PICBASIC PRO™ Compiler

REFERENCE MANUAL

Revised July 12, 2011

microEngineering Labs, Inc
www.melabs.com

Please report errors and inaccuracies to support@melabs.com.

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Chapter 1: Vital Information

1.1 System Overview

PICBASIC PRO Compiler (PBP) is intended to be used within a system comprised of several tools. Below is a brief list of commonly used components, listed in the order in which you are likely to encounter them.

If you purchased PBP on CD, your PBP installation CD includes PICBASIC PRO Compiler, Mecanique's MicroCode Studio IDE, Microchip's MPLAB IDE, and Microchip's MPASM assembler.

If you obtained PBP as a download, the installation does not include MPLAB and MPASM, but the installation process will offer you the chance to download and install MPLAB. MPLAB includes MPASM. The latest version of MPLAB can always be downloaded from Microchip's website (www.microchip.com)

Integrated Development Environment (IDE)

The IDE is the user-interface, in which you create and edit your program. A good IDE will also manage the following tools, invoking them when needed. Examples of IDEs include MicroCode Studio from Mecanique and MPLAB® from Microchip.

Compiler

The compiler is the tool that converts your BASIC program into Assembly Language. PBP is a compiler. PBP depends on an IDE for user interface, and an assembler to finish the conversion to machine-language.

Assembler

The assembler is the tool that converts the Assembly Language into machine language. The assembler runs after the compiler, and is normally invoked automatically. PBP is designed to use Microchip's MPASM assembler, which is included with MPLAB.

Device Programmer

The device programmer takes the machine language code and "burns" it into the microcontroller. Examples of device programmers are the U2 Programmer from melabs and the PICkit™ 3 from Microchip. The melabs U2 Programmer is recommended for ease of use and availability of technical support.

Debugger

A debugger is used to "see" what is happening inside the microcontroller when it runs. The simplest method of debugging is to write bits of code into your program that display information like variable and register values. The term In-Circuit

Debugger (ICD) refers to a device or method that gives you step-by-step control of program execution via a connection to the microcontroller. Examples of debuggers are the ICD3 from Microchip and the software-based ICD system offered in MicroCode Studio PLUS from Mecanique.

1.2 Integrated Development Environment (IDE)

PBP is designed to operate within an Integrated Development Environment (IDE). This means that, by itself, PBP is only a utility that accepts files as inputs and generates files as outputs. The IDE is what provides the user interface and program-editing capability.

1.2.1 MPLAB

Microchip (www.microchip.com) offers a free IDE called MPLAB. It is included on the PBP installation CD. In order to use MPLAB, PBP must be first installed as a language tool within that environment. A utility can be run from the PBP program group on the Start menu that will accomplish the installation and setup.

MPLAB should be installed even if you are using a different IDE. The MPLAB installation includes the Microchip assembler, MPASM, which is needed for operation of PBP.

1.2.2 MicroCode Studio

MicroCode Studio is a purpose-built IDE offered by Mecanique (www.mecanique.co.uk). MicroCode Studio is included on the PBP installation CD. It is a favorite among PBP users for its ease of use.

Mecanique offers an advanced version (MicroCode Studio Plus) that adds features for in-circuit debugging and bootloader programming.

1.2.3 Other IDEs

Any text editor can be used to create programs for PBP, though it is best to use one that is designed with compiler-management capability. Even better is an IDE that is PBP-aware and will highlight PBP syntax with color and text formatting.

1.3 Compile Modes PBPW and PBPL

Throughout this manual, you will find references to "PBPW" and "PBPL". These represent compilation modes that control the maximum size variable type in PBP. WORD variables are 16-bits wide and can hold values 0 to 65535. LONG variables are 32-bits wide and can hold values -2147483648 to 2147483647.

PBPW refers to "PBP in WORD-mode". In this mode, LONG variables are not available to PBP or to the user. When generating temp variables in the background, PBP will use WORDs to save resources and improve execution speed. This mode is available to all target devices.

PBPL refers to "PBP in LONG-mode". In this mode, LONG variables are made available. This mode is only available when compiling for a target device with the "PIC18" prefix. LONG variables are interpreted as twos-complement, signed values in PBP, whereas other variable types are not. This affects the results of some math and comparison operators.

The mode-selection should be available in the compile or project options within the Integrated Development Environment (IDE) that you have chosen. If you are accessing the executable directly or setting up an IDE that requires command-line information to access the executable, the command-line switch –n invokes PBP in LONG mode.

For more information see:

2.6: Variables
3.1: Math Operators
3.3.1: Signed vs. Unsigned Comparisons
8.3: PBPX Command Line Operation

1.4 Microchip Datasheets

At the time of this writing, PBP supports nearly 500 microcontrollers. Each of these devices has its own set of internal registers that perform specific functions. The names and construction of these registers differ between device families. Some family's internal workings are incredibly powerful and complex. Microchip provides a datasheet for each family that details how things work.

In order to use PBP, you must become familiar with the datasheet for the device you have chosen to use. It isn't necessary to read a datasheet from cover to cover, but it will provide the reference documentation that is needed to manage the device with PBP.

PBP is a full-fledged, professional-level compiler for embedded development. It is also a tool with a reputation for ease-of-use, suitable to the hobbyist. If you are moving to PBP from a "microcontroller-like" device that didn't require you to use datasheets, then you have stepped up considerably. We congratulate you and we'll do everything possible to help you make the transition.

Datasheets can be found at **www.microchip.com**. A search of this website using the device part number should turn up the datasheet quickly.

If you need help understanding the datasheet, contact melabs support.

1.5 Microchip Nomenclature

This manual may refer to device families by prefix or instruction set, but one should not assume that prefix always denotes instruction set. The prefixes "PIC12" and "PIC16" include parts from multiple instruction sets:

PIC10 (prefix)	small, inexpensive devices that use the 12-bit or 14-bit instruction sets
PIC12 (prefix)	8-pin devices that may use the 12-bit, 14-bit, or enhanced 14-bit instruction sets
PIC16 (prefix)	devices ranging from 14-pin to 64-pin that may use the 12-bit, 14-bit, or enhanced 14-bit instruction sets
PIC18 (prefix)	high-performance devices that use the 16-bit instruction set
12-bit instruction set (denoted as "Baseline Architecture" by Microchip)	mostly attractive for low cost, these devices may not be compatible with all PBP commands, PBP LONG variables not available
14-bit instruction set (denoted as "Mid-Range Architecture" by Microchip)	compatible with all PBP commands, PBP LONG variables not available
Enhanced 14-bit instruction set (denoted as "Enhanced Mid-Range Architecture" by Microchip)	compatible with all PBP commands, some features in common with 16-bit instruction set, PBP LONG variables not available
16-bit instruction set (denoted as "PIC18 Architecture" by Microchip)	All devices with prefix PIC18, compatible with all PBP commands, PBP LONG variables supported, high-speed and generally better performance than the other families supported by PBP

1.6 Manual Conventions and Notes

1.6.1 Command Prototypes

Each command will be illustrated with a prototype that shows the required and optional parameters that may be used. The key to reading the prototypes is that anything enclosed in braces ({}, curly brackets) is optional when writing the command. For example:

```
HSERIN {ParityLabel,}{Timeout, Label,}[Item{,...}]
```

This prototype indicates that for the HSERIN command:

{ParityLabel,}	A ParityLabel may be optionally inserted followed by a comma.
{Timeout, Label,}	A Timeout value and label may be inserted with commas, and that Timeout and Label must be used together.
[	a square bracket must be used to begin the item list
Item	at least one Item must be inserted
{,…}	multiple Items may be listed and separated by commas
]	a square bracket must close the item list

1.6.2 Special Terminology and Acronyms

Some acronyms and terms that will be used extensively in this manual are:

PBP	PICBASIC PRO™ Compiler
PBPW	PBP in WORD mode
PBPL	PBP in LONG mode
melabs	microEngineering Labs, Inc.

1.6.3 Number formats

Numbers in this manual may be written as decimal (99), hexadecimal ($63) or binary (%1100011). The choice of number format will depend on the context. The intent is to improve readability by expressing numbers in formats that match the application of the value. (see section 2.12 for more information on PBP number formats and handling)

1.6.4 Comments in code examples

For the sake of readability, comments in code examples will begin with a comment character, but may wrap to multiple lines without comment characters on subsequent lines. To compile many of these examples, comment characters would have to be added. For example:

```
WRITE 5,B0                  ' Send value in B0 to EEPROM
                            location 5
```

The comment begins with an apostrophe, but wraps to a second line that would result in a compile error if typed literally into your program. To avoid the error, the example would be written like this:

```
WRITE 5,B0                  ' Send value in B0 to EEPROM
                            ' location 5
```

1.7 Technical Support

microEngineering Labs takes great pride in providing the best technical support possible. Depending on the PBP edition that you have purchased, tech support is available in different forms.

Online Forum	Available for all users
Direct Email	Available for licensed users of premium editions
Telephone	Available for licensed users of premium editions

See the Support section of our website (www.melabs.com) for contact details.

1.7.1 Support Requirements

The support we provide can only be as detailed as the information that you provide to us. Please have the following information ready when requesting support.

- PBP version number.
- Complete, exact error message, if an error has been encountered. (An exact error message will usually result in an immediate solution.)
- The exact part number of the device you are compiling for.
- Complete details about your operating system, including Windows version, your access privilege level, and whether a virtual machine is in use.
- The method that you are using for test/debug. (Hardware platform, ICD device, running in simulation on PC, etc.)

Please note that reading program code verbally over a telephone connection is our least favorite way of providing support. It just doesn't work. We understand that some users prefer the immediate response of a phone call, but this shouldn't preclude an email with a file attachment. Send us an email, then dial.

Chapter 2: PBP Syntax and Programming

2.1 Program Organization (Example)

Here is a brief example program intended for a PIC16F887. Most PBP programs may be organized as shown in this example.

```
' DEVICE CONFIGURATION:  See section 4.9
#CONFIG
   __CONFIG _CONFIG1, _HS_OSC & _LVP_OFF & _CP_OFF
   ;Set HS osc, Low-Voltage Programming disabled,
   ;Code-Protection disabled
#ENDCONFIG


' DEFINEs:  See section 2.2 for more information.
DEFINE  OSC 20              ' Tell PBP the expected system-
                            clock frequency


' ALIASES:  See section 2.4 for more information.
LEDS  Var  PORTD            ' Alias PORTD to LEDS



' VARIABLES:  See section 2.6 for more information.
i     Var  Byte             ' Define loop variable



' INITIALIZE REGISTERS:  See section 2.13 for info.
init:
  ANSEL = %00000000         ' Make AN0-AN7 digital
  ANSELH= %00000000         ' Make AN8-AN13 digital
  TRISD = %00000000         ' Set PORTD to all output


' PROGRAM CODE
mainloop:
  LEDS = %00000001          ' First LED on
  Pause 500                 ' Delay for .5 seconds
  For i = 1 To 7            ' Go through For..Next loop 7
                            times
    LEDS = LEDS << 1        ' Shift on LED one to left
    Pause 500               ' Delay for .5 seconds
  Next i
Goto mainloop               ' Go back to mainloop
```

2.2 I/O Pins

The input/output pins on a PIC microcontroller are accessed as bits within a port register (SFR). Port registers may be named PORTx (x being the port letter) or GPIO. The fundamental method for accessing pins is via Direct-Register-Access using the port register name and bit number:

```
PORTB.2 = 1                 ' Set PORTB, bit-2 high
x = PORTC.0                 ' Read PORTC bit-0 into var x
```

2.2.1 Data Direction

Most pins on the microcontroller can be configured as input or output. In most cases, they will default to input. To specify the data-direction (input or output), a register is provided in which each bit controls the data-direction of a corresponding I/O pin. These data-direction registers are usually named TRISx (x being the port letter). Smaller devices may use the name TRISIO. In most cases, setting a data-direction bit to 0 results in an output pin, setting to 1 results in an input pin. You should always consult the datasheet for the specific device to be sure.

To expand the example above, each of the pins needs to be configured appropriately as input or output.

```
TRISB.2 = 0                 ' Set PORTB.2 to output
TRISC.0 = 1                 ' Set PORTC.0 to input

PORTB.2 = 1                 ' Set PORTB, bit-2 high
x = PORTC.0                 ' Read PORTC bit-0 into var x
```

Another commonly-used method is to set the data-direction registers with 8-bit values instead of setting each pin individually:

```
TRISB = %11111011           ' PORTB.2 output, the rest of
                            PORTB is input
TRISC = %11111111           ' All pins on PORTC are inputs
```

2.2.2 Aliasing

The above examples demonstrate the low-level method for setting data-direction, but hard-coding the actual PORT.BIT names into the program code will make it difficult to reassign pins at a later date. The accepted method of PBP programming is to assign friendly, meaningful names to the pins and use the assigned names in

the program code. These names are known as aliases. See section 2.4 Aliases for more information.

2.2.3 Use in High-Level Commands

The data-direction is set automatically for most of the PBP high-level commands. If the command sends output, the pin is set for output. If the command reads the digital state of the pin, the pin will be set to input. PBP does not set the data-direction back to its original state after such commands are executed.

