the Stamp I counterpart.

CONVERSION: BS1 ⇦ BS2

- None of the arguments may be a nibble variable.
- PIN must be in the range 0..7.
- Returned value is 5 times more than in the Stamp I counterpart.

Example:

```
BS2:        PULSIN  15, 1, Result

BS1:        PULSIN  7, 1, W0
```

PULSOUT

BASIC Stamp I

PULSOUT pin, time

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- TIME is a constant or a bit, byte or word variable in the range 0..65535 representing the pulse width in 10uS units.

BASIC Stamp II

PULSOUT pin, period

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- PERIOD is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535 representing the pulse width in 2uS units.

Conversion: BS1 ⇨ BS2

1. PERIOD = TIME * 5.

- PIN may be a nibble variable in the range 0..15.

Example:

```
BS1:        PULSOUT  1, 10

BS2:        PULSOUT  1, 50
```

Conversion: BS1 ⇦ BS2

1. TIME = PERIOD / 5.

- PIN must be in the range 0..7 and must not be a nibble variable.

Example:

```
BS2:        PULSOUT  15, 25

BS1:        PULSOUT  7, 5
```

PWM

BASIC STAMP I

PWM pin, duty, cycles

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- DUTY is a constant or a bit, byte or word variable in the range 0..255.
- CYCLES is a constant or a bit, byte or word variable in the range 0..255 representing the number of 5ms cycles to output.

BASIC STAMP II

PWM pin, duty, cycles

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- DUTY is a constant, expression or a bit, nibble, byte or word variable in the range 0..255.
- CYCLES is a constant, expression or a bit, nibble, byte or word variable in the range 0..255 representing the number of 1ms cycles to output.

C

CONVERSION: BS1 ⇨ BS2

1. CYCLES = CYCLES * 5.

- PIN may be a nibble variable in the range 0..15.

Example:

```
BS1:        PWM  0, 5, 1

BS2:        PWM  0, 5, 5
```

CONVERSION: BS1 ⇦ BS2

1. CYCLES = CYCLES / 5.

- PIN must be in the range 0..7 and must not be a nibble variable.

Example:

```
BS2:        PWM  15, 5, 20

BS1:        PWM  7, 5, 4
```

RANDOM

BASIC STAMP I

RANDOM variable

- VARIABLE is a byte or word variable in the range 0..65535.

BASIC STAMP II

RANDOM variable

- VARIABLE is a byte or word variable in the range 0..65535.

CONVERSION: BS1 ⇨ BS2

- The numbers generated for any given input will not be the same on the Stamp II as in the Stamp I.

CONVERSION: BS1 ⇦ BS2

- The numbers generated for any given input will not be the same on the Stamp I as in the Stamp II.

RCTIME

BASIC Stamp I

POT pin, scale, bytevariable

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- SCALE is a constant or a bit, byte or word variable in the range 0..255.
- BYTEVARIABLE is a byte variable.

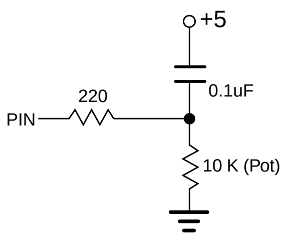
BASIC Stamp II

RCTIME pin, state, variable

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- STATE is a constant, expression or a bit, nibble, byte or word variable in the range 0..1.
- VARIABLE is a bit, nibble, byte or word variable.

Conversion: BS1 ⇨ BS2

1. Modify the circuit connected to PIN to look similar to the following diagram. (Note, your values for the resistors and capacitor may be different).



2. Insert two lines before the POT command as follows:

   HIGH pin   ; where PIN is the same PIN in the POT command.

PAUSE delay ; where DELAY is an appropriate time in milliseconds to allow the capacitor to; fully discharge. You may have to try different DELAY values to find an optimal; value.

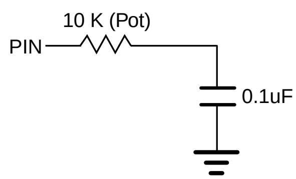
3. Change the command's name from 'POT' to 'RCTIME'.

4. Replace the SCALE argument with a STATE argument; our example requires a 1.

- PIN may be a nibble variable in the range 0..15.

CONVERSION: BS1 ⇦ BS2

1. Modify the circuit connected to PIN to look similar to the following diagram. (Note, your values for the resistor and capacitor may be different).



2. Delete the code before the RCTIME command which discharges the capacitor. This code usually consists of two lines as follows:

HIGH pin ; where PIN is the same PIN in the RCTIME command.

