BASIC Stamp® Programming Manual

Version 1.8

PARALLAX INC®

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

BASIC Stamp I:
- STAMP.EXE software version 2.0
- 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 BBS and 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.

BASIC Stamp II:

Contents

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 computer system:

- IBM PC or compatible computer
- 3.5-inch disk drive
- Serial 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 Programming Manual (this manual)
- BASIC Stamp I programming cable (parallel port DB25-to-3 pin)
- BASIC Stamp II programming cable (serial port DB9-to-DB9)
- BASIC Stamp I and BASIC Stamp II schematics
- 3.5-inch diskette

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).

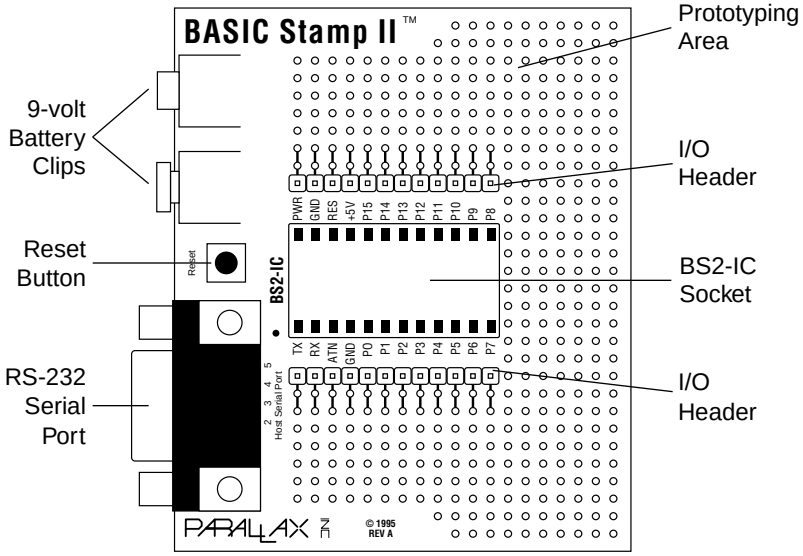
To connect the BASIC Stamp II to your PC, follow these steps:

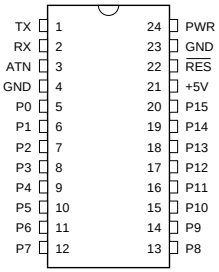
1) Plug the BS2-IC onto the carrier board. The BS2-IC plugs into a 24-pin DIP socket, located in the center of the carrier. When plugged onto the carrier board, the words "Parallax BS2-IC" should be near the reset button.

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	RES	Active-low reset	Pull low to reset; goes low during reset.
23	GND	System ground	
24	PWR **	Regulator input	Voltage regulator input; takes 5-15 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

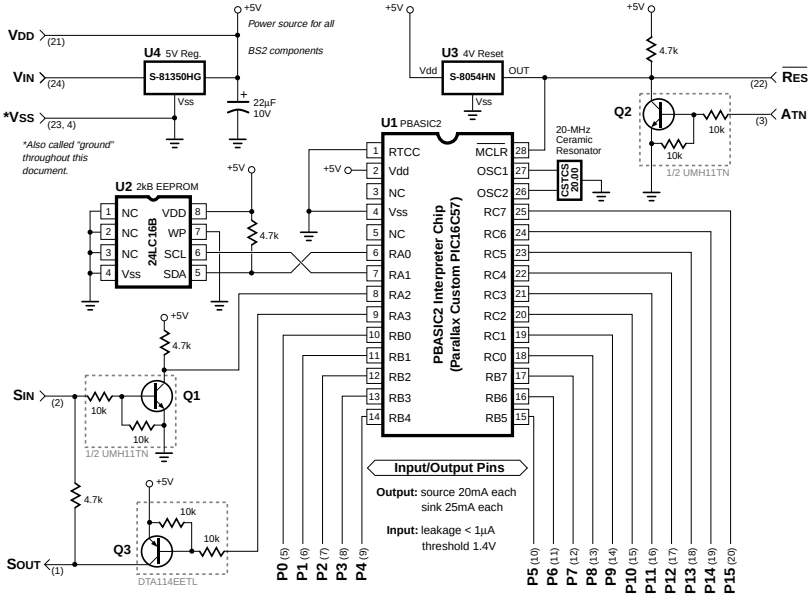
DEBUG — Send variables to PC for viewing.

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 parentheses—(#)—are 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 VDD and leave U4's input (VIN) open.

Note that figure H-1 uses CMOS terms for the power supply rails, VDD for the positive supply and VSS 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 VDD, VCC, and +5V are interchangeable, as are VSS, 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.