Either the PORT.PIN designations or the aliases you have assigned may be used directly in PBP commands. For instance, there is no need to read a pin value to a variable before testing it. You can test an input pin directly with:

```
IF switch = 0 THEN          ' Check state of switch pin
  HIGH led1                 ' LED on
  PAUSE 500                 ' Delay 500mS
  LOW led1                  ' LED off
ENDIF
I2CREAD PORTB.5, PORTB.4, $A0, location,[B_val]
```

Note the use of the HIGH and LOW commands in the preceding example. These are considered high-level commands because they do more than just set the bit in the PORTx register. They also set the data-direction to output.

2.2.4 Additional Configuration

Setting data-direction does not otherwise configure the pin for analog or digital operation. If analog inputs are to be used, or if an analog input needs to be configured for digital operation, this must be done manually by setting the appropriate registers. See section 8.1.4 Analog Inputs for more information.

Most pins will have several functions that can be enabled/disabled with register settings. Watch out for functions that are enabled by default and that will interfere with digital operation. The analog conversion inputs mentioned above are a good example of this. It is common to have to disable analog functions on pins in order to use them for digital I/O.

2.2.5 Pin Characteristics

Microchip provides several types of I/O pins on most devices. You should consult the datasheet when in the design stage to make sure that you choose appropriate pins. Here are some clues:

- Most pins will source 20-25mA of current, but not all. Some, especially on high pin-count devices, will be limited to 2mA per pin.
- In most cases, the total current that a port can supply is limited. In other words, the sum of the current supplied by all the pins on a single port has a limit that supersedes the individual pin limits. In many cases, each pin is limited to 25mA, but the sum of the eight pins on the port is limited to 125mA.
- There are several different types of input pins (Schmidt, CMOS, TTL, etc.) that each have different threshold voltage characteristics.
- Some pins are designated input-only and cannot be used as outputs.
- Some pins may be "open-drain" output types, meaning that they can't source current (drive voltage high). They can only sink current (drive voltage low).
- If a pin is capable of functioning as an input for an analog converter or comparator, it will usually be configured as an analog input by default. These pins must be reconfigured in order to use them as digital I/O.

2.3 DEFINEs

The DEFINE keyword in PBP is used to set parameters for compilation and assembly. This should not be confused with #DEFINE, which is used for conditional compilation. Further explanation of DEFINE and how it works can be found at the end of this section.

Only a few of the many DEFINE terms will be mentioned here. The rest are associated with PBP commands and will be discussed on the appropriate command pages.

2.3.1 DEFINE OSC

The most important DEFINE in PBP is:

```
DEFINE OSC 4                ' Oscillator speed in MHz:
                            3(3.58) 4 8 10 12 16 20 24 25 32
                            33 40 48 64
```

In this DEFINE, OSC is set to a number that represents the anticipated system clock frequency in MHz. DEFINE OSC is used extensively by PBP to convert time values to instruction cycles. Any time-critical operation like a pause or a generated baud rate is completely dependent on DEFINE OSC.

Note that each PIC MCU has a specified maximum frequency of operation. The higher frequencies that are available to PBP may not be useable on the device you have chosen. Check the datasheet for the max frequency rating.

If DEFINE OSC is omitted, PBP assumes a default value of DEFINE OSC 4 and calculates based on a 4MHz system clock.

There are a limited number of valid numbers that can be used: 3 (3.58MHz), 4, 8, 10, 12, 16, 20, 24, 25, 32, 33, 40, 48, 64. These are the only frequencies for which PBP is able to accurately calibrate its timing. If you use a system clock that runs at a frequency that isn't listed here, you timing will be scaled when the program executes.

For example, let's assume that you have a good reason to use a 9MHz crystal to clock your MCU. Using "DEFINE OSC 10" will result in your timing to be scaled on the slow side, because the actual clock will run at 90% of the DEFINEd value. A "PAUSE 10" will pause for 11.1mS. Your 9600 baud serial commands will run at 8640 baud.

Note that "DEFINE OSC" doesn't set or change the actual clock frequency. It only tells PBP what to expect. The actual frequency is set by selecting a crystal, changing the device configuration, setting registers in your program, or (most commonly) a combination of all of these.

2.3.2 Global DEFINEs

Other DEFINEs that are important, though less frequently used, are:

```
DEFINE NO_CLRWDT 1          'Don't insert CLRWDTs
DEFINE LOADER_USED 1        'Bootloader is being used
DEFINE OSCCAL_1K 1          'Set OSCCAL for 1K PIC12
DEFINE OSCCAL_2K 1          'Set OSCCAL for 2K PIC12
DEFINE RESET_ORG 0h         'Change reset address for PIC18
DEFINE INTHAND Label        'Assign assembler interrupt
                            handler label
DEFINE INTLHAND Label       'Assign assembler low priority
                            interrupt handler label for
                            PIC18
```

See section 8.6 for a condensed list of DEFINEs with brief explanations.

2.3.3 DEFINEs defined

For the user familiar with Assembly Language, the major clue to understanding is that *DEFINEs in PBP are converted literally to Assembly Language #DEFINE directives.*

For the practical PBP user, there are a couple of fundamental points to consider:

1) DEFINEs are CASE SENSITIVE!
2) Specific DEFINEs are generally associated with PBP commands. The command pages will describe how the relevant DEFINEs affect the operation of each command.

DEFINEs are used by PBP to change the generated Assembly Language that makes up the compiled program. A DEFINE might simply change an internal register setting, or it might result in the use of an alternative Assembly Language routine to accomplish a task.

A good example is in our serial communication commands SEROUT2 and DEBUG. DEBUG uses a DEFINE to set the serial baud rate, while SEROUT2 accepts a baud-rate parameter when the command is executed.

The difference is that "DEFINE DEBUG_BAUD 9600" actually causes PBP to find and compile a DEBUG routine that only works at 9600 baud. The SEROUT2 routine is compiled with the capability of working at different baud rates, depending on the parameters passed to it. Since DEBUG is compiled for a specific baud rate, it can't be changed when the program is running. SEROUT2 will accept a variable to set the baud rate on the fly.

Multiple DEFINEs for the same parameter will cause compile/assembly errors in PBP.

It doesn't matter where you place DEFINEs in your code, but it is good practice to keep them together at the top of the program.

2.4 Aliases

Aliases are simply alternate names for variables, portions of variables, registers, or bits within registers. Alias names are assigned using the VAR keyword.

Alias names should be limited to 31 alpha-numeric characters (letters and numbers) in length. PBP will accept longer names, but all names will be truncated to 31 characters during compilation. Names are not case-sensitive. Names cannot begin with a number. The only special character allowed in names is the underscore "_" character.

```
long_val  VAR  LONG        'Variable declarations
word_val  VAR  WORD
byte_val  VAR  BYTE[8]

'Examples of Aliases

time         VAR  long_val
speed        VAR  word_val
speed_low    VAR  word_val.BYTE0
second_byte  VAR  BYTE[1]
data_pin     VAR  PORTB.3
```

Aliases are important as a means to make global changes throughout your code, as well as a method for making some names more meaningful. For example, let's take the simple operation of blinking an LED that is connected to a pin:

```
mainloop:
    HIGH PORTB.0
    PAUSE 500
    LOW PORTB.0
    PAUSE 500
GOTO mainloop
```

The above example works, but when someone else reads the code, they will have no idea what is connected to PORTB.0 until they consult the schematic. A more readable method, with no penalty in resources used, is:

```
power_LED  VAR  PORTB.0    'Assign an Alias to PORTB.0

mainloop:
    HIGH power_LED
    PAUSE 500
    LOW power_LED
    PAUSE 500
GOTO mainloop
```

To further demonstrate the power of Aliases, consider what happens if you have to use a different pin for the LED. You can change the first example by using search-n-replace in your editor, but this could become problematic if the pin is specified in other places in a large program. In the second example, you can simply change the alias, and it will globally change every instance, throughout the program.

```
power_LED  VAR  PORTC.2    'Change the LED pin
```

Here is another example of a real world method where aliases are used to make the code more easily portable:

```
led1      VAR  PORTB.2     ' Name the LED pin
switch1   VAR  PORTC.0     ' Name the Switch pin

OUTPUT led1                ' Make LED pin output
INPUT  switch1             ' Make Switch pin output
```

The example above uses the convenient INPUT and OUTPUT commands to set the data-direction. These commands will automatically find the associated data-direction bit for each pin and set it appropriately, automatically adapting to changes in the alias designation.

Note: The keyword SYMBOL can also be used to create Aliases, but this method is not recommended. You may see it in older PBP programs that you find on the web.

2.5 Labels

Labels are names used to mark a place in a program. Usually, labels are used in conjunction with GOTO, GOSUB or similar commands that need a location to jump to in a program. Labels don't use any resources on the MCU.

Label names should be limited to 31 alpha-numeric characters (letters and numbers) in length. PBP will accept longer names, but all names will be truncated to 31 characters during compilation. Names are not case-sensitive. Names cannot begin with a number. The only special character allowed in names is the underscore "_" character.

Labels should be denoted with a colon afterwards.

```
mainloop:
   SEROUT 0,N2400,["Hello, World!",13,10]
   PAUSE 500
GOTO mainloop
```

2.6 Variables

Variables are where temporary data is stored in a PICBASIC PRO program. They are created using the **VAR** keyword. Variables may be bit-, byte- and word-sized for PBPW, and bit-, byte-, word- and long-sized for PBPL. Space for each variable is automatically allocated in the microcontroller's RAM by PBP.

Each variable type can be created as a scalar variable, which holds only one value, or an array variable which can hold many values. Assume that any reference to "variables" in this manual means scalar variables.

Variable names should be limited to 31 alpha-numeric characters (letters and numbers) in length. PBP will accept longer names, but all names will be truncated to 31 characters during compilation. Names are not case-sensitive. Names cannot begin with a number. The only special character allowed in names is the underscore "_" character.

2.6.1 Creating Scalar Variables

The format for creating a variable is as follows:

```
Variable_Name VAR Type {.Modifiers}
```

Variable_Name is any unique identifier (name), excluding reserved words.

Type is **BIT**, **BYTE**, **WORD** and, for PBPL, **LONG**.

Type	# of bits	Range
BIT	1	0 to 1
BYTE	8	0 to 255
WORD	16	0 to 65535
LONG *	32	-2147483648 to 2147483647

** PBPL Only*

As the table shows, BIT, BYTE and WORD variables are always unsigned, i.e. positive numbers. LONG variables, which are only available in PBPL, are always signed, twos-complement numbers. They may hold positive or negative values.

PBPL interprets LONG variable types as signed numbers. WORDs, BYTEs, and of course BITs are always interpreted as positive, unsigned integers when used in a PBP math operation.

If the result of an operation could possibly be negative, it should be stored to a long-sized variable type to preserve the sign. If a negative result is placed in a

variable type other than long, subsequent calculations using this value will interpret it as a positive number.

```
hours   VAR  BYTE          'range 0 to 255

minutes VAR  WORD          'range 0 to 65535

seconds VAR  LONG          '-2147483648 to 2147483647
```

Modifiers can be used to specify certain attributes of the variable when created:

address	A numeric address may be used as a modifier. This instructs PBP where to locate the variable in RAM.
BANKx	Instructs PBP to locate the variable in a specific bank of RAM.
SYSTEM	The default behavior of PBP is to append a prefix underscore character when creating the variable in Assembly Language. The SYSTEM modifier inhibits this behavior so that the variable name will be identical in PBP code and Assembly code.

Note that the SYSTEM keyword also assigns priority to the variable when PBP is allocating RAM locations. SYSTEM variables will be allocated before other variables.

```
ticker  VAR  BYTE  BANK0  SYSTEM
'Creates "ticker" as a BYTE in BANK0, with no Assembly
'prefix character

wsave   VAR  BYTE $70
'Creates "wsave" at RAM address 0x70 (hex)
```

A note about BIT variables:

When a BIT variable is created, PBP must reserve a full BYTE of RAM and then assign a name to one bit. This is fine in most cases, but you may wish to control this yourself. To create a bit variable and control the BYTE it's assigned to, you can use aliasing to do it manually:

```
my_flags    VAR  BYTE      'Create a container for bits
flag0       VAR  my_flags.0    'Assign an alias to bit-0
flag1       VAR  my_flags.1    'Assign an alias to bit-1
```

This is exactly what PBP would do in the background, but it will assign its own name to the "container" BYTE variable. It's useful to take control and assign this

name manually, especially when debugging in an environment that won't show individual bits in a watch window.

2.6.2 Creating Array Variables

Array variables are created using the same syntax as scalar variables, but the number of elements in the array is enclosed in brackets and appended to the variable-type keyword:

```
samples  VAR  BYTE[16]
'Create an array of 16 BYTE elements - samples[0] through
'samples[15]
```

All of the modifiers allowed for scalar variables can also be used for array variables:

```
samples  VAR  BYTE[16] BANK3 SYSTEM
```

Because of the way arrays are accessed and allocated in memory, there are size limits for each type:

Size	Maximum Number of elements	
	PIC18 Devices	Other Devices
BIT	256	256
BYTE	limited only by available RAM	96
WORD	limited only by available RAM	48
LONG	limited only by available RAM	LONGs not available

Arrays must fit entirely within one RAM-bank on 12-bit and 14-bit devices (PIC10, PIC12, and PIC16). Arrays may span banks on PIC18 devices. On PIC18 devices, BYTE, WORD and LONG-sized arrays are only limited in length by the amount of available memory. The compiler will assure that arrays, as well as scalar variables, will fit in memory before successfully compiling.