PAUSE delay ; where DELAY is an appropriate time in milliseconds to allow the capacitor to; fully discharge.

3. Change the command's name from 'RCTIME' to 'POT'.

4. Use the ALT-P key combination to determine the appropriate scale factor for the POT you are using as described in the BASIC Stamp I manual.

5. Replace the STATE argument with a SCALE argument.
6. Make VARIABLE a byte variable.

- PIN must be in the range 0..7 and must not be a nibble variable.

READ

BASIC Stamp I

READ location, variable

- LOCATION is a constant or a bit, byte or word variable in the range 0..255.
- VARIABLE is a bit, byte or word variable.

BASIC Stamp II

READ location, variable

- LOCATION is a constant, expression or a bit, nibble, byte or word variable in the range 0..2047.
- VARIABLE is a bit, nibble, byte or word variable.

Conversion: BS1 ⇨ BS2

- LOCATION and VARIABLE may be a nibble variable for efficiency.
- LOCATION may be in the range 0..2047.

C

Conversion: BS1 ⇦ BS2

- LOCATION and VARIABLE must not be a nibble variable.
- LOCATION must be in the range 0..255.

REVERSE

BASIC STAMP I

REVERSE pin

- PIN is a constant or a bit, byte or word variable in the range 0..7.

BASIC STAMP II

REVERSE pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇨ BS2

- PIN may be a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

CONVERSION: BS1 ⇦ BS2

- PIN must be a constant or a bit, byte or word variable in the range 0..7.

Example:

```
BS2:        REVERSE  15

BS1:        REVERSE  7
```

SERIN

BASIC STAMP I

SERIN pin, baudmode {,(qualifier {,qualifier...}) } {,{#} variable...}

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- BAUDMODE is a constant or a bit, byte or word variable in the range 0..7 or a symbol with the following format: [T | N][2400 | 1200 | 600 | 300].
- QUALIFIERs are optional constants or a bit, byte or word variables which must be received in the designated order for execution to continue.
- VARIABLE is a bit, byte or word variable.
- # will convert ascii numbers to a binary equivalent.

BASIC STAMP II

SERIN rpin{\fpin}, baudmode, {plabel,} {timeout, tlabel,} [inputdata]

- RPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..16.
- FPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- BAUDMODE is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535.
- PLABEL is a label to jump to in case of a parity error.
- TIMEOUT is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535 representing the number of milliseconds to wait for an incoming message.
- TLABEL is a label to jump to in case of a timeout.
- INPUTDATA is a set of constants, expressions and variable names separated by commas and optionally proceeded by the formatters available in the DEBUG command, except the ASC and REP

formatters. Additionally, the following formatters are available:

STR	bytearray\L{\E}	input a string into bytearray of length L with optional end-character of E. (0's will fill remaining bytes).
SKIP	L	input and ignore L bytes.
WAITSTR	bytearray{\L}	Wait for bytearray string (of L length, or terminated by 0 if parameter is not specified and is 6 bytes maximum).
WAIT	(value {,value...})	Wait for up to a six-byte sequence.

CONVERSION: BS1 ⇨ BS2

1. BAUDMODE is a constant or a bit, nibble, byte or word variable equal to the bit period of the baud rate plus three control bits which specify 8-bit / 7-bit, True / Inverted and Driven / Open output. The following table lists the Stamp I baudmodes and the corresponding Stamp II baudmode:

SERIN Baudmode Conversion		
Stamp I Baudmode		Stamp II Baudmode
0	T2400	396
1	T1200	813
2	T600	1646
3	T300	3313
4	N2400	396 + $4000
5	N1200	813 + $4000
6	N600	1646 + $4000
7	N300	3313 + $4000

2. INPUTDATA includes QUALIFIERS and VARIABLES and must

be encased in brackets, "[" and "]". If QUALIFIERS are present, insert the modifier "WAIT" immediately before the open parenthesis before the first QUALIFIER.

3. Replace any optional "#" formatters with the equivalent "DEC" formatter.

- RPIN = PIN and may be in the range 0..16
- BAUDMODE may be any bit period in between 300 baud and 50000 baud and can be calculated using the following formula: INT(1,000,000 / Baud Rate) - 20.
- The optional formatter may include any formatter listed for INPUTDATA above.