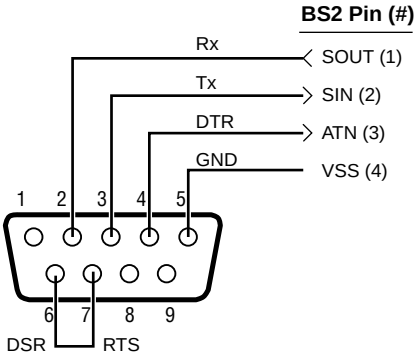
The ATN line interfaces with the data-terminal ready (DTR) handshaking line of the PC COM port. Electrically, it works like the SIN line receiver, with a +12V signal at ATN turning on the Q2 transistor, pulling its collector to ground. Q2's collector is connected to the MCLR (reset) line of the PBASIC2 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 con-

tains 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.

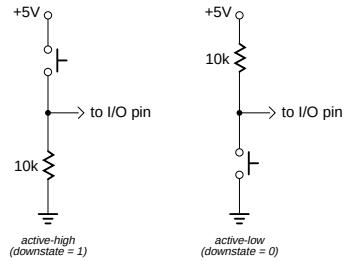
Button does not stop program execution. In order for its delay and autorepeat functions to work properly, Button must be executed from within a program loop.

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

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

Figure I-2

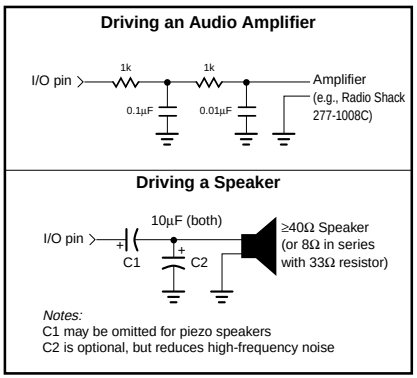
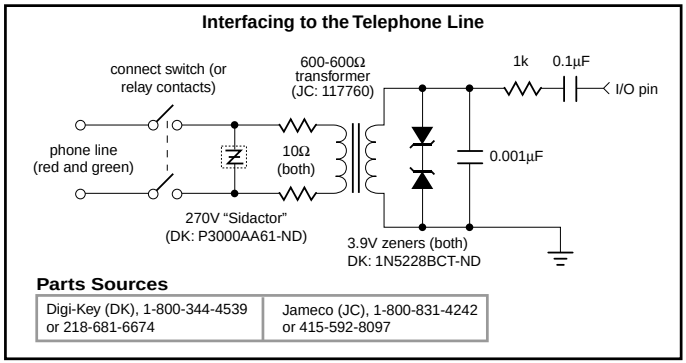


Figure I-3



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 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.

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.
```

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.

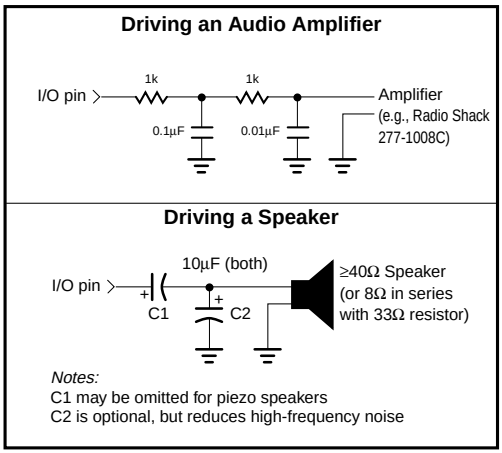
Frequency Considerations

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,

Figure I-4



the first 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.
```

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.

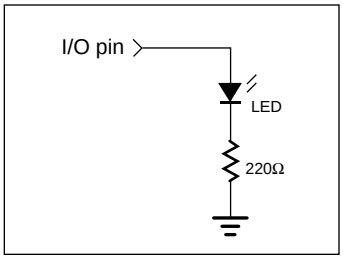
High performs both of these actions with a single, fast instruction.

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.

- ***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
```

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.

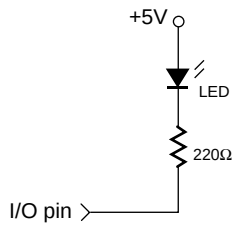


Figure I-6

```
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

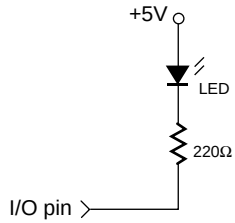
Nap uses the same shutdown/startup mechanism as Sleep, with one big difference. During Sleep, the BS2 automatically compensates for variations in the speed of the watchdog timer oscillator that serves as its alarm clock. As a result, longer Sleep intervals are accurate to approximately ±1 percent. Nap 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 18ms when the BS2 wakes up. The r eason 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.

Figure I-7



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.

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

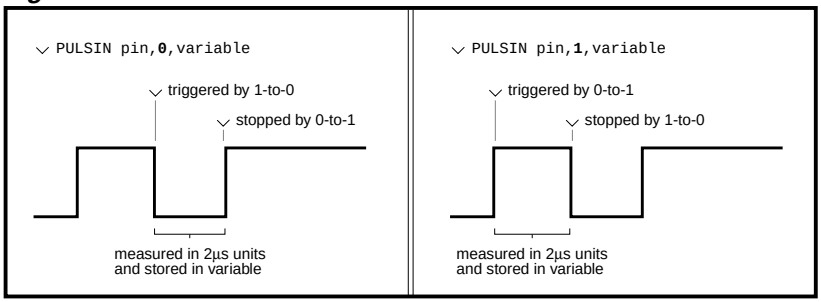
You can think of Pulsin as a fast stopwatch that is triggered by a change in state (0 or 1) on the specified pin. When the state on the pin changes to the state specified in Pulsin, the stopwatch starts. When the state on the pin changes again, the stopwatch stops.