2.6.3 Using Scalar Variables

Using previously-created variables is straightforward. Simply write variable names in commands or expressions.

Note that PBP is aware of a variable's type and will make decisions based on this. The behavior of certain commands may change based on the type of variables that

are used. The underlying math routines will always be tailored to the variable types used for input and result. In most cases, the use of BYTE variables will result in faster-executing code.

```
B_val  VAR  BYTE           'Create a BYTE variable
location VAR WORD          'Create a WORD variable
B_val = PORTB              'Read PORTB into B_val
location = 0               'Set location to 0
I2CREAD DPin,CPin,$A0,location,[B_val]
'Read to B_val from a 24LC512 memory chip at location 0
```

In the example above, the variable-type assigned to "location" affects how the I2CREAD command functions. If the memory was a 24LC01, a BYTE variable would be required.

The smallest variable type in PBP is the BIT. BYTES are made up of BITs, WORDs are made up of BYTES, and LONGs are made up of WORDS. Using modifiers, you can access the smaller entities within a larger variable.

To access bit-7 in a byte variable, you may use "BIT7", or simply "7" after the variable name, separated by a period:

```
B_val.7 = 1                'Set bit-7 in B_val to 1
```

To access byte-2 in a LONG variable, use the modifier "BYTE2":

```
long_val.BYTE2 = 255       'Set byte-2 to 255
```

The following are all legal in PBP:

```
long_val  VAR  LONG
word_val  VAR  WORD
byte_val  VAR  BYTE

long_val.WORD1 = 0
long_val.BYTE3 = 255
long_val.31 = 1
word_val.BYTE1 = 0
word_val.15 = 0
byte_val.7 = 0
```

When using a variable with a modifier, PBP will see the variable-type of the *modifier*. This can save execution time. For example, you might want to fill a WORD variable by combining the states of registers PORTC and PORTB. It's perfectly valid to write:

```
word_val = (PORTC << 8) + PORTB
```

But the operation executes faster if you write:

```
word_val.BYTE1 = PORTC
word_val.BYTE0 = PORTB
```

The following table shows how modifiers refer to "nested" data objects:

Variable Modifiers				
LONG	WORD1	BYTE3	BIT31	most-significant-bit (MSB)
			BIT30	
			BIT29	
			BIT28	
			BIT27	
			BIT26	
			BIT25	
			BIT24	
		BYTE2	BIT23	
			BIT22	
			BIT21	
			BIT20	
			BIT19	
			BIT18	
			BIT17	
			BIT16	
	WORD0	BYTE1	BIT15	
			BIT14	
			BIT13	
			BIT12	
			BIT11	
			BIT10	
			BIT9	
			BIT8	
		BYTE0	BIT7	
			BIT6	
			BIT5	
			BIT4	
			BIT3	
			BIT2	
			BIT1	
			BIT0	least-significant-bit (LSB)

2.6.4 Using Array Variables

A single Array Variable can be visualized as a list of values. The variable name is how you access the list, and a number –or index– is used to point to any single value within the list.

The index value is enclosed in brackets and appended after the array variable's name. The index can be a literal number, a variable, or an expression.

For the following examples, an array named "stored" is used:

```
stored  VAR  WORD[8]        'Create an array named "stored"
                            with 8 elements.
```

Note that the 8 elements in our array are numbered 0 through 7. There is no element-8. This is very important, because PBP doesn't place a limit at the end of the array. If you write "stored[8]", PBP won't generate and error and you will be accessing memory outside of the array. This could have disastrous results and be very difficult to debug.

The elements of "stored" can be written individually:

```
stored[0] = 1260
stored[1] = 2500
```

Or, you might want to write values with a loop. You could read PORTB once per second and save 8 readings:

```
FOR index = 0 TO 7          'Loop 8 times
    stored[index] = PORTB   'Save value of PORTB
    PAUSE 1000              'Wait a second
NEXT index                  'Loop again
```

PBP offers commands ARRAYREAD and ARRAYWRITE that make it very easy to store multiple values in an array:

```
ARRAYWRITE stored, [1260,2500,10000,0,0,100,200,400]
```

A multi-dimensional table of values can be emulated using multiple index variables to construct an index expression. To treat our array as a table with 2 columns (x) and 4 rows (y), we can write:

```
x = 1                       'x points to second column
y = 2                       'y points to third row
stored[(x * 4) + y] = 100   'Write value to location 1,2
```

In the example above, the x coordinate is multiplied by 4 because we imagine that the array exists as multiple columns that are 4-rows deep. To move across columns in the same row, the actual array index must be incremented by 4.

The following table represents the array in two dimensions. Each location within it shows how the x,y formula results in the actual index value that is used to access the single-dimensional array.

x,y = 0,0 (0 * 4) + 0 = 0	x,y = 1,0 (1 * 4) + 0 = 4
x,y = 0,1 (0 * 4) + 1 = 1	x,y = 1,1 (1 * 4) + 1 = 5
x,y = 0,2 (0 * 4) + 2 = 2	x,y = 1,2 (1 * 4) + 2 = 6
x,y = 0,3 (0 * 4) + 3 = 3	x,y = 1,3 (1 * 4) + 3 = 7

One more note about array variables. The modifiers associated with scalar variables can't be used with array variables:

```
stored[1].BYTE0 = 0         'ERROR
```

Instead, a temp variable may be used to manipulate a single byte within the value:

```
temp_word = stored[1]       'copy the value to a temp
temp_word.BYTE0 = 0         'change the temp value
stored[1] = temp_word       'update the array value
```

Advanced techniques may be used to access arrays in many different ways. See section 7.6 Array Handling Mechanism for more information.

2.7 Constants

The CON keyword may be used to assign a meaningful name to a fixed value in a program. This is useful when adjusting the value after the program is written, and makes the program easier to read. Constants are simply substitutions made during compile. They do not consume any memory on the microcontroller.

Constant names should be limited to 31 alpha-numeric characters (letters and numbers) in length. PBP will accept longer names, but all names will be truncated to 31 characters during compilation. Names are not case-sensitive. Names cannot begin with a number. The only special character allowed in names is the underscore "_" character.

adjustment CON 64396 'Create constant "adjustment"

```
result = (rate * time) ** adjustment
'Using the constant name is the same as using the number.
```

Constants are treated as 16-bit unsigned values when using PBPW. They are treated as 32-bit signed values in PBPL. In all cases, however, you may use a negative decimal value when creating a constant. The difference is in the subsequent treatment of the value in the different versions of PBP.

```
preset  CON  -500          ' 65036 in PBPW,  -500 in PBPL
```

In the above example, PBPW represents the constant with a 16-bit, twos-complement value. Subsequent operations using the constant will see this as a positive value.

2.8 Modifiers

Modifiers are keywords that, when placed in proximity to certain other entities in PBP, can change behavior, perform conversions, or otherwise refine the operation of the program.

Modifiers are discussed in detail in other parts of this manual. They are best explored in conjunction with other commands and operators, because they aren't stand-alone entities. This section is simply a list of modifiers with some clues about where to find more information.

2.8.1 Modifiers used when creating variables

BANKA, BANK0-BANK15, SYSTEM

See section 2.6 Variables

2.8.2 Modifiers that access binary subsets of numeric values

BIT0-BIT31, BYTE0-BYTE3, WORD0-WORD1

See section 2.6.3 Using Scalar Variables

2.8.3 Modifiers for parsing and formatting ASCII strings

BIN, BIN1-BIN32, IBIN, IBIN1-IBIN32, SBIN, SBIN1-SBIN32, ISBIN, ISBIN1-ISBIN32

HEX, HEX1-HEX8, IHEX, IHEX1-IHEX8, SHEX, SHEX1-SHEX8, ISHEX, ISHEX1-ISHEX8

DEC, DEC1-DEC10, IDEC, IDEC1-IDEC10, SDEC, SDEC1-SDEC10, ISDEC, ISDEC10-ISDEC10

REP, SKIP, STR, WAIT, WAITSTR

See 2.10 Input Modifiers for Parsing Strings and 2.11 Output Modifiers for Formatting Strings

2.8.4 Modifiers for specifying variable types in data space

Modifiers that specify variable types when passing values to Data Space (EEPROM): (See commands READ, WRITE, DATA, EEPROM)

WORD, LONG

See commands:

5.14 DATA
5.63 READ
5.86 WRITE

2.9 ASCII and Strings

At some point it will be necessary to work with strings of text in your program. The most common example is to output information on a display. Since PBP has no STRING variable type, you must use special techniques to manipulate strings.

In most commands where strings are likely to be used, PBP will accept literal strings in quotes and handle them appropriately.

```
HSEROUT ["Hello World"]     'send string "Hello World"
```

This works for serial communications commands, LCDOUT, ARRAYWRITE, and a few more.

Array variables can be used to store strings and recall them. (See commands ARRAYREAD and ARRAYWRITE

PBP allows you to use a single ASCII character in quotes anyplace where a numeric constant is accepted. The ASCII character will be converted to its numeric equivalent at compile-time.

```
ASCII = digit + "0"         'same as ASCII = digit + 48
```

An assortment of string-formatting modifiers is available for use within the item list of many commands that generate string output. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

For commands that read strings as inputs, modifiers are available to parse the input string and fill variables with numeric values. These modifiers are capable of extracting data from input strings to various variable types:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar\n{\c}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{\n}	Wait for character string

See section 2.10 for details on string-parsing modifiers.

2.10 Input Modifiers for Parsing Strings

The following information applies to output commands ARRAYREAD, DEBUGIN, SERIN2, HSERIN, and HSERIN2. All of these commands accept an item list to determine how received data is parsed and variables are filled. The modifiers described in this section allow you to control this behavior.

Modifier overview:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar*n*{*c*}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{*n*}	Wait for character string

For the examples in this section, item lists will be denoted with square brackets, even though some commands do not use brackets. Please use the enclosing brackets only when appropriate for the command you are using.

Examples in this section are taken from a program in which variable declarations are:

```
testword VAR WORD          ' Define word variable
testbyte VAR BYTE          ' Define byte variable
test8    VAR BYTE[8]       ' Define array variable with 8
                           locations
```

2.10.1 DEC

```
DEC{1..10}
```

Use DEC to convert an ASCII representation of a decimal number to a numeric value. DEC will recognize characters "0" – "9", and "-".

If the leading character is the "-" (minus), DEC will convert the following number to a twos-complement signed value.

DEC will wait for a recognized character to begin conversion, and automatically end conversion when an unrecognized character is encountered.

When written with a number (DEC2, DEC10, etc.), DEC will end the conversion when the specified number of digits are collected.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Y"), DEC testword]
```

Waits for ASCII "Y", then looks for an ASCII string that could represent a decimal number. It finds the string "-546", which it converts to a signed integer and stores in testword.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Y-"),DEC2 testword, testbyte]
```

In this example, we use the DEC2 modifier to collect the only 2 decimal digits after the wait-string "Y-" is received. This results in the decimal value 54 being stored to testword. The next character is "6", which is stored as ASCII in testbyte. The testbyte value is decimal 54, which is the ASCII code for "6".

2.10.2 BIN

```
BIN{1..32}
```

Use BIN to convert an ASCII representation of a binary number to a numeric value. BIN will recognize characters "0", "1", and "-".

If the leading character is the "-" (minus), BIN will convert the following number to a twos-complement signed value.

BIN will wait for a recognized character to begin conversion, and automatically end conversion when an unrecognized character is encountered.

When written with a number (BIN2, BIN16, etc.), BIN will end the conversion when the specified number of digits are collected.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("X"), BIN testbyte]
```

Waits for ASCII "X", then looks for an ASCII string that could represent a binary number. It finds the string "-1011", which it converts to a signed integer. Value in testbyte is %11110101, which is the twos-complement equivalent of %-1011.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("ZZ-"), BIN testbyte]
```

```
Waits for ASCII string "ZZ-", then looks for a string that
could represent a binary number.  It finds "0001", which it
converts to a signed integer. Value in testbyte is %00000001.
```

2.10.3 HEX

```
HEX{1..8}
```

Use HEX to convert an ASCII representation of a binary number to a numeric value. HEX will recognize characters "0"-"9", "a"-"f", "A"-"F", and "-"

If the leading character is the "-" (minus), HEX will convert the following number to a twos-complement signed value.

HEX will wait for a recognized character to begin conversion, and automatically end conversion when an unrecognized character is encountered.