Example:

```
BS1:    SERIN  0, 1, ("ABCD"), #B0, B1

BS2:    SERIN  0, 813, [WAIT("ABCD"), DEC FirstByte, SecondByte]
```

CONVERSION: BS1 ⇦ BS2

1. PIN = RPIN and must be in the range 0..7.
2. Remove the FPIN argument "\fpin" if it is specified. No flow control pin is available on the Stamp I.
3. BAUDMODE is a constant or a symbol or a bit, byte or word variable representing one of the predefined baudmodes. Refer to the BAUDMODE Conversion table above for Stamp II baudmodes and their corresponding Stamp I baudmodes. While the Stamp II baudmode is quite flexible, the Stamp I can only emulate specific baud rates.
4. Remove the PLABEL argument if it is specified. No parity error checking is done on the Stamp I.
5. Remove the TIMEOUT and TLABEL arguments if they are specified. No timeout function is available on the Stamp I; the program will halt at the SERIN instruction until satisfactory data arrives.
6. Remove the brackets, "[" and "]".

7. If QUALIFIERS are specified within a WAIT modifier, remove the word “WAIT”.

8. IF QUALIFIERS are specified within a WAITSTR modifier, replace the word “WAITSTR” with an open parenthesis, “(“. Convert the bytearray into a constant text or number sequence separated by commas if necessary (remove the length specifier “\L” if one exists) and insert a close parenthesis, “)”, immediately afterward.

9. If a variable is preceded with a DEC formatter, replace the word “DEC” with “#”.

10. Any formatter other than DEC and WAIT or WAITSTR has no direct equivalent in the Stamp I and must be removed. Additional variables or parsing routines will have to be used to achieve the same results in the Stamp I as with the Stamp II.

Example:

```
BS2:    SERIN 15, 813, 1000, TimedOut, [WAIT("ABCD"), DEC
        FirstByte, SecondByte]

BS1:    SERIN 7, 1, ("ABCD"), #B0, B1
```

SEROUT

BASIC STAMP I

SEROUT pin, baudmode, ({#} data {, {#} data...})

- PIN is a constant or a bit, byte or word variable in the range 0..7.
- BAUDMODE is a constant or a bit, byte or word variable in the range 0..15 or a symbol with the following format: {O}[T | N][2400 | 1200 | 600 | 300].
- DATA is a constant or a bit, byte or word variable.
- # will convert binary numbers to ascii text equivalents up to 5 digits in length.

BASIC STAMP II

SEROUT tpin{\fpin}, baudmode, {pace,} {timeout, tlabel,} [outputdata]

- TPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..16.
- FPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.
- BAUDMODE is a constant, expression or a bit, nibble, byte or word variable in the range 0..60657.
- PACE is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535 specifying a time (in milliseconds) to delay between transmitted bytes. This value can only be specified if the FPIN is not specified.
- TIMEOUT is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535 representing the number of milliseconds to wait for the signal to transmit the message. This value can only be specified if the FPIN is specified.
- TLABEL is a label to jump to in case of a timeout. This can only be specified if the FPIN is specified.

- OUTPUTDATA is a set of constants, expressions and variable names separated by commas and optionally proceeded by the formatters available in the DEBUG command.

CONVERSION: BS1 ⇨ BS2

1. BAUDMODE is a constant or a bit, nibble, byte or word variable equal to the bit period of the baud rate plus three control bits which specify 8-bit / 7-bit, True / Inverted and Driven / Open output. The following table lists the Stamp I baudmodes and the corresponding Stamp II baudmode:

SEROUT Baudmode Conversion		
Stamp I Baudmode		Stamp II Baudmode
0	T2400	396
1	T1200	813
2	T600	1646
3	T300	3313
4	N2400	396 + $4000
5	N1200	813 + $4000
6	N600	1646 + $4000
7	N300	3313 + $4000
8	OT2400	396 + $8000
9	OT1200	813 + $8000
10	OT600	1646 + $8000
11	OT300	3313 + $8000
12	ON2400	396 + $C000
13	ON1200	813 + $C000
14	ON600	1646 + $C000
15	ON300	3313 + $C000

1. Replace the parentheses, “(“ and “)”, with brackets, “[“ and “]”.
2. Replace any optional “#” formatters with the equivalent “DEC” formatter.

- TPIN = PIN and may be in the range 0..16.
- BAUDMODE may be any bit period in between 300 baud and 50000 baud and can be calculated using the following formula: INT(1,000,000 / Baud Rate) - 20.
- The optional formatter may include any valid formatter for the DEBUG command.