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

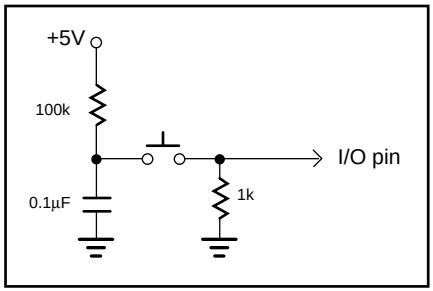


Demo Program

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.

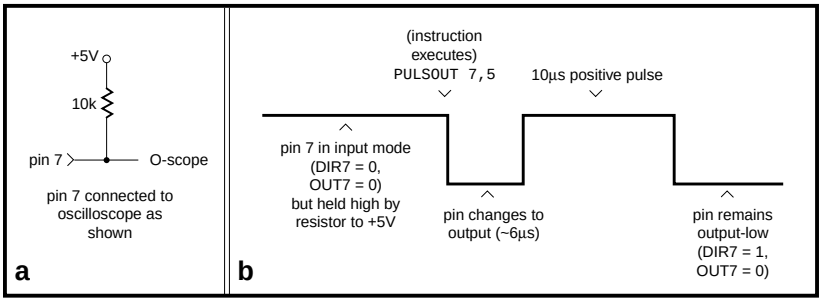


Figure I-10

To make the BS2 work the same way, copy the state of the pin's INS bit to 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.
```

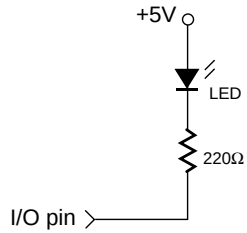


Figure I-11

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.

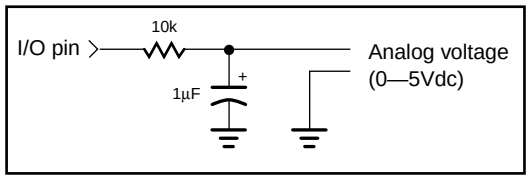
How do you determine how long to charge a capacitor? Use this rule-of-thumb formula: Charge time = 4 * R * C. For instance, figure I-12 uses a 10k (10×10^3 ohm) resistor and a 1µF (1×10^{-6} F) capacitor: Charge time = $4 * 10 \times 10^3 * 1 \times 10^{-6} = 40 \times 10^{-3}$ seconds, or 40ms. Since 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.

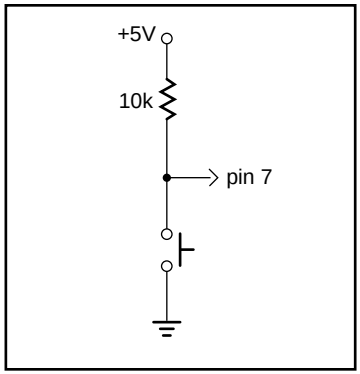
Demo Program

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 instruction.

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.

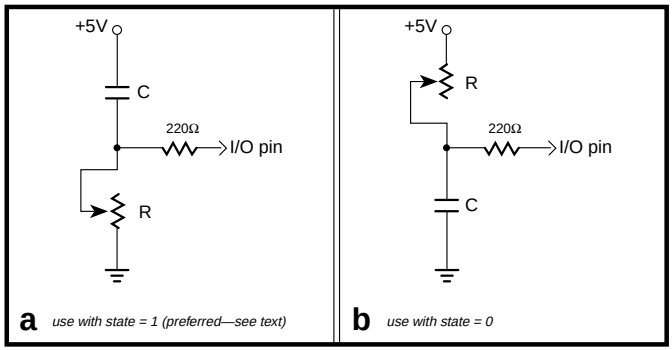
Explanation

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.

Figure I-14



Before RCtime executes, the capacitor must be put into the state specified 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:

$$t = R \times C$$

The general RC timing formula uses t to tell us the time required for an RC circuit to change from one voltage to another:

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.

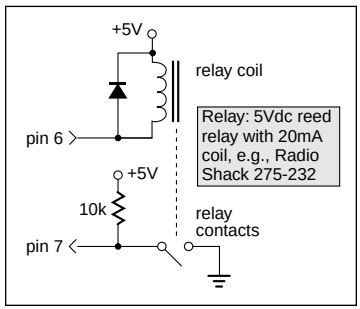
```
result var word' Word variable to hold result.
again:
  high 7                                  ' Discharge the cap
  pause 1                                 ' for 1 ms.
  RCTIME 7,1,result                       ' Measure RC charge time.
  debug cls,dec result                    ' Show value on screen.
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.

```
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.
```

Figure I-15



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.