When written with a number (HEX2, HEX4, etc.), HEX will end the conversion when the specified number of digits are collected.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("X-"), HEX testbyte]
```

```
Waits for ASCII string "X-", then looks for a string that could
represent a hexadecimal number. It finds "1011" which it tries
to store in the  testbyte variable.  Since the value of $1011
is too large for a single  byte, it only stores the least
significant 8 bits.  Value in testbyte is $11 or %00010001.
```

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("X-"), HEX2 testbyte]
```

```
Same as previous example, but we have used HEX2 instead of HEX.
This causes the compiler to collect the string "10" and store
it in testbyte.  Value in testbyte is $10 or %00010000.
```

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Z-"), HEX testbyte]
```

```
Since this example waits for the string "Z-", it ignores the
"1011" string.  The first string it finds that could be hex
data is "F7". Value in testbyte is $F7.
```

2.10.4 SKIP

```
SKIP n
```

Use SKIP (followed by a count 255 or less) to skip the specified number of characters before resuming processing.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Y"), SKIP 2, DEC2 testword, testbyte]
```

```
Waits for the string "Y", then skips the next 2 characters "-
5". It then collects the 2-digit decimal number 46 and stores
it to testword.  The next byte received is "Z", which is stored
as ASCII to testbyte.
```

2.10.5 STR

```
STR ArrayVar\n{\c}
```

The STR modifier is used to move data into an array variable without converting it.

STR must be followed by a backslash and a number that specifies how many characters (bytes) to collect.

Optionally, an additional backslash can be added and followed by a character, cause STR to collect characters until it encounters the character you specify.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("F"), STR test8\8]
```

```
Waits for the string "F", then collects the next 8 characters.
These are stored as ASCII in 8 locations of the array variable
test8.  Values in test8 array are:
```

```
test8[0] = "7"
test8[1] = "Z"
test8[2] = "Z"
test8[3] = "-"
test8[4] = "0"
test8[5] = "0"
test8[6] = "0"
test8[7] = "1"
```

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Z",45), STR test8\8\"0"]
```

```
The STR item is the same as in the previous example, except we
have added the stop character "0".  When it encounters "0" at
the sixth character, it  replaces it and fills the rest of the
test8 array with null (zero) values. Values in test8 array are:


test8[0] = "F"
test8[1] = "7"
test8[2] = "Z"
test8[3] = "z"
test8[4] = "-"
test8[5] = 0
test8[6] = 0
test8[7] = 0
```

2.10.6 WAIT

```
WAIT ( )
```

The WAIT() modifier is used to suspend processing until a match for a specific constant to string is encountered.

The data within the parentheses can be a comma-separated list of values, a string in quotes, or a combination of both.

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("X"), testbyte]
```

```
Waits for ASCII "X", then reads the next byte without a
modifier. Numeric value of testbyte is 45, the ASCII code for
"-".
```

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Y-"), DEC testword, WAIT("-"), HEX testbyte]
```

Waits for the string "Y-", then collects a string that could represent a decimal number ("546"). It then waits again for the string "-". After that it collects the next string that looks like hex data, "F7".

```
input: "X-1011Y-546Z-F7ZZ-0001"
[WAIT("Z",45), STR test8\8\"0"]
```

This example demonstrates how you can put multiple characters in the WAIT. It waits for the string "Z-", since the ASCII code for "-" is 45.

2.10.7 WAITSTR

```
WAITSTR ArrayVar{\n}
```

WAITSTR is used like WAIT, but it attempts to match against a string that has been previously stored in an array variable.

The following examples use the test8 array in the WAITSTR modifier. These examples use ARRAYWRITE to set the value in test8 before each test.

```
ARRAYWRITE test8, ["X-"]
input: "X-1011Y-546Z-F7ZZ-0001"
[WAITSTR test8\2, testbyte]
```

Waits for ASCII "X-", then reads the next byte without a modifier. testbyte = "1"

```
ARRAYWRITE test8, ["F7ZZ-"]
input: "X-1011Y-546Z-F7ZZ-0001"
[WAITSTR test8\5, testbyte]
```

Waits for ASCII "F7ZZ-", then reads the next byte without a modifier. testbyte = "0"

2.11 Output Modifiers for Formatting Strings

The following information applies to output commands ARRAYWRITE, DEBUG, SEROUT2, HSEROUT, HSEROUT2, and LCDOUT. All of these commands accept an item list to determine output. Numeric data included in this item list can be converted to ASCII strings using the following modifiers.

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

For the examples in this section, item lists will be denoted with square brackets ([ ]), even though some commands do not use brackets. Please use the enclosing brackets only when appropriate for the command you are using.

2.11.1 DEC

```
{I}{S}DEC{1..10}
```

Use DEC to convert a numeric value to a string that represents the number in decimal format.

When preceded by the letter "I", DEC will format the output with a leading "#" character to signify decimal.

When preceded by the letter "S", DEC will interpret the input value as signed (twos-complement), and format the output with a minus sign "-" if negative. If the "S" is not used, DEC interprets all values (including signed LONGs) as positive integers.

When a number (1-10) is appended to the DEC modifier, the output is limited to the specified number of decimal digits. If the number of digits specified is more than required to represent the value, leading zeros will be used to pad the output string. If the number of digits specified is less than required to accurately represent the value, only the specified number of trailing digits will be displayed and the most significant (leading) digits will be truncated.

```
testword = 50123
[DEC testword]
output: "50123"

testword = 56
[DEC testword]
output: "56"
```

The most common usage of DEC. Number of output digits changes with the value of the input.

```
testword = 50123
[DEC3 testword]
output: "123"

testword = 56
[DEC3 testword]
output: "056"
```

DEC3 is used to force a 3-character output. Leftmost digits are truncated if necessary. Leading zeros are used to pad the output.

```
testword = 50123
[SDEC testword]
output: "-15413"

testword = 56
[DEC3 testword]
output: "56"
```

Since 50123 (stored in a 16-bit variable) is equivalent to the signed, twos-complement value -15413, SDEC will output the negative value with a minus sign.

If the sign bit isn't set in a variable, as is the case with value 56, SDEC gives the same result as DEC.

```
testword = 50123
[ISDEC testword]
output: "#-50123"

testword = 56
[IDEC testword]
output: "#56"
```

```
IDEC and ISDEC prepend a "#" character before the output string.
```

```
testword = 50123
[DEC testword/100, ".", DEC3 testword]
output: "50.123"
```

```
DEC can be used to easily generate an output string with decimal places.
```

2.11.2 BIN

```
{I}{S}BIN{1..32}
```

Use BIN to convert a numeric value to a string that represents the number in binary format.

When preceded by the letter "I", BIN will format the output with a leading "%" character to signify binary.

When preceded by the letter "S", BIN will interpret the input value as signed (twos-complement), and format the output with a minus sign "-" if negative. If the "S" is not used, BIN interprets all values (including signed LONGs) as positive integers.

When a number (1-32) is appended to the BIN modifier, the output is limited to the specified number of binary digits. If the number of digits specified is more than required to represent the value, leading zeros will be used to pad the output string. If the number of digits specified is less than required to accurately represent the value, only the specified number of trailing digits will be displayed and the most significant (leading) digits will be truncated.

```
testbyte = %11001011
[BIN testbyte]
output: "11001011"
```

BIN creates an output string composed of characters "1" and "0" to represent the binary value.

```
testbyte = %11001011
[IBIN testbyte]
output: "%11001011"
```

IBIN prepends a "%" character before the value to signify binary.

```
testbyte = %11001011
[SBIN testbyte]
output: "-110101"
```

Since %11001011 can represent a negative number when stored in a byte variable, SDEC will output the string to show this.

```
testbyte = %11001011
[IBIN16 testbyte]
output: "%0000000011001011"
```

IBIN16 forces the output to be 16 binary digits and prepends a "%" to signify binary

2.11.3 HEX

```
{I}{S}HEX{1..8}
```

Use HEX to convert a numeric value to a string that represents the number in hexadecimal format.

When preceded by the letter "I", HEX will format the output with a leading "$" character to signify hexadecimal.

When preceded by the letter "S", HEX will interpret the input value as signed (twos-complement), and format the output with a minus sign "-" if negative. If the "S" is not used, HEX interprets all values (including signed LONGs) as positive integers.

When a number (1-8) is appended to the HEX modifier, the output is limited to the specified number of hexadecimal digits. If the number of digits specified is more than required to represent the value, leading zeros will be used to pad the output string. If the number of digits specified is less than required to accurately represent the value, only the specified number of trailing digits will be displayed and the most significant (leading) digits will be truncated.

```
testword = $C3F0
[HEX testword]
output: "C3F0"
```

```
HEX creates an output string that represents a hexadecimal
number.
```

```
testword = $C3F0
[IHEX testword]
output: "$C3F0"
```

```
IHEX prepends a "$" character to signify hexadecimal
```

```
testword = $C3F0
[SHEX testword]
output: "-3C10"
```

```
SHEX interprets the 16-bit input value as a twos-complement
signed number and outputs a string that represents the negative
value.
```

```
testword = $C3F0
[HEX2 testword]
output: "F0"
```

```
HEX2 limits the output string to two hexadecimal digits
```

2.11.4 REP

```
REP char\count
```

Use REP to repeat a character a specified number of times in the output string.

The character is limited to a single character. Multiple-character strings are not allowed.

The character count may be a constant or variable, maximum 255.

```
[REP "@"\16]
output: "@@@@@@@@@@@@@@@@"
```

```
REP is used to repeat a single character multiple times.
```

```
testbyte = 16
[REP "@"\testbyte]
output: "@@@@@@@@@@@@@@@@"
```

```
A variable may be used to store the character and/or the count.
This can be useful for padding with a variable number of
spaces.
```

2.11.5 STR

```
STR ArrayVar{\count}
```

STR followed by a byte array variable and optional count will send a string of characters.

The number of output characters may be specified by a count appended with a backslash. The count can be a constant or variable, maximum value 255.

Output begins at the zero location in the array and counts upward. If a null (zero) is encountered in the array, the output is terminated.

```
ARRAYWRITE testarray, ["Hello World",0]
[STR testarray\5]
output: "Hello"
```

```
Use STR to output the contents of an array variable. The \5
causes only the first 5 characters in the array to be output.
```

```
ARRAYWRITE testarray, ["Hello World",0]
[STR testarray]
output: "Hello World"
```

Use STR to output the contents of an array variable. Output terminates when the null (zero) value is encountered.

2.12 Numbers

When you write numeric values in a program, PBP allows you to write them as base-10 decimal, base-16 hexadecimal, or base-2 binary.

To write a decimal number, simply write it without a prefix:

```
x = 255
```

To write a hexadecimal number, prefix it with "$" to let PBP know that you how to interpret it:

```
x = $FF
```

To write a binary number, prefix it with "%":

```
x = %11111111
```

There is no penalty associated with one number format over another. You may choose the format that makes the most sense to you. To PBP, a number is a number. These choices are simply different ways to represent the exact same value.

PBP will also accept a quoted ASCII character as a number. If you write a character in quotes, it will be converted to the numeric ASCII code that represents the character in the standard ASCII character set:

```
x = "A"                    ' same as writing x = 65
```

2.13 Registers

The term "Register" refers to a special memory location that is built into the microcontroller. These locations are part of the construction of the chip, and they each perform a special function. In Microchip's documents, you will see them referred to as "Special Function Registers" or "SFRs".

In PBP programs, registers may be accessed by name, without any special pre-definition. We call this Direct Register Access. When you read a PBP example program, you may see something like:

```
ANSEL = 0                    ' Make all pins digital
```

This can be confusing to the novice, because "ANSEL" isn't declared as a variable and it isn't a command. It is the name of a register on a specific PIC microcontroller. Note that the register names aren't the same for all PIC devices, nor do similarly-named registers work the same from one device to the next.

The details about the registers are found in the Microchip datasheet for the device you are compiling for. The datasheet is your friend. We don't advocate reading it from cover to cover in one sitting, but you need to be comfortable with it as a reference document. It holds the keys to exploiting the power of the microcontroller.

2.14 Comments

Comments in PBP are denoted with an apostrophe (') or a semicolon (;).

Comments don't consume any resources. Most programmers will agree that you will never save time by omitting a comment. A well written program devotes more space to comments than to code. Our recommendation is to shrink your code, expand your comments.

There is no penalty for long, informative comments:

```
' using IOCBF you can tap 1 or more keys very fast, and
' never miss a press. Much faster than reading the
' entire port. And key presses do not generate an
' interrupt. Only set flag bits in IOCBF for each
' individual input that was edge-triggered.

IF IocFlag THEN     ' if keys SW13, 14, 15 or 16 were
                    ' pressed,
   State = 1        ' indicate LCD update needed
   GOSUB GetKeys    ' get the button/buttons pressed
ENDIF
```

2.15 Case Sensitivity

PBP is not case sensitive, but Assembly Language is. This means that there are situations where case matters.

2.15.1 DEFINEs

Since many of the DEFINEs in PBP pass data directly to the assembler, they should be considered case-sensitive. All defined parameters should be written in upper-case:

```
DEFINE  OSC  20             ' Correct
DEFINE  osc  20             ' Incorrect, and will not
                            generate an error message
```

2.15.2 Variables

PBP doesn't differentiate different case-versions of variable names. To PBP, "speed" is the same as "Speed".