Example:

```
BS1:     SEROUT  3, T2400, ("Start", #B0, B1)

BS2:     SEROUT  3, 396, ["Start", DEC FirstByte, SecondByte]
```

CONVERSION: BS1 ⇦ BS2

1. PIN = TPIN and must be in the range 0..7.
2. Remove the FPIN argument "\fpin" if it is specified. No flow control pin is available on the Stamp I.
3. BAUDMODE is a constant or a symbol or a bit, byte or word variable representing one of the predefined baudmodes. Refer to the BAUDMODE Conversion table above for Stamp II baudmodes and their corresponding Stamp I baudmodes. While the Stamp II baudmode is quite flexible, the Stamp I can only emulate specific baud rates.
4. Remove the PACE argument if it is specified. No pace value is allowed on the Stamp I.
5. Remove the TIMEOUT and TLABEL arguments if they are specified. No timeout function is available on the Stamp I; the program will transmit data regardless of the status of the receiver.
6. Replace the brackets, "[" and "]", with parentheses, "(" and ")".
7. If a variable is preceded with a DEC formatter, replace the word "DEC" with "#".
8. Any formatter other than DEC has no direct equivalent in the Stamp I and must be removed. Additional variables or constants will have to be used to achieve the same results in the Stamp I as with the Stamp II.

Example:

BS2: SEROUT 15, 3313, 1000, TimedOut, [“Start”, DEC FirstByte, SecondByte]

BS1: SEROUT 7, T300, (“Start”, #B0, B1)

SHIFTIN

BASIC STAMP I

NO EQUIVELANT COMMAND

BASIC STAMP II

SHIFTIN dpin, cpin, mode, [result{\bits} { ,result{\bits}... }]

- DPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the data pin.
- CPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the clock pin.
- MODE is a constant, symbol, expression or a bit, nibble, byte or word variable in the range 0..4 specifying the bit order and clock mode. 0 or MSBPRE = msb first, pre-clock, 1 or LSBPRE = lsb first, pre-clock, 2 or MSBPOST = msb first, post-clock, 3 or LSBPOST = lsb first, post-clock.
- RESULT is a bit, nibble, byte or word variable where the received data is stored.
- BITS is a constant, expression or a bit, nibble, byte or word variable in the range 1..16 specifying the number of bits to receive in RESULT. The default is 8.

C

CONVERSION: BS1 ⇨ BS2

- Code such as the following:

```
SYMBOL  Value = B0          'Result of shifted data
SYMBOL  Count = B1          'Counter variable
SYMBOL  CLK = 0             'Clock pin is pin 0
SYMBOL  DATA = PIN1         'Data pin is pin 1

DIRS  =  %00000001          'Set Clock pin as output and Data pin as input

FOR  Count = 1 TO 8
   PULSOUT CLK,1            'Preclock the data
   Value = Value * 2 + DATA 'Shift result left and grab next data bit
NEXT Count
```

May be converted to the following code:

```
Value     VAR    BYTE          'Result of shifted data
CLK       CON    0             'Clock pin is pin 0
DATA      CON    1             'Data pin is pin 1

DIRS  =  %0000000000000001     'Set Clock pin as output and Data pin
as input

SHIFTIN  DATA, CLK, MSBPRE, [Value\8]
```

CONVERSION: BS1 ⇦ BS2

- Code such as the following:

```
Value     VAR    BYTE          'Result of shifted data

DIRS  =  %0000000000000001     'Clock pin is 0 and Data pin is 1

SHIFTIN  1, 0, LSBPOST, [Value\8]
```

May be converted to the following code:

```
SYMBOL  Value = B0             'Result of shifted data
SYMBOL  Count = B1             'Counter variable

DIRS  =  %00000001             'Clock pin is 0 and Data pin is 1

FOR  Count = 1 TO 8
  Value = DATA * 256 + Value / 2   'Shift grab next data bit and shift right
  PULSOUT CLK,1                    'Postclock the data
NEXT Count
```

SHIFTOUT

BASIC Stamp I

NO EQUIVELANT COMMAND

BASIC Stamp II

SHIFTOUT dpin, cpin, mode, [data{\bits} {, data{\bits}... }]

- DPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the data pin.
- CPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the clock pin.
- MODE is a constant, symbol, expression or a bit, nibble, byte or word variable in the range 0..1 specifying the bit order. 0 or LSBFIRST = lsb first, 1 or MSBFIRST = msb first.
- DATA is a constant, expression or a bit, nibble, byte or word variable containing the data to send out.
- BITS is a constant, expression or a bit, nibble, byte or word variable in the range 1..16 specifying the number of bits of DATA to send. The default is 8.