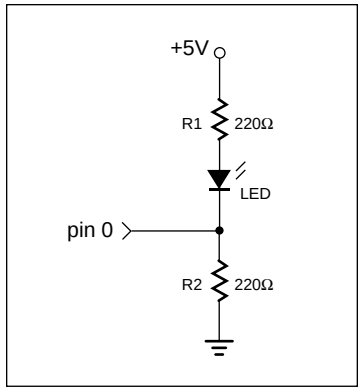
Remember that "input" really has two meanings: (1) Setting a pin to input makes it possible to check the state (1 or 0) of external circuitry connected to that pin. The state is in the corresponding bit of the INS register. (2) Setting a pin to input also disconnects the output driver (corresponding 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.

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

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. Here's a QBASIC code fragment that clears the DTR bit on com 1:

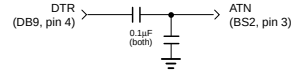
```
temp = INP(&H3FC)
OUT &H3FC,temp AND 254
```

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.

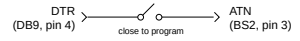
Option 2: Capacitive Coupling of ATN

Insert the circuit below between the PC's DTR output and the BS2's ATN input. The series capacitor blocks DTR's 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.

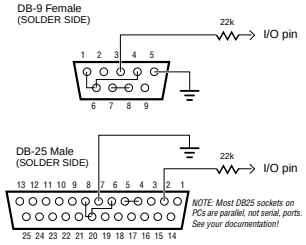


description and schematic. The SIN pin goes to a PC's serial data-out pin on the DB9 connector built into BS2 carrier boards. The connector is wired to allow the STAMP2 host program to remotely reset the BS2 for programming, so it may have to be modified before it can be used with other software; see 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

Pinouts for Standard PC COM Port Connectors with Serin Hookup



Function	DB9	DB25
Protective Ground	–	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-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.

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

Corresponding Baudmode Value
Common Data Rates and Their Baudmodes

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	27764	188	8380
9600	16468	24660	84	8276
19200	16416	24608	32	8224
38400	16390	24582	6	8198

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 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.

Figure I-19

Calculating Baudmode for BS2 Serin

Step 1: Calculate the Bit Period (bits 0-12)

Bits 0 through 12 of the baudmode are the bit period, expressed in microseconds (µs). Serin's actual bit period is always 20µs longer than specified. Use the following formula to calculate the baudmode bit period for a given baud rate:

$$\text{INT}\left(\frac{1{,}000{,}000}{\text{baud rate}}\right) - 20$$

(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):

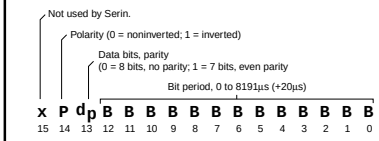
0 = noninverted
16384 = inverted

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 you're more comfortable thinking in terms of bits, here's a bit map of Serin's baudmode:



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.

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:

```
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.

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 hand-shaking 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

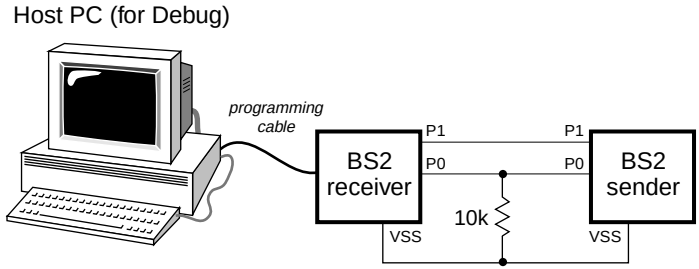
Here's an example that demonstrates fpin flow control. It assumes that two BS2s are powered up and connected together as shown in figure I-20.

```
' 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.

Figure I-20



Demo Program
See the examples above.

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 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

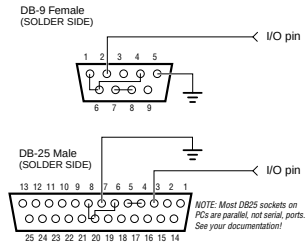
The BS2 can transmit data serially through any of its I/O pins (tpin = 0—15) or through the SOUT pin (tpin = 16) that goes to the DB9 programming connector on BS2 carrier boards. Most common serial devices use the RS-232 standard in which a 1 is represented by –12V and a 0 by +12V. Serout through the 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 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 hard-

Figure I-21

Pinouts for Standard PC COM Port Connectors with Serout Hookup



Function	DB9	DB25
Protective Ground	–	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.

ware 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 trans-

Figure I-22

Calculating Baudmode for BS2 Serout

Step 1: Calculate the Bit Period (bits 0—12)

Bits 0 through 12 of the baudmode are the bit period, expressed in microseconds (µs). Serout's actual bit period is always 20µs longer than specified. Use the following formula to calculate the baudmode bit period for a given baud rate:

$$\text{INT}\left(\frac{1{,}000{,}000}{\text{baud rate}}\right) - 20$$

(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)

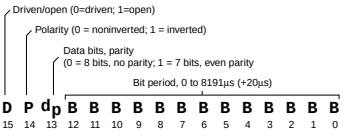
Bit 15 tells Serout whether to drive the output in both states (0 and 1), or drive to one state and leave open in the other. If you select open, the state that is driven is determined by polarity: with inverted polarity open modes drive to +5V only; noninverted open modes drive to ground (0V) only. Bit 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 you're more comfortable thinking in terms of bits, here's a bit map of Serout's baudmode:



ferred in 7E mode can only represent values from 0 to 127, rather 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.