Sometimes, though, a variable name will be written in an Assembly Language routine that is included in the PBP program using commands @ or ASM..ENDASM. In the Assembly Language code, variable names do become case-sensitive.

```
Speed  VAR  BYTE SYSTEM

speed = 0                   'Allowed in PBP
@    clrf  speed            'may cause error
@    clrf  Speed            'Correct
```

2.16 White Space

White Space refers to spaces and tabs inserted in commands. Inserting white space thoughtfully can make a program easier to read and understand. Some PBP commands need white space to separate things. PBP doesn't care if tabs are used instead of spaces, nor does it care if multiple white space characters are used instead of a single character.

```
LCDOUT DEC speed          'Single spaces used
LCDOUT     DEC speed      'Tabs or multiple spaces used
```

Assembly Language is sensitive to starting column, and starting column is controlled by adding white space. The correct Assembly Language syntax is beyond the scope of this manual, but here is an example of the most common error:

```
@clrf  Speed              ;Command clrf in first column
                          causes error
@    clrf  Speed          ;Correct with tab or spaces
```

2.16.1 Tabbing For Readability

It is customary to indent program lines using tabs to help show the intended structure of a program. Blocks of code that operate conditionally, or in a loop, are indented to make the conditional or loop structure easier to see. Nested blocks and loops are given an additional level of indentation. Consider the following example for readability.

```
FOR x = 0 TO 8
  PORTA = x
  IF x = 2 THEN
    PORTB = PORTB + 1
  ELSE
    PORTB = PORTC
  ENDIF
NEXT x
```

Without indented lines, the program is much more difficult to decipher:

```
FOR x = 0 TO 8
PORTA = x
IF x = 2 THEN
PORTB = PORTB + 1
ELSE
PORTB = PORTC
ENDIF
NEXT x
```

2.17 Line-Extension (_)

Long lines of program code in PBP can be broken into multiple lines for readability. This is accomplished using an underscore (_) to tell PBP to continue parsing the current command on the next line. The underscore must be the last character on the line that you break.

This is very useful for long lookup tables and item lists:

```
LOOKUP I, [$45,$35,$67,$7E,_
           $8F,$00,$0F,$C0,_
           $EF,$55,$01,$00], value
```

2.18 Line-Concatenation (:)

Multiple commands may be written on a single line using colon characters to tell PBP where to insert a "virtual" line break. This can pack more code into less space, but it generally makes the program more difficult to read.

```
x = x + 2 : HIGH led : LOW cs
```

2.19 INCLUDE

Use PBP's INCLUDE directive to read a text file and place its contents in your program. INCLUDE performs a simple text substitution at the location where INCLUDE is written.

```
INCLUDE "more_code.pbp"    'include file contents here
```

Chapter 3: Operators

Overview of Operators

Math Operators	Description
+	Addition
-	Subtraction
*	Multiplication
**	Top 16 Bits of Multiplication
*/	Middle 16 Bits of Multiplication
/	Division
//	Remainder (Modulus)
<<	Shift Left
>>	Shift Right
ABS	Absolute Value*
ATN	Arctangent
COS	Cosine
DCD	2n Decode
DIG	Digit
DIV32	31-bit x 15-bit Divide
HYP	Hypotenuse
MAX	Maximum*
MIN	Minimum*
NCD	Encode
REV	Reverse Bits
SIN	Sine
SQR	Square Root

Bitwise Operators	Description
&	Bitwise AND
|	Bitwise OR
^	Bitwise Exclusive OR
~	Bitwise NOT
&/	Bitwise NOT AND
|/	Bitwise NOT OR
^/	Bitwise NOT Exclusive OR
<<	SHIFT LEFT
>>	SHIFT RIGHT

Operators

Comparison Operator	Description
= or ==	Equal to
<> or !=	Not Equal to
<	Less Than to
>	Greater Than to
<=	Less Than or Equal to
>=	Greater Than or Equal to

Logical Operator	Description
AND or &&	Logical AND
OR or ||	Logical OR
XOR or ^^	Logical Exclusive OR
NOT or !	Logical NOT
ANDNOT	Logical NAND
ORNOT	Logical NOR
XORNOT	Logical NXOR

PICBASIC PRO Compiler performs all operations in full hierarchal order. This means that there is precedence to the operators. Multiplies and divides are performed before adds and subtracts. If incorrect assumptions are made about the order in which operations are performed, you may encounter unexpected results. To ensure the operations are carried out in the order that you intended, use parenthesis to group the operations. Parenthesis may be used to group all types of operators, including mathematical, comparison, bitwise, and logical.

A = (B + C) * (D - E)

IF (((PORTA >> 4) < 6) OR (PORTB = 0)) THEN…

The following table lists the operators in default hierarchal order. (Parentheses will override.) Operators with the same precedence level (on the same line in the table below) will be evaluated in the order (left to right) that they are encountered in the written expression.

Highest Precedence
( ) (anything enclosed in parentheses)
- (unary)
! or NOT, ABS, COS, DCD, DIV32, NCD, SIN, SQR
<<, >>, ATN, DIG, HYP, MAX, MIN, REV
***, /, **, */, //**
+, - (in math), ~
= or ==, <> or !=, <, <=, >, >=
&, |, ^, &/, |/, ^/
AND, OR, XOR, ANDNOT, ORNOT, XORNOT
Lowest Precedence

Left-to-right is, in our opinion, unacceptable as a method of specifying the order of evaluation. USE PARENTHESES to avoid ambiguity!

All math operations when compiling with PBPW are unsigned and performed with 16-bit precision. Math operations for PBPL use 32-bit precision and may be signed or unsigned, depending on the variable-types used.

Bitwise operators, including the shift operators, always operate in an unsigned fashion, regardless of the variable type they are acting on, signed or unsigned.

3.1 Math Operators

Math Operators	Description
+	Addition
-	Subtraction
*	Multiplication
**	Top 16 Bits of Multiplication
*/	Middle 16 Bits of Multiplication
/	Division
//	Remainder (Modulus)
<<	Shift Left
>>	Shift Right
ABS	Absolute Value*
ATN	Arctangent
COS	Cosine
DCD	2n Decode
DIG	Digit
DIV32	31-bit x 15-bit Divide
HYP	Hypotenuse
MAX	Maximum*
MIN	Minimum*
NCD	Encode
REV	Reverse Bits
SIN	Sine
SQR	Square Root

3.1.1 Multiplication

PBPW performs unsigned 16-bit x 16-bit multiplication, while PBPL performs signed 32-bit x 32-bit multiplication.

```
W1 = W0 * 1000              ' Multiply value in W0 by 1000
                            and place the result in W1
```

PBPL interprets only LONG variable types as signed numbers. Words, bytes, and of course bits are always interpreted as positive, unsigned integers when used as inputs in a PBP math operation.

If the result of a multiplication could possibly be negative, it should be stored to a LONG variable type to preserve the sign. If a negative result is placed in a variable type other than LONG, subsequent calculations using this value will interpret it as a positive number.

```
B0 = 4
L0 = B0 * -1
' Result is -4 in L0
W0 = B0 * -1                ' Result is 65532 in W0
```

3.1.2 '*/' and '**' Special Multiplication

There are two special multiplication operators that allow large result values to be handled in a special way. These operators ignore some of the least-significant bytes of the result and return higher order bytes instead. With PBPW, this allows you to work (in a limited way) with 32-bit multiplication results. With PBPL, the top 32 bits of a 48-bit result are available.

The '*/' operator discards the least-significant byte of the result (byte0), and returns the 4 higher bytes to the result variable. If the result variable is a word or byte, the value will be truncated to fit.

```
W3 = W1 */ W0               ' Multiply W1 by W0, ignorebyte0
                            of the result, return byte1 and
                            byte2 in W3
L3 = L1 */ L0               ' Multiply L1 by L0, ignore
                            byte0 of the result, return
                            byte1 through byte4 in L3
```

A simple way to think about '*/' is that it shifts the result 8 places to the right, resulting in an automatic division by 256. (This does not hold true if the result is a negative number.) This is useful for multiplying by non-integer constants.

If you wished to convert miles to kilometers, for example, you would need to multiply by a constant 1.6. PBP's integer math won't allow you to write "1.6" in an equation, but you can use '*/' to accomplish the same result:

```
kilometers = miles */ 410
' Same as kilometers = (miles * 410) / 256
```

The '**' operator is similar, but ignores two bytes instead of one. When using PBPL with long variable types, it returns byte2 through byte5 of the 48-bit result value. This gives a result that is shifted 16 places to the right, an inherent divide by 65536.

W2 = W0 ** 1000 ‘ Multiply W0 by 1000 and place the high order 16 bits(which may be 0) in W2

3.1.3 Division

PBPW performs unsigned 16-bit x 16-bit division. The '/' operator returns the 16-bit result.

PBPL performs signed 32-bit x 32-bit division. The '/' operator returns the 32-bit result.

```
W1 = W0 / 1000              ' Divide value in W0 by 1000and
                            place the result in W1
```

PBPL interprets only LONG variable types as signed numbers. Words, bytes, and bits are always interpreted as positive, unsigned integers when used as terms in a PBP math operation.

If the result of a division could possibly be negative, it should be stored to a LONG-sized variable type to preserve the sign. If a negative result is placed in a variable type other than LONG, subsequent calculations using this value will interpret it as a positive number.

```
B0 = 4
L0 = B0 / -1                ' Result is -4 in L0
W0 = B0 / -1                ' Result is 65532 in W0
```

3.1.4 Remainder (Modulus)

The '//' operator returns the remainder. This is sometimes referred to as the modulus of the number.

```
W2 = W0 // 1000
' Divide value in W0 by 1000 and place the remainder in W2
```

If the result of a division could possibly be negative, it should be stored to a LONG-sized variable type to preserve the sign. If a negative result is placed in a variable type other than LONG, subsequent calculations using this value will interpret it as a positive number.

```
B0 = 23
L0 = B0 // -4               ' Result is -3 in L0
W0 = B0 // -4               ' Result is 65533 in W0
```

3.1.5 ABS

ABS returns the absolute value of a number. If a byte is greater than 127 (high bit set), **ABS** will return 256 - value. If a word is greater than 32767 (high bit set), **ABS** will return 65536 - value. If a long is negative, **ABS** will return 4294967296 - value.

```
B1 = ABS B0
```

ABS always interprets input variables and expressions as twos-complement signed numbers. This is true regardless of PBPW/PBPL mode selection and/or variable type.

3.1.6 ATN

ATN returns the 8-bit arctangent of 2 twos-complement 8-bit values. If a byte is greater than 127 (high bit set), it is treated as a negative value. The arctangent returned is in binary radians, 0 to 255, representing a range of 0 to 359 degrees.

```
ang = x ATN y
```

3.1.7 COS

COS returns the 8-bit cosine of a value. The result is in two's complement form (i.e. -127 to 127). It uses a quarter-wave lookup table to find the result. Cosine starts with a value in binary radians, 0 to 255, as opposed to the usual 0 to 359 degrees.

```
B1 = COS B0
```

3.1.8 DCD

DCD returns the decoded value of a bit number. It changes a bit number (0 - 31) into a binary number with only that bit set to 1. All other bits are set to 0.

```
B0 = DCD 2                  ' Sets B0 to %00000100
```

3.1.9 DIG

DIG returns the value of a decimal digit. Input the digit number (0 – 9, with 0 being the rightmost digit). DIG returns the value of the decimal digit that you specified.

DIG is commonly used to distill BCD digits from numeric values and to isolate single digits for display on seven-segment LCD.

```
B0 = 123                    ' Set B0 to 123
B1 = B0 DIG 2               ` Sets B1 to 1 (digit 2 of 123)
```

3.1.10 DIV32

PBPW's multiply (*) function operates as a 16-bit x 16-bit multiply yielding a 32-bit internal result. However, since PBPW only supports a maximum variable size of 16 bits, access to the result had to happen in 2 steps: c = b * a returns the lower 16 bits of the multiply while d = b ** a returns the upper 16 bits. There was no way to access the 32-bit result as a unit.

In many cases it is desirable to be able to divide the entire 32-bit result of the multiply by a 16-bit number for averaging or scaling. A special operator has been provided for this purpose: DIV32. DIV32 is actually limited to dividing a 31-bit unsigned integer (max 2147483647) by a 15-bit unsigned integer (max 32767). This should suffice in most circumstances.

As PBPW only allows a maximum variable size of 16 bits, DIV32 assumes that a multiply was just performed and that the internal compiler variables still contain the 32-bit result of the multiply. No other operation may occur between the multiply and the DIV32, else the internal variables may be altered, destroying the 32-bit multiplication result.

This means, among other things, that ON INTERRUPT must be DISABLEd from before the multiply until after the DIV32. If ON INTERRUPT is not used, there is no need to add DISABLE to the program. Interrupts in assembler should have no effect on the internal variables so they may be used without regard to DIV32.

The following code fragment shows the operation of DIV32:

```
a  VAR  WORD
b  VAR  WORD
c  VAR  WORD
dummy  VAR  WORD
b = 500
c = 1000
DISABLE                    ' Necessary if On Interrupt used
dummy = b * c              ' Could also use ** or */
a = DIV32 100
ENABLE                     ' Necessary if On Interrupt used
```

This program assigns b the value 500 and c the value 1000. When multiplied together, the result would be 500000. This number exceeds the 16-bit word size of a variable (65535). So the dummy variable contains only the lower 16 bits of the result. In any case, it is not used by the DIV32 function. DIV32 uses variables internal to the compiler as the operands.