C

Conversion: BS1 ⇨ BS2

Code such as the following:

```
SYMBOL  Count = B1            'Counter variable
SYMBOL  CLK = 0               'Clock pin is pin 0
SYMBOL  DATA = PIN1           'Data pin is pin 1

DIRS  =  %00000011            'Set Clock and Data pins as outputs

   B0 = 125                   'Value to be shifted out

FOR  Count = 1 TO 8
   DATA = BIT7                'Send out MSB of B0
   PULSOUT CLK,1              'Clock the data
   B0 = B0 * 2                'Shift the value left; note that this causes us
                              'to lose the value
NEXT Count                    'when we're done shifting
```

May be converted to the following code:

```
Value        VAR     BYTE                            'Value to be shifted out
CLK          CON     0                               'Clock pin is pin 0
DATA         CON     1                               'Data pin is pin 1

DIRS  =  %0000000000000011                           'Set Clock and Data pins as
                                                     'outputs

Value = 125

SHIFTOUT  DATA, CLK, MSBFIRST, [Value\8]             'Note that value is still intact
                                                     'after were done shifting
```

CONVERSION: BS1 ⇦ BS2

Code such as the following:

```
Value        VAR     BYTE                            'Value to be shifted out
CLK          CON     0                               'Clock pin is pin 0
DATA         CON     1                               'Data pin is pin 1

DIRS  =  %0000000000000011                           'Set Clock and Data pins as
                                                     'outputs

Value = 220

SHIFTOUT  DATA, CLK, LSBFIRST, [Value\8]             'Note that value is still intact
                                                     'after were done shifting
```

May be converted to the following code:

```
SYMBOL  Count = B1                                   'Counter variable
SYMBOL  CLK = 0                                      'Clock pin is pin 0
SYMBOL  DATA = PIN1                                  'Data pin is pin 1

DIRS  =  %00000011                                   'Set Clock and Data pins as
                                                     'outputs

             B0 = 220                                'Value to be shifted out

FOR  Count = 1 TO 8
             DATA = BIT0                             'Send out LSB of B0
             PULSOUT CLK,1                           'Clock the data
             B0 = B0 / 2                             'Shift the value left; note that
                                                     'the value is lost after were
                                                     'done
NEXT Count                                           'shifting
```

SLEEP

BASIC STAMP I

SLEEP seconds

- SECONDS is a constant or a bit, byte or word variable in the range 1..65535 specifying the number of seconds to sleep.

BASIC STAMP II

SLEEP seconds

- SECONDS is a constant, expression or a bit, nibble, byte or word variable in the range 0..65535 specifying the number of seconds to sleep.

CONVERSION:

No conversion necessary.

SOUND (See FREQOUT)

STOP

BASIC STAMP I

NO EQUIVELANT COMMAND

BASIC STAMP II

STOP

- Execution is frozen, such as with the END command, however, low-power mode is not entered and the I/O pins never go into high impedance mode.

CONVERSION: BS1 ⇨ BS2

Code such as the following:

```
StopExecution:     GOTO StopExecution
```

May be converted to the following code:

```
StopExecution:     STOP
```

CONVERSION: BS1 ⇦ BS2

Code such as the following:

```
Quit:     STOP
```

May be converted to the following code:

```
Quit:     GOTO Quit
```

C

TOGGLE

BASIC Stamp I

TOGGLE pin

- PIN is a constant or a bit, byte or word variable in the range 0..7.

BASIC Stamp II

TOGGLE pin

- PIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 ⇨ BS2

- PIN may be a nibble variable and may be in the range 0..15.

Conversion: BS1 ⇦ BS2

- PIN must not be a nibble variable and must be in the range 0..7.

Example:

```
BS2:    TOGGLE 15

BS1:    TOGGLE 7
```

WRITE

BASIC STAMP I

WRITE location, data

- LOCATION is a constant or a bit, byte or word variable in the range 0..255.
- DATA is a constant or a bit, byte or word variable.

BASIC STAMP II

WRITE location, data

- LOCATION is a constant, expression or a bit, nibble, byte or word variable in the range 0..2047.
- DATA is a constant, expression or a bit, nibble, byte or word variable.

CONVERSION: BS1 ⇨ BS2

- LOCATION and DATA may be a nibble variable for efficiency.
- LOCATION may be in the range 0..2047.

CONVERSION: BS1 ⇦ BS2

- LOCATION and DATA must not be a nibble variable.
- LOCATION must be in the range 0..255.