Table I-6

Corresponding Baudmode Value
Common Data Rates and Their Baudmodes

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	27764	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.

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 value, " 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 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 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, 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 characters.
```

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

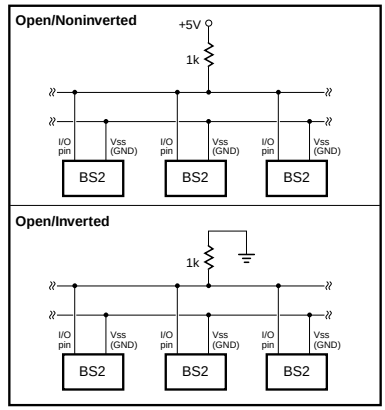
The open baudmodes can be used to connect multiple BS2s to a single pair of wires to create a party-line network. Open baudmodes only actively drive the Serout pin in one state; in the other state they disconnect the pin. If BS2s in a network used the always-driven baudmodes, two BS2s could simultaneously 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.

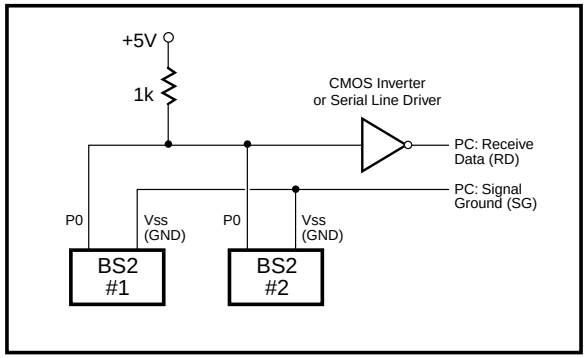
Figure I-23



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 2 predefined symbol 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.

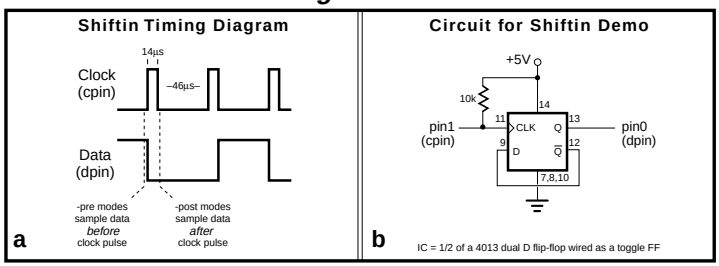
At their heart, synchronous-serial devices are essentially shift-registers—trains of flip-flops that pass data bits along in a bucket-brigade fashion to a single data-output pin. Another bit is output each time the appropriate edge (rising or falling, depending on the device) appears on the clock line. 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

Figure I-25



data this will give us; each bit will be the inverse of the previous one. If the first bit 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-regis-

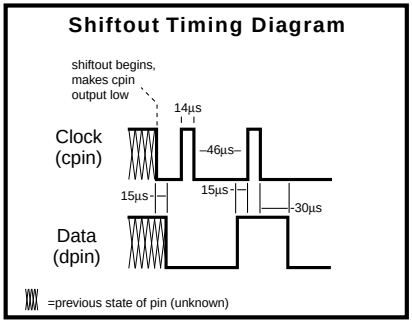
ters—trains of flip-flops that pass data bits along in a bucket-brigade fashion to a single data-output pin. Another bit is input each time the appropriate edge (rising or falling, depending on the device) appears on the clock line. BS2 application note #2 explains shift-register operation in detail.

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.

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

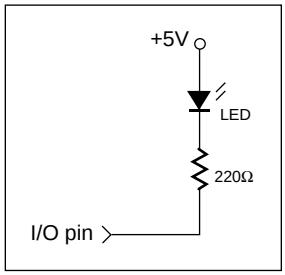
restores the I/O directions dictated by your program.

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.

Figure I-27




```
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
```

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).

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.
```

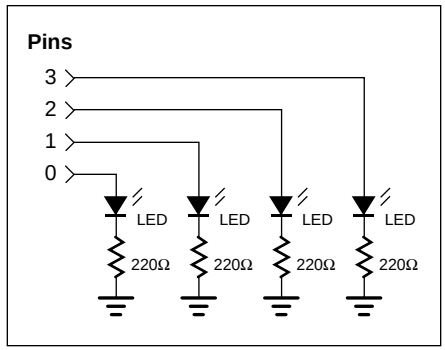
If you change the previous example to copy IN2 to OUT2 before Toggling, you'll see that the state of the pin does change.