In this example, DIV32 divides the 32-bit result of the multiplication b * c by 100 and stores the result of this division, 5000, in the word-sized variable a.

DIV32 is not supported by PBPL as that version of the compiler always uses a 32-bit x 32-bit divide.

3.1.11 HYP

HYP returns the hypotenuse of a right triangle, or the length of the side opposite the right angle. It simply calculates the square root of the sum of the squares of the length of the 2 sides adjacent to the right angle.

For PBPW, the input values are treated as twos-complement numbers representing a range of +127 to -128. For PBPL, a long variable or constant must be used if a negative value is to be represented. In any case, the value returned is always positive.

```
B2 = B0 HYP B1
' Same as B2 = SQR ((B0 * B0)+ (B1 * B1))
```

3.1.12 MAX and MIN

MAX and **MIN** returns the maximum and minimum, respectively, of two numbers. It is usually used to limit numbers to a value.

```
B1 = B0 MAX 100
' Set B1 to the larger of B0and 100 (B1 will be between100
                              & 255)
B1 = B0 MIN 100
' Set B1 to the smaller of B0 and 100 (B1 can't be bigger
                              than 100)
```

3.1.13 NCD

NCD returns the priority encoded bit number (1 - 32) of a value. It is used to find the highest bit set in a value. It returns 0 if no bit is set.

```
B0 = NCD %01001000          ' Sets B0 to 7
```

3.1.14 REV

REV reverses the order of the lowest bits in a value. The number of bits to be reversed is from 1 to 32.

```
B0 = %10101100 REV 4        ' Sets B0 to %00000011
```

3.1.15 SIN

SIN returns the 8-bit sine of a value. The result is in two's complement form (i.e. -127 to 127). It uses a quarter-wave lookup table to find the result. SIN starts with a value in binary radians, 0 to 255, as opposed to the usual 0 to 359 degrees.

```
B1 = SIN B0
```

3.1.16 SQR

SQR returns the square root of a value. Since PICBASIC PRO only works with integers, the result will always be an 8-bit integer (16-bits for PBPL) no larger than the actual result.

```
B0 = SQR W1                 ' Sets B0 to square root of W1
```

3.2 Bitwise Operators

Bitwise Operators	Description
&	Bitwise AND
|	Bitwise OR
^	Bitwise Exclusive OR
~	Bitwise NOT
&/	Bitwise NOT AND
|/	Bitwise NOT OR
^/	Bitwise NOT Exclusive OR
<<	SHIFT LEFT
>>	SHIFT RIGHT

Bitwise operators perform manipulation of binary values. Since all numbers can be expressed as binary, bitwise operators can be performed on all values in PBP, including variables, constants, and internal registers.

With the exception of the SHIFT and Bitwise NOT operators, a bitwise operator applies its bitwise (Boolean) logic to each corresponding bit of two input values. The result may be placed in a variable or used in a comparison. Consider the following AND operation between two BYTE values:

```
     %10101010
&    %11110000
     %10100000
```

Each of the 8 bit-positions is individually combined for a single bit result:

```
       ↓   ↓   ↓   ↓   ↓   ↓   ↓   ↓
      %1  %0  %1  %0  %1  %0  %1  %0
&     %1  %1  %1  %1  %0  %0  %0  %0
      %1  %0  %1  %0  %0  %0  %0  %0
```

If the destination variable type has more bits than either input term, the result will be right-justified and undetermined bits will be zeros. For example:

```
A  VAR  BYTE
B  VAR  BYTE
C  VAR  WORD

A = %10101010
B = %11110000
C = A & B                    ' C = %0000000010100000
```

The result of the AND operation of the two byte inputs is %10100000, but since the C variable is a 16-bit WORD the result in C will be %0000000010100000.

Bitwise Operators

For each Boolean-type operator, we express the logic in a small table using a single bit. The table shows the inputs as A and B, then the result of all conditions of both inputs.

3.2.1 & Bitwise AND

A	B	A & B
0	0	0
0	1	0
1	0	0
1	1	1

If A and B are 1, then result is 1.

The & operator is commonly used to "mask" bits (force bits to zero):

```
result = PORTB & %00001111 'Force the most significant 4
                           bits to zero
```

3.2.2 | Bitwise OR

A	B	A | B
0	0	0
0	1	1
1	0	1
1	1	1

If A or B is 1, then result is 1.

The | operator can be used to force bits to a logic one:

```
PORTB = PORTB | %00000011  ' Force PORTB.0 and PORTB.1 to
                           one
```

3.2.3 ^ Bitwise EXCLUSIVE OR (XOR)

A	B	A ^ B
0	0	0
0	1	1
1	0	1
1	1	0

If only A or only B is 1, then result is 1.

The ^ operator is commonly used to invert selected bits:

```
PORTB = PORTB ^ %00001111  'Invert only bits 3,2,1,0 of
                           PORTB
```

3.2.4 ~ Bitwise NOT (INVERT)

A	~A
0	1
1	0

Result is the inverse of A.

The ~ operator works with a single input expression. The input is the expression immediately following the operator.

```
PORTB = ~ PORTB            ' Invert every bit in PORTB
result = ~ (PORTB & %00001111)
'Invert the result of the & operation
```

3.2.5 &/ Bitwise NOT AND (NAND)

A	B	A &/ B
0	0	1
0	1	1
1	0	1
1	1	0

Result is the inverse of bitwise AND.

The &/ operator returns the same result as the combination of ~ and &:

```
result = PORTB &/ %00001111
result = ~(PORTB & %00001111)  ' Same result
```

3.2.6 |/ Bitwise NOT OR (NOR)

A	B	A |/ B
0	0	1
0	1	0
1	0	0
1	1	0

Result is the inverse of bitwise OR.

The &/ operator returns the same result as the combination of ~ and !:

```
result = PORTB |/ %00001111
result = ~ (PORTB | %00001111) ' Same result
```

3.2.7 ^/ Bitwise NOT EXCLUSIVE OR (XNOR)

A	B	A ^/ B
0	0	1
0	1	0
1	0	0
1	1	1

Result is the inverse of bitwise XOR.

The ^/ operator returns the same result as the combination of ~ and ^:

```
result = PORTB ^/ %00001111
result = ~(PORTB ^ %00001111)  ' Same result
```

3.2.8 << SHIFT LEFT

The << operator shifts all the bits in the input to the left the specified number of places. The bits shifted "out" on the left are discarded. New bits shifted in are always zeros. Consider the following example that represents a SHIFT LEFT one place: (%10110111 << 1)

```
(discard) ← 1 ← 0 ← 1 ← 1 ← 0 ← 1 ← 1 ← 1 ← (zero)
            0   1   1   0   1   1   1   0
```

Example:

```
A = $10110111
result = A << 1             ' result = %01101110
result = A << 2             ' result = %11011100
result = A << 3             ' result = %10111000
```

SHIFT LEFT is commonly used to multiply a value by a power of 2. Shifting executes a lot faster than multiplication, but is limited to powers of 2 (2, 4, 8, etc.) because of the operation can only be performed on binary numbers.

```
result = value << 2
'SHIFT LEFT 2 places, same as (result = value * 4)
```

Another example is to move bit values in a variable out of the way so new bit values may be "shifted in" from the right:

```
FOR i = 0 TO 7
    value = value << 1      'Shift bits left one place
    value.0 = PORTB.0       'read read and store input
NEXT i
```

3.2.9 >> SHIFT RIGHT

SHIFT RIGHT is identical to SHIFT LEFT, except the bits are moved to the right, the rightmost (least significant) bits are discarded, and zeros are used to fill the leftmost (most significant) bits.

SHIFT RIGHT is commonly used to divide a value by a power of 2. Shifting executes a lot faster than division, but is limited to powers of 2 (2, 4, 8, etc.) because of the operation can only be performed on binary numbers.

```
result = value >> 2
'SHIFT LEFT 2 places, same as (result = value / 4)
```

Another common application is to move the most-significant 4 bits to the least significant position in the variable:

```
result = PORTB >> 4         'Read most-significant half of
                            PORTB
```

3.3 Comparison Operators

Comparison Operator	Description
= or ==	Equal to
<> or !=	Not Equal to
<	Less Than to
>	Greater Than to
<=	Less Than or Equal to
>=	Greater Than or Equal to

Comparison operators are used to compare (test the relationship of) two expressions. The concept is that the operator returns a true value (1) when the condition is satisfied and a false (0) if the condition is not satisfied. These operators are used in commands that perform tests in order to direct the program flow. Some common examples would be:

```
'Test for a switch input
IF ( PORTB.0 = 0 ) THEN switched

'Loop until a counter expires
DO WHILE ( counter > 0 )
LOOP
```

3.3.1 Signed vs. Unsigned Comparisons

Numbers in PBP may be treated as unsigned (always positive) or signed (positive and negative), depending on the type of variable in use. LONG variables are treated as signed, other variable types are not.

```
Bval  VAR  BYTE
Lval  VAR  LONG
Bval  = -1                ' result is hex $FF
Lval  = -1                ' result is hex $FFFFFFFF
```

In the above example, PBP will treat the value in Bval as 255, but it will treat the value in Lval as -1. If you look for a negative value in Bval, you will never find it.

```
If ( Bval < 0 ) THEN negative  'Will never test true
```

Consideration should also be given to the typecasting of temp variables that PBP uses when a compound comparison is written. Consider the example:

```
Bval  VAR  BYTE
Bval = 0
IF ((Bval - 1) < 0) THEN negative
```

In the above example, the expression "Bval – 1" will be written to a temp variable for holding before the comparison is executed. When using PBPW, the temp variable will be a WORD. When using PBPL, the temp variable will be a LONG. The result is that the comparison will return false in PBPW, but true in PBPL.

As with all operators in PBP, comparisons should be grouped with parenthesis to specify the order in which the comparisons are performed (see Logical Operators).

3.3.2 Equal To (= or ==)

```
expression1 = expression2
```

If the evaluated numeric result of expression1 is equal to that of expression2, the result is true. Otherwise, the result is false.

3.3.3 Not Equal To (<> or !=)

```
expression1 <> expression2
```

If the evaluated numeric result of expression1 is not equal to that of expression2, the result is true. Otherwise, the result is false.

3.3.4 Less Than (<)

```
expression1 < expression2
```

If the evaluated numeric result of expression1 is less than that of expression2, the result is true. Otherwise, the result is false.

3.3.5 Greater Than (>)

```
expression1 > expression2
```

If the evaluated numeric result of expression1 is greater than that of expression2, the result is true. Otherwise, the result is false.

3.3.6 Less Than or Equal To (<=)

```
expression1 <= expression2
```

If the evaluated numeric result of expression1 is less than, or equal to, that of expression2, the result is true. Otherwise, the result is false.

3.3.7 Greater Than or Equal To (=>)

```
expression1 => expression2
```

If the evaluated numeric result of expression1 is greater than, or equal to, that of expression2, the result is true. Otherwise, the result is false.

3.4 Logical Operators

Logical Operator	Description
AND or &&	Logical AND
OR or ||	Logical OR
XOR or ^^	Logical Exclusive OR
NOT or !	Logical NOT
ANDNOT	Logical NAND
ORNOT	Logical NOR
XORNOT	Logical NXOR

Logical operators are used to logically combine multiple comparisons. In other words, they allow you to test for multiple conditions within a single command. This is best shown by example:

```
IF (x = 0) AND ((y = 0) OR (z = 0)) THEN label
```

The above example will jump to the label if either y or z are equal to zero, provided that x is also equal to zero.

3.4.1 Using Parentheses

Note the way parentheses are used in the preceding example to specify the grouping of the logic. It's important to realize that, without parentheses, the logic can be interpreted differently:

```
IF x = 0 AND y = 0 OR z = 0 THEN label
```

The most likely result here will be that PBP interprets the conditional statement from left to right and groups it like this:

```
IF ((x = 0) AND (y = 0)) OR (z = 0) THEN label
```

The operation of the example has now changed dramatically. It will now jump to label if z is equal to zero, regardless of the state of x and y. USE PARENTHESES to avoid this confusion.

3.4.2 Logical vs. Bitwise

Logical operators are very different than bitwise operators! There are circumstances under which PBP will allow the use of logical operators in

expressions. This means that no error message will be generated when you mistakenly use a logical operator in a bitwise calculation. Consider the following:

```
result = PORTB AND %00001111
' Returns logical result (1 or 0)
```

The above example will compile and give a result. The value of the result can only be one or zero (true or false). If the intent is to use a bitwise operation to obtain a binary result, you MUST USE BITWISE OPERATORS:

```
result = PORTB & %00001111
' Returns 8-bit binary result
```

When considering the truth status of expressions that may equate to numeric or binary values, PBP interprets a zero value as false and anything else as true. Therefore, "IF PORTB THEN" is the same as "IF PORTB > 0 THEN".

3.4.3 AND

```
expression1 AND expression2
```

If both expression1 and expression2 are true, the result is true. If either expression is false, the result is false.

3.4.4 OR

```
expression1 OR expression2
```

If either expression1 or expression2 is true, the result is true. If both expressions are false, the result is false.

3.4.5 XOR

```
expression1 XOR expression2
```

If only expression1 or only expression2 is true, the result is true. If both expressions are false, the result it false. If both expressions are true, the result is false.