XOUT

BASIC STAMP I

NO EQUIVELANT COMMAND

BASIC STAMP II

XOUT mpin, zpin, [house\keyorcommand{\cycles}
{, house\keyorcommand{\cycles}... }]

- MPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the modulation pin.
- ZPIN is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the zero-crossing pin.
- HOUSE is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying the house code A..P respectively.
- KEYORCOMMAND is a constant, expression or a bit, nibble, byte or word variable in the range 0..15 specifying keys 1..16 respectively or is one of the commands in the following table:

X-10 Commands	
X-10 Command (symbol)	**Value**
UNITON	%10010
UNITOFF	%11010
UNITSOFF	%11100
LIGHTSON	%10100
DIM	%11110
BRIGHT	%10110

- CYCLES is a constant, expression or a bit, nibble, byte or word variable in the range 2..65535 specifying the number of cycles to send. (Default is 2).

CONVERSION:

No conversion possible.

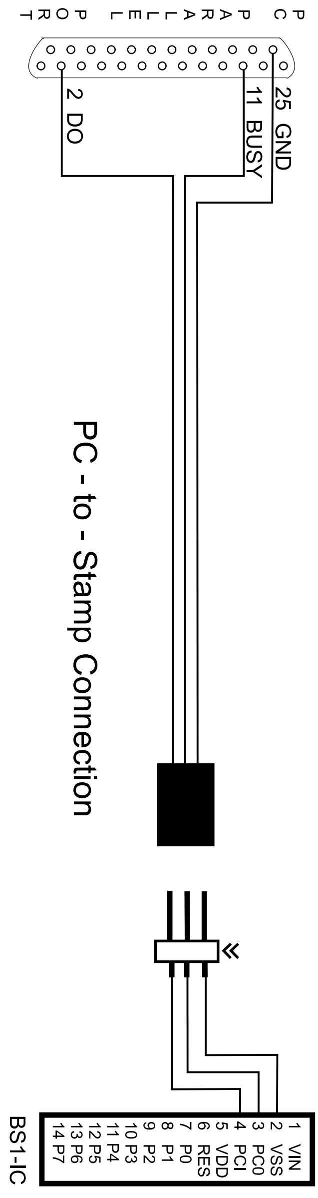
This appendix contains electrical and physical details and schematics of the BASIC Stamp I and BASIC Stamp II modules (BS1-IC and BS2-IC). The schematics show interpreter chip connections for the SSOP package type only. When duplicating the BASIC Stamp module circuit using DIP or SOIC packaged interpreter chips, please consult the appropriate databook or call Parallax Technical Support for assistance.

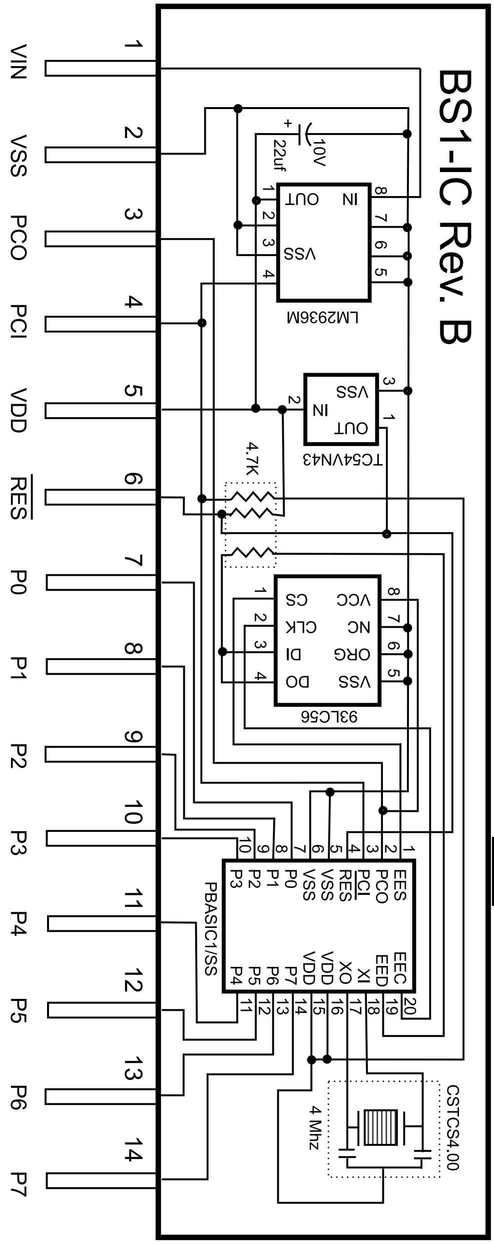
BASIC Stamp I circuit in SMT

* PBASIC 1.4 Interpreter
* 256-Byte EEPROM
* 4MHz Resonator
* 5V Regulator
* 4V Brown-Out Reset
* PC Parallel Interface
* 8 User I/O Pins
* 1.4 mA Run / 40uA Sleep
  (No loads, I/O's @ VSS/VDD)