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.

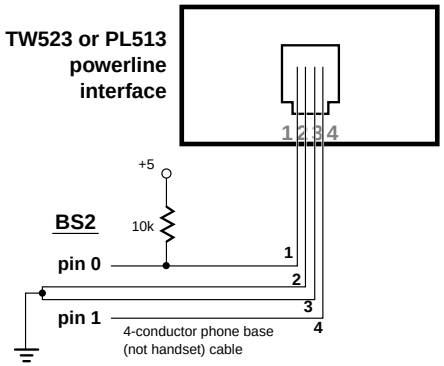
Once this simple setup is complete, the user controls the modules by pressing keys on the control box. Pressing "1 ON" turns module 1 on.

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
```

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.")

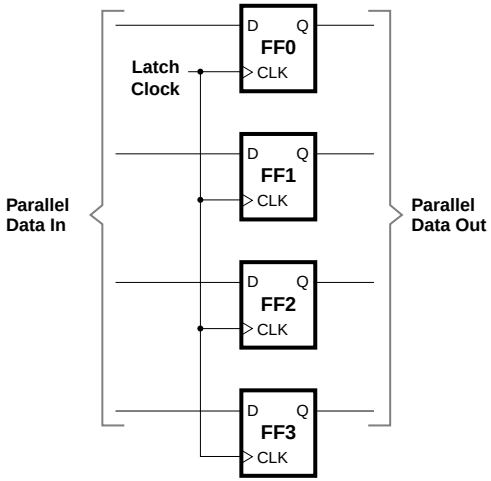


Figure 1. Parallel latch.

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.

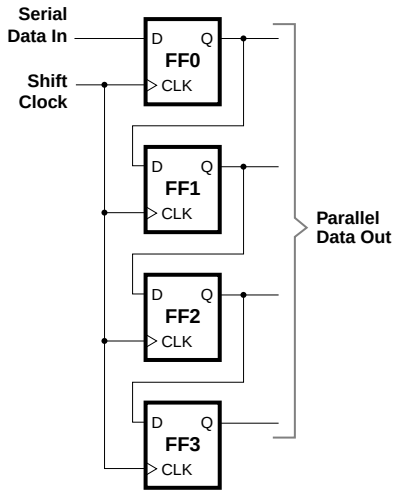


Figure 2. Serial shift register.

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.

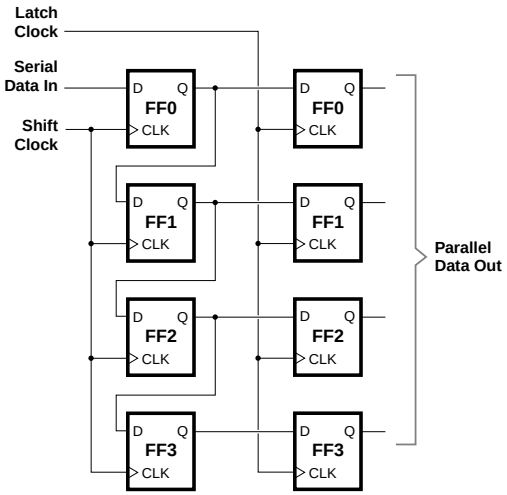


Figure 3. A shift register plus a latch makes a serial-to-parallel converter.

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.

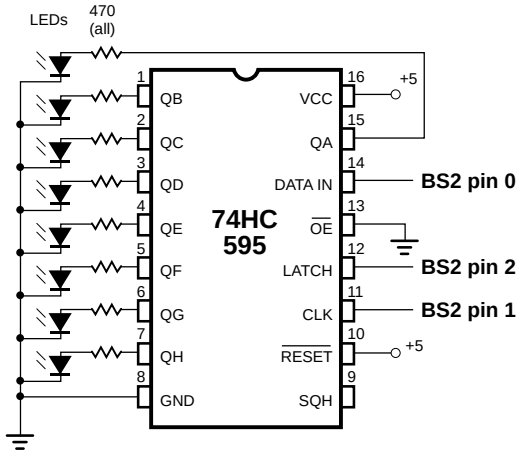


Figure 4. Schematic to accompany 74HC595.BS2.

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.

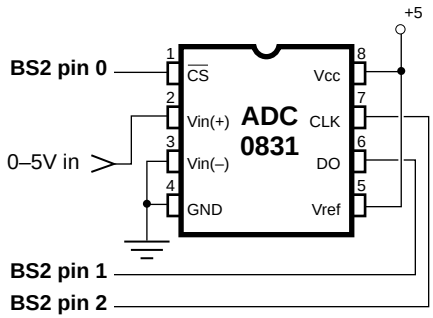


Figure 5. Schematic for ADC0831.BS2.

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.

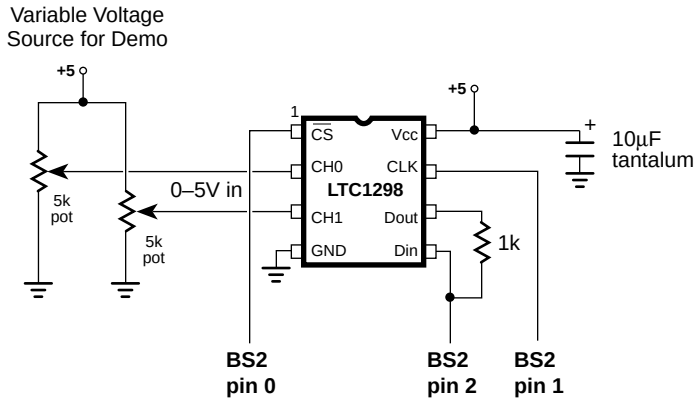


Figure 6. Schematic for LTC1298.BS2.

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.
```