3.4.6 NOT

```
NOT expression
```

If expression is true, result is false. If expression is false, result is true.

3.4.7 ANDNOT

```
expression1 ANDNOT expression2
```

If both expression1 and expression2 are false, the result is true. If either expression1 or expression2 is true, the result is false. Logically the same as:

```
NOT (expression1 AND expression2)
```

3.4.8 ORNOT

```
expression1 ORNOT expression2
```

If either expression1 or expression2 is true, the result is false. If both expression1 and expression2 are false, the result is true. Logically the same as:

```
NOT (expression1 OR expression2)
```

3.4.9 XORNOT

```
expression1 XORNOT expression2
```

If only expression1 or only expression2 is true, the result is false. If both expressions are false, the result is true. If both expressions are true, the result is true. Logically the same as:

```
NOT (expression1 XOR expression2)
```

Chapter 4: Directives

Directives

Directives are different than commands in that they only affect how the program is compiled. They don't actually execute when the program runs on the microcontroller. However, they may cause the compiler to insert code that does execute at run-time.

There are two types of directives in this section:

Preprocessor directives, denoted with a # character, were put in place to fill the need for users to conditionally compile sections of code and to access areas like device configuration which requires code-replacement at the lowest level.

Compile-Time directives advise the compiler to insert code for event handling, most notably interrupt handling. Directives like ON INTERRUPT specify a label for the handling routines. All compile-time directives also serve as markers, or boundaries, to denote sections in your program where event-handling code is inserted or omitted.

Note that compile-time directives are not dependent on program flow. They act "geographically" in your program, causing PBP to change compile methods for lines that fall below the directive. When you write "ENABLE", think "Enable for all lines below this point".

In interrupt code examples, you may see something like:

```
GOTO mainloop

DISABLE

myint:                          ' Interrupt handler routine
```

Many users question this, pointing out that the DISABLE will never execute. They are correct, it will never execute, but it doesn't matter. DISABLE is a marker that tells PBP to omit interrupt-checking background code for all program lines that are placed below the directive line. A correctly-commented example would read:

```
GOTO mainloop

DISABLE                         ' Disable interrupt-checking for
                                all routines that follow.
myint:                          ' Interrupt handler routine
```

4.1 DISABLE

```
DISABLE
```

DISABLE both debug and interrupt processing following this instruction. Interrupts can still occur but the BASIC interrupt handler in the PICBASIC PRO program and the debug monitor will not be executed until an ENABLE is encountered.

DISABLE and ENABLE are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON DEBUG and ON INTERRUPT for more information.

```
DISABLE                     ' Disable interrupts in handler

myint:
    led = 1                 ' Turn on LED when interrupted
Resume                      ' Return to main program

Enable                      ' Enable interrupts after
                            handler
```

4.2 DISABLE DEBUG

```
DISABLE DEBUG
```

DISABLE DEBUG processing following this instruction. The debug monitor will not be called between instructions until an ENABLE or ENABLE DEBUG is encountered.

DISABLE DEBUG and ENABLE DEBUG are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON DEBUG for more information.

```
DISABLE DEBUG                ' Disable debug monitor calls
```

4.3 DISABLE INTERRUPT

```
DISABLE INTERRUPT
```

DISABLE INTERRUPT processing following this instruction. Interrupts can still occur but the BASIC interrupt handler in the PICBASIC PRO program will not be executed until an ENABLE or ENABLE INTERRUPT is encountered.

DISABLE INTERRUPT and ENABLE INTERRUPT are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON INTERRUPT for more information.

```
DISABLE INTERRUPT           ' Disable interrupts in handler

myint:
    led = 1                 ' Turn on LED when interrupted
Resume                      ' Return to main program

Enable Interrupt            ' Enable interrupts after
                            handler
```

4.4 ENABLE

```
ENABLE
```

ENABLE debug and interrupt processing that was previously DISABLEd following this instruction.

DISABLE and ENABLE are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON DEBUG and ON INTERRUPT for more information.

```
DISABLE                    ' Disable interrupts in handler
myint:
    led = 1                ' Turn on LED when interrupted
RESUME                     ' Return to main program

ENABLE                     ' Enable interrupts after
                           handler
```

4.5 ENABLE DEBUG

```
ENABLE DEBUG
```

ENABLE DEBUG processing that was previously DISABLEd following this instruction.

DISABLE DEBUG and ENABLE DEBUG are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON DEBUG for more information.

```
ENABLE DEBUG                ' Enable calls to the debug
                            monitor
```

4.6 ENABLE INTERRUPT

```
ENABLE INTERRUPT
```

ENABLE INTERRUPT processing that was previously DISABLEd following this instruction.

DISABLE INTERRUPT and ENABLE INTERRUPT are pseudo-ops in that they give the compiler directions, rather than actually generate code. See ON INTERRUPT for more information.

```
DISABLE INTERRUPT          ' Disable interrupts in ISR

myint:
    led = 1                ' Turn on LED when interrupted
RESUME                     ' Return to main program

ENABLE INTERRUPT           ' Enable interrupts after
                           handler
```

4.7 ON DEBUG

```
ON DEBUG GOTO Label
```

ON DEBUG allows a debug monitor routine to be executed between each PICBASIC PRO command.

The method by which this happens is similar to the method used by ON INTERRUPT GOTO. Once ON DEBUG GOTO is encountered, a call to the specified debug label is inserted before each PICBASIC PRO instruction in the program. DISABLE DEBUG prevents the insertion of this call while ENABLE DEBUG resumes the insertion of the call.

A monitor routine may be written that is activated before each instruction. This routine can send data to an LCD or to a serial communication program. Any program information may be displayed or even altered in this manner. A small monitor program example is posted on our web site.

A word-sized system variable that resides in BANK0 is required to provide a place to store the address the program was at before the monitor routine was called by ON DEBUG GOTO. An additional byte-sized system variable is required for PIC18 parts.

```
DEBUG_ADDRESS  VAR WORD BANK0 SYSTEM
DEBUG_ADDRESSU VAR BYTE BANK0 SYSTEM   'PIC18 only
```

Another byte-sized variable may be used to return the level of the current program stack:

```
DEBUG_STACK    VAR BYTE BANK0 SYSTEM
```

This level should never be greater than 4 for 12- and 14-bit core PIC MCUs, 12 for PIC17 devices or 27 for PIC18 devices in a PICBASIC PRO program. The supplied variable will be incremented at each GOSUB and decremented at each RETURN. This variable should be set to 0 at the beginning of the program.

Adding this variable to a program does add overhead in that the value of the variable must be incremented and decremented at each GOSUB and RETURN.

4.8 ON INTERRUPT

```
ON INTERRUPT GOTO Label
```

ON INTERRUPT allows the handling of microcontroller interrupts by a PICBASIC PRO subroutine. This method is intended to simplify the creation of interrupt service routines. It may not respond to interrupts as quickly as methods using Assembly Language.

See section 6.1 Interrupts Using ON INTERRUPT for a more complete discussion.

```
ON INTERRUPT GOTO myint ' Interrupt handler is myint
INTCON = %10010000       ' Enable RB0 interrupt
DISABLE                  ' Disable interrupts in handler
myint:
    led = 1              ' Turn on LED when interrupted
    INTCON.1 = 0         ' Clear interrupt flag
RESUME                   ' Return to main program

ENABLE                   ' Enable interrupts after
                         handler
```

To turn off interrupts permanently (or until needed again) once ON INTERRUPT has been used, set INTCON to $80:

```
INTCON = $80
```

4.9 #CONFIG...#ENDCONFIG

```
#CONFIG
    ;configuration directives in Assembly Language
#ENDCONFIG
```

#CONFIG can be used to insert a block of Assembly Language directives that specify settings for target device's configuration words. These settings control things like the oscillator type, code protection, and other parameters that must be set before the program code executes. For detailed information about configuration words, see the datasheet for the specific PIC microcontroller that you are compiling for. Most datasheets will list the information in a section named "Configuration" or "Special Features".

The #CONFIG block is similar to the ASM..ENDASM and @ runtime commands because its contents are written in Assembly Language. It is a special case, however, and differs from the runtime commands in significant ways. The code enclosed in a #CONFIG block always replaces the default configuration settings that PBP would normally include. The code is placed in a special location in the generated Assembly Language. This location is reserved for configuration directives; therefore #CONFIG should not be used for other Assembly instructions.

Microchip determines the form and syntax of the actual configuration directives, and they are not consistent for different families of PIC microcontrollers. We have attempted to include the information for each chip in a device information file. The files are located in your PBP install in the Device Reference folder. (PIC16F877.INFO, PIC18F4620.INFO, etc.)

Here are a few examples that you might use for various parts:

```
'Config for 16F877A
#CONFIG
    __config _XT_OSC & _WDT_ON & _LVP_OFF & _CP_OFF
#ENDCONFIG

'Config for 18F46J50
#CONFIG
    CONFIG XINST  = OFF
    CONFIG PLLDIV = 5
    CONFIG WDTPS  = 512
    CONFIG CPUDIV = OSC1
    CONFIG OSC    = HSPLL
#ENDCONFIG
```

#CONFIG..#ENDCONFIG

The conditional compile directives can be used to set the configuration according to the selected target device. The following code snippet demonstrates this. When compiled for any device other than the 18F25K20 or 18F25K22, a custom error will be generated. Not that the example also initializes ANSELx SFRs differently for the different devices.

```
#IF __PROCESSOR__ = "18F25K22"
    #config
        CONFIG  FOSC = HSHP
        CONFIG  WDTEN = OFF
        CONFIG  PWRTEN = ON
        CONFIG  BOREN = OFF
        CONFIG  PBADEN = OFF
        CONFIG  MCLRE = INTMCLR
        CONFIG  LVP = OFF
        CONFIG  DEBUG = OFF
        CONFIG  XINST = OFF
    #endconfig
    ANSELA = 0   ; All Digital
    ANSELB = 0
    ANSELC = 0
#ELSE
    #IF __PROCESSOR__ = "18F25K20"
        #config
            CONFIG  FOSC = HS
            CONFIG  WDTEN = OFF
            CONFIG  PWRT = ON
            CONFIG  BOREN = OFF
            CONFIG  PBADEN = OFF
            CONFIG  MCLRE = OFF
            CONFIG  LVP = OFF
            CONFIG  DEBUG = OFF
            CONFIG  XINST = OFF
        #endconfig
        ANSEL = 0  ; All Digital
        ANSELH = 0
    #ELSE
        #ERROR "Program does not support " + __PROCESSOR__
    #ENDIF
#ENDIF
```

4.10 #DEFINE

```
#DEFINE  constant_name  {value}
```

The #DEFINE directive creates a compile-time constant and, optionally, assigns a value to the constant.

constant_name may be any word that is not in the reserved word list, not used for another entity (variable, constant, alias, label, etc) within the PBP program, and does not exist as a register (SFR) name in the target PIC MCU.

Constant names should be limited to 31 characters in length. PBP will accept longer names, but all names will be truncated to 31 characters during compilation. Names cannot begin with a number. The only special character allowed in names is the underscore "_" character.

value may be numeric, or a string enclosed in quotation marks:

```
#DEFINE  foo  10
#DEFINE  foo1  "18F"
```

Once created, these constants can be used in conditionals with #IF, #IFDEF, and #IFNDEF. The can also be used with message directives #MSG, #ERROR, and #WARNING.

Compile-time constants created with #DEFINE are not the same as run-time constants created with the CON directive, and are not accessible to PBP program code. Compile-time constants are only accessible to preprocessor (#) directives listed in this section.

There are several pre-defined system constants that are created automatically and accessible in the same fashion as those created manually with #DEFINE. These constants are named in the form __name__. They are:

__DATE__	Date of compilation from computer's clock
__TIME__	Time of compilation from the computer's clock
__TIMESTAMP__	Date and time of compilation
__PROCESSOR__	The target device part number (eg "18F2620")
__VERSION__	The version of PBP
__LONG__	Indicator that PBPL is in use. (Value is 1 if compiler is invoked as PBPL, 0 if compiler is invoked as PBPW.)
__LINE__	The line number where written (Used with #MSG, #ERROR, or #WARNING to report a line number.)

#DEFINE

__FILE__	The name of the PBP program file

Compile-time constants can also be created with the –d command line switch when PBPX is invoked. See section 8.3 PBPX Command Line Operation.

4.11 #ERROR

```
#ERROR  {"message"}
```

The #ERROR directive, when encountered, will abort the compilation process and report the error message that you specify.

This directive should always be written inside of a conditional block. If #ERROR is used outside of a conditional, it will always abort the compile.

```
#IF __LONG__ = 0
  #ERROR "This program requires PBPL"
#ENDIF
```

4.12 #IF…#ELSE…#ENDIF

```
#IF  condition {AND|OR condition}
```

The #IF allows sections of code to be omitted or compiled based on a condition. The conditional expression must be constructed from compile-time constants that have been previously declared using #DEFINE. (Run-time variables and constants cannot be used here.)

The purpose of this directive is to give the user the means to easily and globally change the program before it is compiled based on a control constant. This is useful when a single program needs to be compiled with modifications for different application types, but the user desires to maintain only one program file.