<table>
<tr><th>PIN</th><th>NAME</th><th>FUNCTION</th><th colspan="2">DESCRIPTION</th></tr>
<tr><td>1</td><td>VIN</td><td>Regulator In</td><td colspan="2">Input to 5V regulator. Accepts 5.5 - 15 VDC. If power is applied directly to VDD, pin may be left unconnected.</td></tr>
<tr><td>2</td><td>VSS</td><td>Ground</td><td>Connects to PC Parallel Port pin 25 (GND).</td><td rowspan="3">These pins are arranged to connect straight-across to a 3-pin header for the BASIC Stamp programming cable.</td></tr>
<tr><td>3</td><td>PCO</td><td>PC Out</td><td>Connects to PC Parallel Port pin 11 (BUSY).</td></tr>
<tr><td>4</td><td>PCI</td><td>PC In</td><td>Connects to PC Parallel Port pin 2 (D0).</td></tr>
<tr><td>5</td><td>VDD</td><td>Regulator Out

Power In</td><td colspan="2">Output from 5V regulator (VIN powered). Can source up to 50mA,
including P0-P7 loads.
Power input (VIN not powered). Accepts 4.5V-5.5V. Load is dependent upon
run/sleep mode and P0-P7 sourcing.</td></tr>
<tr><td>6</td><td>$\overline{RES}$</td><td>Reset I/O</td><td colspan="2">Goes low when VDD is less than 4V. Pulled high by a 4.7K resistor. May be
monitored as a brown-out/reset indicator. Can be pulled low externally
(i.e. button to GND) to force a reset. Do not drive high.</td></tr>
<tr><td>7
8
9
10
11
12
13
14</td><td>P0
P1
P2
P3
P4
P5
P6
P7</td><td>User I/O 0
User I/O 1
User I/O 2
User I/O 3
User I/O 4
User I/O 5
User I/O 6
User I/O 7</td><td colspan="2">User port pins that can be configured as inputs or outputs.
In output mode:
- Pins can source up to 20 mA each. Total of all pins should not exceed 40 mA.
- Pins can sink up to 25 mA each. Total of all pins should not exceed 50 mA.
In input mode:
-Pins are floating (1uA leakage) and can be driven high or low. The 0/1 threshold
is approx. 1.4V. For low power during sleep, make sure no pins are floating.
Drive them to VSS or VDD, or make them unconnected outputs.</td></tr>
</table>

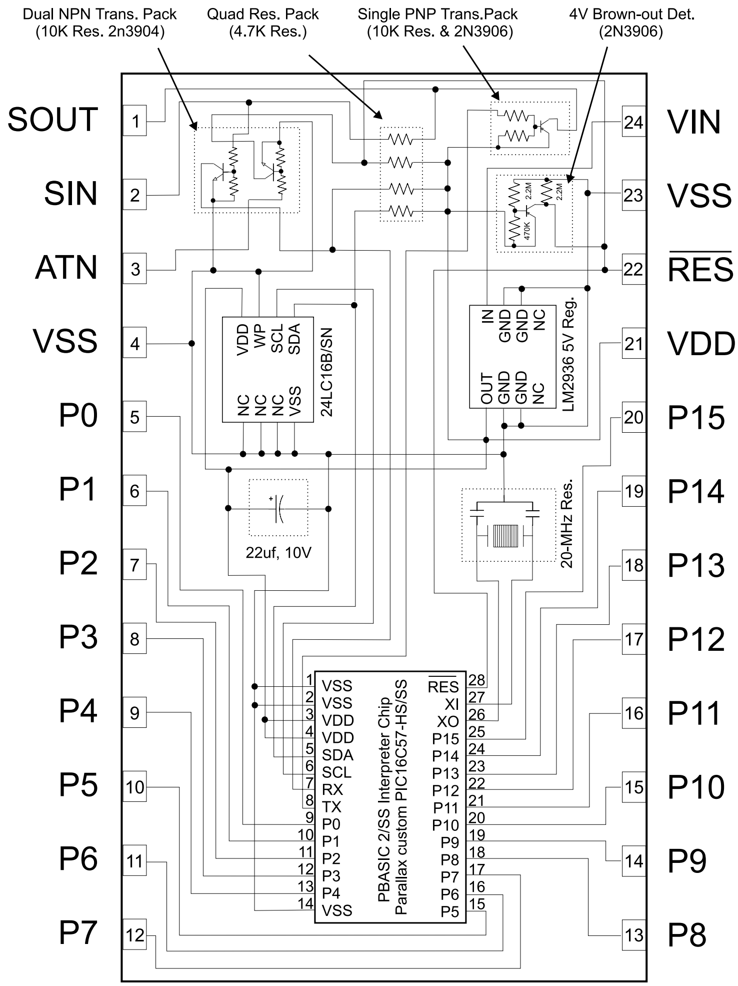

PC PARALLEL PORT
25 GND
11 BUSY
2 DO
PC - to - Stamp Connection
BS1-IC
1 VIN
2 VSS
3 PC0
4 PCI
5 VDD
6 RES
7 P0
8 P1
9 P2
10 P3
11 P4
12 P5
13 P6
14 P7