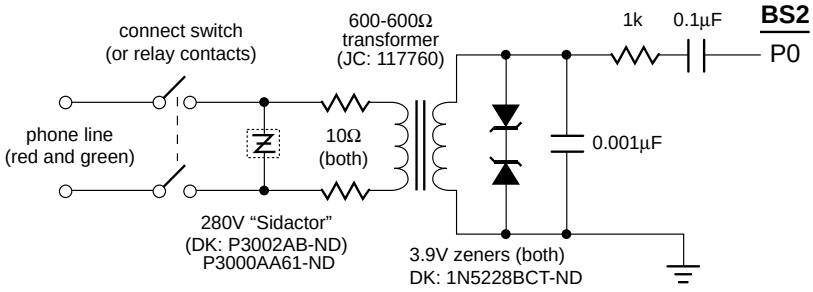
```
' LISTING 3. BIDIRECTIONAL COMMUNICATION WITH LTC1298
' Program: LTC1298.BS2 (LTC1298 analog-to-digital converter)
' This program demonstrates use of the Shiftout and Shiftin instructions
' to communicate with an LTC1298 serial ADC. Shiftout is used to
' send setup data to the ADC; Shiftin to capture 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.

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



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 pritner or terminal often requires sending linefeed and carriage return codes. This common pair is referred to as “LF/CR.”

Appendix A

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

Appendix B

BASIC Stamp I and Stamp II Conversions

C

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 R BS2

1. First do this...
2. Next do this...

- You might like to know this...
- You might want to try this...

CONVERSION: BS1 Q 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	PIN0 - PIN7	I/O pins; bit addressable.
	DIRS	DIR0 - DIR7	I/O pin direction control; bit addressable.
W0	B0	BIT0 - BIT7	Bit addressable.
	B1	BIT8 - BIT15	Bit addressable.
W1	B2		
	B3		
W2	B4		
	B5		
W3	B6		
	B7		
W4	B8		
	B9		
W5	B10		
	B11		
W6	B12		Used by GOSUB instruction.
	B13		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:

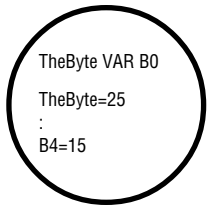
1. They may be referenced via their direct name or by defining symbols as aliases.

   - OR -

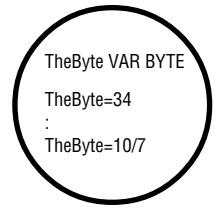
2. They may be referenced by defining variables of specific types (byte, word, etc.). The software will automatically assign variables to registers in an efficient manner.

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*.

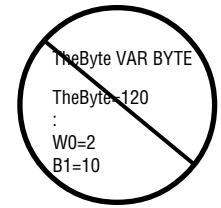
It is important to note that defining variables of specific types in the Stamp II is not directly equivalent to assigning symbols to registers in the Stamp I. Defining variables of specific types on the Stamp II allows the software to efficiently and automatically organize variable space within the general 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.
```

- 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 R 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 Q 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:

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 Q 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 R 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 Q 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 )
```

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.

- LABEL is a valid label to jump to in the event of a button press.

CONVERSION: BS1 R 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 Q 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 R 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 Q 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 R 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 Q 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)

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 R 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 Q 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 R 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 Q 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 R 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 = $1 / (95 \times 10^{-6} + ((127 - \text{NOTE}) * 83 \times 10^{-6})$.
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 Q 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 R BS2

- Up to 255 GOSUBs can be used in the program.
- No general purpose variables are modified with the occurrence of GOSUB.

Conversion: BS1 Q 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 R BS2

- PIN may be a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 Q 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
```

C

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 R BS2

1. If VARIABLE is PINS or PIN0..PIN7 then replace in with INS or IN0..IN7.

Conversion: BS1 Q 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 R BS2

- PIN may be a nibble variable in the range 0..15.

Conversion: BS1 Q BS2

- PIN must not be a nibble variable and must be in the range 0..7 only.

Example:

```
BS2:    INPUT 15

BS1:    INPUT 7
```

C

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 R 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 Q 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 R 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 Q 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 R 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 Q 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 R BS2

- PIN may be a constant or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 Q 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
```

C

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 R BS2

- PIN may be a constant or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 Q 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
```

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)

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 R 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 Q 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 R 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 Q 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.