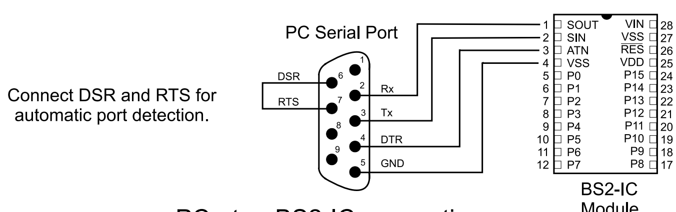

BS1-IC Rev. B
VIN
VSS
PCO
PCI
VDD
RES
P0
P1
P2
P3
P4
P5
P6
P7
10V
22uf
LM2936M
IN
OUT
VSS
TC54VN43
4.7K
93LC56
CS
CLK
DI
DO
VCC
NC
ORG
VSS
PBASIC1/SS
EES
PCO
PCI
RES
VSS
VSS
P0
P1
P2
P3
EEC
EED
XI
XO
VDD
VDD
P7
P6
P5
P4
CSTCS4.00
4 Mhz

BASIC Stamp II circuit in SMT

* PBASIC2 Interpreter
* 2048-Byte EEPROM
* 20MHz Resonator
* 5V Regulator
* 4V Brown-Out Reset
* PC Serial Interface
* 16 User I/O Pins
* 8mA Run / 100uA Sleep
  (No loads, I/O's @ VSS/VDD)

PIN	NAME	FUNCTION	DESCRIPTION	
1	SOUT	Serial Out	Temporarily connects to PC's Rx.	After programming, these pins may be left unconnected.
2	SIN	Serial In	Temporarily connects to PC's Tx.	
3	ATN	Attention	Temporarily connects to PC's DTR.	
4	VSS	Ground	Temporarily connects to PC's GND.	
5	P0	User I/O 0	User port pins that can be programmed as inputs or outputs.	
6	P1	User I/O 1	In output mode:	
7	P2	User I/O 2	Pins will source from VDD or sink to VSS. Pins	
8	P3	User I/O 3	should not be allowed to source more that 20mA or	
9	P4	User I/O 4	sink more than 25mA each. As groups, PO-P7	
10	P5	User I/O 5	and P8-P15 should not be allowed to source more	
11	P6	User I/O 6	than 40mA or sink more that 50mA each.	
12	P7	User I/O 7	In input mode:	
13	P8	User I/O 8	Pins are floating (less than 1uA leakage). The	
14	P9	User I/O 9	0/1 logic threshold is approximately 1.4V.	
15	P10	User I/O 10		
16	P11	User I/O 11	Note: To realize low power during sleep, make sure that	
17	P12	User I/O 12	no pins are floating, causing erratic power drain.	
18	P13	User I/O 13	Either drive them to VSS or VDD, or program	
19	P14	User I/O 14	them as outputs that don't have to source	
20	P15	User I/O 15	current.	
21	VDD	Regulator Out Power In	Output from 5V regulator (VIN powered). Should not be allowed to source more than 50mA, including P0-P15 loads. Power input (VIN not powered). Accepts 4.5V-5.5V. Current consumption is dependent upon run/sleep mode and I/O's.	
22	$\overline{\text{RES}}$	Reset I/O	When low, all I/O's are inputs and program execution is suspended. When high, program executes from start. Goes low when VDD is less that 4V or ATN is greater than 1.4V. Pulled to VDD by a 4.7K resistor. May be monitored as a brown-out/reset indicator. Can be pulled low externally (i.e. button to VSS) to force a reset. Do not drive high.	
23	VSS	Ground	Ground. Located adjacent to VIN for easy battery hookup.	
24	VIN	Regulator In	Input to 5V regulator. Accepts 5.5V to 15V. If power is applied directly to VDD, pin may be left unconnected.	





PC - to - BS2-IC connection

I

BASIC Stamp I Index

I

BASIC Stamp I Index

- L -

- M -

- T -

- U -

- V -

- W -

- X -

I