Conversion: BS1 R 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 Q 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 R BS2

- The numbers generated for any given input will not be the same on the Stamp II as in the Stamp I.

Conversion: BS1 Q 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.

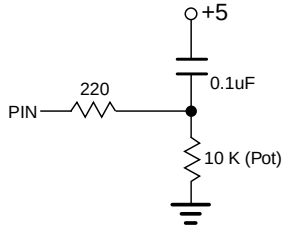
BASIC Stamp II

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 R 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.

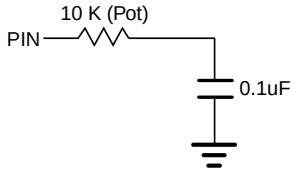
```
PAUSE  delay    ; where DELAY is an appropriate time in milliseconds to allow the capacitor to; fully discharge. You may have to try different DELAY values to find an optimal; value.
```

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 Q 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 R BS2

- LOCATION and VARIABLE may be a nibble variable for efficiency.
- LOCATION may be in the range 0..2047.

Conversion: BS1 Q 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 R BS2

- PIN may be a constant, expression or a bit, nibble, byte or word variable in the range 0..15.

Conversion: BS1 Q 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 R 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 Q 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 R 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 Q 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 R 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 Q 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.

Conversion: BS1 R 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 Q 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 R BS2

Code such as the following:

```
StopExecution:      GOTO StopExecution
```

May be converted to the following code:

```
StopExecution:      STOP
```

Conversion: BS1 Q BS2

Code such as the following:

```
Quit:       STOP
```

May be converted to the following code:

```
Quit:       GOTO Quit
```

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 R BS2

- PIN may be a nibble variable and may be in the range 0..15.

Conversion: BS1 Q 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 R BS2

- LOCATION and DATA may be a nibble variable for efficiency.
- LOCATION may be in the range 0..2047.

Conversion: BS1 Q 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.

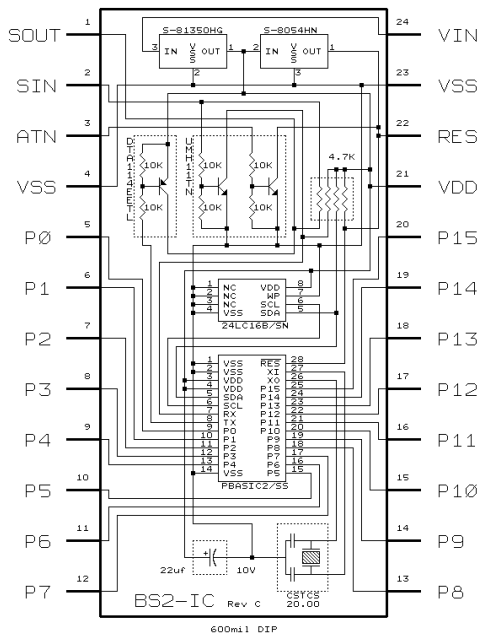
BASIC Stamp II Schematic

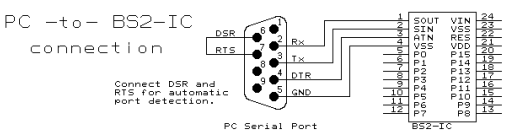
BS2-IC Complete BASIC Stamp II circuit in SMT

- ✳ 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. In output mode: Pins will source from VDD or sink to VSS. Pins should not be allowed to source more than 20ma or sink more than 25ma each. As groups, P0-P7 and P8-P15 should not be allowed to source more than 40ma or sink more than 50ma each. In input mode: Pins are floating (less than 1ua leakage). The 0/1 logic threshold is approximately 1.4V. NOTE: To realize low power during sleep, make sure that no pins are floating, causing erratic power drain. Either drive them to VSS or VDD, or program them as outputs that don't have to source current.	
6	P1	User I/O 1		
7	P2	User I/O 2		
8	P3	User I/O 3		
9	P4	User I/O 4		
10	P5	User I/O 5		
11	P6	User I/O 6		
12	P7	User I/O 7		
13	P8	User I/O 8		
14	P9	User I/O 9		
15	P10	User I/O 10		
16	P11	User I/O 11		
17	P12	User I/O 12		
18	P13	User I/O 13		
19	P14	User I/O 14		
20	P15	User I/O 15		
21	VDD	Regulator Out	Output from 5V regulator (VIN powered). Should not be allowed to source more than 50ma, including P0-P15 loads.	
		Power In	Power input (VIN not powered). Accepts 4.5V-5.5V. Current consumption is dependent upon run/sleep mode and I/O's.	
22	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 than 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 no drive high.	
23	VSS	Ground	Ground. Located adjacent to VIN for easy battery hookup.	
24	VIN	Regulator In	Input to 5V regulator. Accepts 5V to 15V. If power is applied directly to VDD, pin may be left unconnected.	





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