One example would be to compile the same program for two different PIC MCUs. Consider the case where the hardware exists in two versions; one is an older version that uses the PIC16F877A, and an updated hardware revision exists that uses the PIC16F887. These parts are almost identical, except for some differences in register names and settings. You could accommodate both parts with a conditional compile.

```
#IF  __PROCESSOR__ = "16F877"
    ADCON1 = 7              'All pins digital on the 877A
#ELSE
    ANSEL = 0               'AN0-AN7 digital on the 887
    ANSELH = 0              'AN8-AN13 digital on the 887
#ENDIF
```

Note the difference between the compile-time #IF and the run-time IF. When the #IF is used, only one section of code is actually compiled. The unused code is "thrown away" before compilation. This saves code space and avoids compilation errors associated with non-existent register names. The run-time IF would attempt to compile both sections of code for later execution based on a run-time condition.

The #IF and associated directives will control ANY code written. This includes variable and constant declarations, configuration blocks, in-line Assembly blocks, and program code. This makes them very powerful, but opens the door to potential syntax errors when used improperly. Consider the following:

```
#DEFINE  omit  1           'Set a flag to omit code

#IF  omit <> 1
    FOR x = 0 TO 7
      HIGH LED
      PAUSE 100
      LOW LED
      PAUSE 100
#ENDIF
    NEXT x
```

In this example, a compile error will result only when the compile-time constant "omit" is set to 1. In that case, the top portion of the FOR..NEXT is omitted, leaving only the NEXT.

4.13 #IFDEF…#ELSE…#ENDIF

```
#IFDEF  constant
```

The #IFDEF directive checks to see whether a constant has been defined. With #IFDEF, the value of the constant is irrelevant. If the constant exists, #IFDEF will be satisfied, regardless of the value.

Consider the case where hardware exists in two versions; one uses analog inputs on PORTA and one uses switches on PORTA. You could accommodate both parts with a conditional compile that is triggered by the existence of the compile-time constant "SET_DIGITAL":

```
#DEFINE  SET_DIGITAL        'Create constant that specifies
                            digital operation

#IFDEF  SET_DIGITAL         'Compile this section only for
                            digital operation
    ADCON1 = 7              'All pins digital on the 877A
#ENDIF
```

#IFDEF, like #IF, must be used with #ENDIF. It can also be used with #ELSE:

```
#DEFINE  SET_DIGITAL        'Create constant that specifies
                            digital operation

#IFDEF  SET_DIGITAL         'Compile this section only for
                            digital operation
    ADCON1 = 7              'All pins digital on the 877A
#ELSE
    ADCON1 = %00000010      ' Set PORTA analog
#ENDIF
```

4.14 #IFNDEF…#ELSE…#ENDIF

```
#IFNDEF  constant
```

The #IFNDEF directive is the opposite of #IFDEF. #IFNDEF evaluates a true condition if the specified constant is NOT defined.

4.15 #MSG

```
#MSG "message"
```

The #MSG directive causes a message to be reported to the user during compilation.

The message may be a string enclosed in quotes, a compile-time constant, or a concatenation of both.

```
#MSG "Compiling for target " + __PROCESSOR__
```

4.16 #WARNING

```
#WARNING {"message"}
```

The #WARNING directive will report the specified warning message during compilation, but it will allow the compilation to continue.

This directive would normally be written inside of a conditional block. If written outside of a conditional, a warning will always be reported.

```
#IF __LONG__ = 1
  #WARNING "PBPW is recommended for this program"
#ENDIF
```

Chapter 5: Commands

5.1 Overview of Commands

@	Insert one line of assembly language code.
ADCIN	Read on-chip analog to digital converter.
ARRAYREAD	Parse array (string) and fill variables.
ARRAYWRITE	Send variables and constants to array (string).
ASM..ENDASM	Insert assembly language code section.
BRANCH	Computed **GOTO** (equivalent to **ON GOTO**).
BRANCHL	**BRANCH** out of page (long **BRANCH**).
BUTTON	Debounce and auto-repeat input on specified pin.
CALL	Call assembly language subroutine.
CLEAR	Zero all variables.
CLEARWDT	Clear (tickle) Watchdog Timer.
COUNT	Count number of pulses on a pin.
DATA	Define initial contents of on-chip EEPROM.
DEBUG	Asynchronous serial output with fixed pin and baud.
DEBUGIN	Asynchronous serial input with fixed pin and baud.
DISABLE	Disable **ON DEBUG** and **ON INTERRUPT** processing.
DISABLE DEBUG	Disable **ON DEBUG** processing.
DISABLE INTERRUPT	Disable **ON INTERRUPT** processing.
DO..LOOP	Repeatedly execute a block of statements.
DTMFOUT	Produce touch-tone frequencies on a pin.
EEPROM	Define initial contents of on-chip EEPROM.
ENABLE	Enable **ON DEBUG** and **ON INTERRUPT** processing.
ENABLE DEBUG	Enable **ON DEBUG** processing.
ENABLE INTERRUPT	Enable **ON INTERRUPT** processing.
END	Stop program execution and enter low power mode.
ERASECODE	Erase block of code memory.
EXIT	Exit the current block structure.
FOR..NEXT	Repeatedly execute statements in a counted loop.
FREQOUT	Produce 1 or 2 frequencies on a pin.
GOSUB	Call BASIC subroutine at specified label.
GOTO	Continue execution at specified label.
HIGH	Make pin output high.
HPWM	Output hardware pulse width modulated pulse train.
HSERIN	Hardware asynchronous serial input.
HSERIN2	Hardware asynchronous serial input, second port.

Command Overview

HSEROUT	Hardware asynchronous serial output.
HSEROUT2	Hardware asynchronous serial output, second port.
I2CREAD	Read from I^2C device.
I2CWRITE	Write to I^2C device.
IF..THEN..ELSE..ENDIF	Conditionally execute statements.
INPUT	Make pin an input.
LCDIN	Read from LCD RAM.
LCDOUT	Display characters on LCD.
{**LET**}	Assign result of an expression to a variable.
LOOKDOWN	Search constant table for value.
LOOKDOWN2	Search constant / variable table for value.
LOOKUP	Fetch constant value from table.
LOOKUP2	Fetch constant / variable value from table.
LOW	Make pin output low.
NAP	Power down processor for short period of time.
ON DEBUG	Execute BASIC debug monitor.
ON GOSUB	Computed **GOSUB**.
ON GOTO	Computed **GOTO** (equivalent to **BRANCHL**).
ON INTERRUPT	Execute BASIC subroutine on an interrupt.
OWIN	1-wire input.
OWOUT	1-wire output.
OUTPUT	Make pin an output.
PAUSE	Delay (1 millisecond resolution).
PAUSEUS	Delay (1 microsecond resolution).
PEEK	Read byte from register.
PEEKCODE	Read byte from code space.
POKE	Write byte to register.
POKECODE	Write byte to code space when programming device.
POT	Read potentiometer on specified pin.
PULSIN	Measure pulse width on a pin.
PULSOUT	Generate pulse on a pin.
PWM	Output pulse width modulated pulse train to pin.
RANDOM	Generate pseudo-random number.
RCTIME	Measure pulse width on a pin.
READ	Read byte from on-chip EEPROM.
READCODE	Read word from code memory.
REPEAT..UNTIL	Execute statements until condition is true.
RESUME	Continue execution after interrupt handling.
RETURN	Continue at statement following last **GOSUB**.

REVERSE	Make output pin an input or an input pin an output.
SELECT CASE	Compare a variable with different values.
SERIN	Asynchronous serial input (BS1 style).
SERIN2	Asynchronous serial input (BS2 style).
SEROUT	Asynchronous serial output (BS1 style).
SEROUT2	Asynchronous serial output (BS2 style).
SHIFTIN	Synchronous serial input.
SHIFTOUT	Synchronous serial output.
SLEEP	Power down processor for a period of time.
SOUND	Generate tone or white-noise on specified pin.
STOP	Stop program execution.
SWAP	Exchange the values of two variables.
TOGGLE	Make pin output and toggle state.
USBIN	USB input.
USBINIT	Initialize USB.
USBOUT	USB output.
USBSERVICE	USB service loop.
WHILE..WEND	Execute statements while condition is true.
WRITE	Write byte to on-chip EEPROM.
WRITECODE	Write word to code memory.
XIN	X-10 input.
XOUT	X-10 output.

5.2 @

```
@ Statement
```

When used at the beginning of a line, **@** provides a shortcut for inserting one assembly language *Statement* into your BASIC program. You can use this shortcut to mix assembly language code with PICBASIC PRO statements.

```
i Var Byte
rollme Var Byte
For i = 1 To 4
    @   rlf _rollme, F     ; Rotate byte left once
Next i
```

The **@** shortcut can also be used to include assembly language routines in another file. For example:

```
@ Include "fp.asm"
```

@ resets the bank selection to 0 before executing the assembly language instruction. The bank selection should not be altered using **@**.

See section 7.1. In-Line Assembly Language for more information.

Related Commands:

```
CALL
ASM..ENDASM
```

5.3 ADCIN

```
ADCIN Channel, Var
```

Read the on-chip analog to digital converter *Channel* and store the result in *Var.* While the ADC registers can be accessed directly, ADCIN makes the process a little easier.

Channel is the channel-number assigned to the input pin that you wish to use. This should not be confused with the pin number or the PORT.PIN designation. Each ADC input is assigned a channel number, usually designated with the form ANx. Use only the number. *Channel* may be a variable.

Var can be a BYTE, WORD, or LONG variable. If the expected result is to be more than an 8-bit value, BYTE variables should not be used.

ADCIN is a hardware-based command that requires the existence of an Analog Conversion Peripheral on the PIC MCU. Some configuration is required to allow proper operation of the peripheral.

The data-direction should be set to input using the appropriate TRIS or TRISIO register, or by using PBP's INPUT command.

The channel should be configured for analog operation. This is controlled in a variety of registers in the many PIC MCUs that are supported, so the datasheet must be consulted. The setting is commonly in registers ADCON1, ANSEL, ANSELH, ANSELA, ANSELB, ANCON, etc. Look in the datasheet's section on Analog Converter (ADC) first. If the channel configuration register is not found there, check the section on I/O ports.

The result should be configured as left-justified if you are performing an 8-bit conversion. It should be right-justified if more than 8-bit precision is required. This is also a register setting and will be found in the datasheet section on the Analog Converter (ADC).

The number of bits in the result that PBP returns is controlled with the following DEFINE. Most PIC MCUs offer up to 10-bits of precision. Some offer more.

```
DEFINE  ADC_BITS  8        ' Set for 8-bit result (default)
```

You may set ADC_BITS to values 8-16, but in reality the result will either be 8-bits or the maximum precision available (10-bits, in most cases).

The ADC clock source should also be set. A DEFINE is offered for this, as well.

ADCIN

```
DEFINE ADC_CLOCK 3          ' Set clock source (rc =3)
```

The ADC_CLOCK value corresponds to a value set with 2-5 bits in a register within the PIC MCU. In most cases, the default value of 3 (binary %11) selects an independent RC clock that returns an accurate conversion result without regard for the system clock frequency. Conversion execution time may be enhanced in some cases by changing this setting.

Some PIC MCU defy PBP's attempts to translate the ADC_CLOCK define to a register setting. If you are having trouble with your ADCIN performance, try setting the ADC clock source with a direct register setting in addition to the DEFINE.

There is also a defined value called ADC_SAMPLEUS. Its unit is microseconds. This value represents a delay that is executed after the ADC channel is selected and before the conversion is started.

```
DEFINE ADC_SAMPLEUS 50      ' Set sampling time in
                            microseconds
```

Its purpose is to eliminate crosstalk between ADC channels. The default value of 50uS is usually sufficient. If you are only reading a single channel, you may reduce the value to enhance execution time. If you experience crosstalk, where voltage changes on one channel affect the reading from another, try increasing the ADC_SAMPLEUS value.

Here is an ADCIN example taken from a program intended for the 16F887:

```
DEFINE ADC_BITS     10      ' Set number of bits in result
DEFINE ADC_SAMPLEUS 50      ' Set sampling time in uS
'DEFINE ADC_CLOCK    3      ' This define is inoperative on
                            16F88x
adval VAR WORD              ' Create adval to store result

ADCON0 = %11000000          ' Set ADC_CLOCK to RC (DEFINE
                            ACD_CLOCK inoperative on the
                            16F88x)
ADCON1 = %10000000          ' Right-Justify result in
                            ADRESH:ADRESL registers
ANSEL = %00000001           ' Set AN0-AN7 to digital with
                            the exception of AN0
ANSELH = %00000000          ' Set AN8 and higher channels to
                            digital operation
TRISA = %11111111           ' Set PORTA to all input

ADCIN 0, adval              ' Read channel 0 to adval
```

5.4 ARRAYREAD

ARRAYREAD ArrayVar, {Maxlength, Label,}**[**Item...**]**

Read one or more *Item*s from byte array *ArrayVar* using SERIN2 modifiers. ARRAYREAD can be used to scan a byte array for values and other strings and move these elements to other variables.

An optional *Maxlength* and *Label* may be included to allow the program to limit the number of characters read from the array so as not to read past its allocated length. *Maxlength* must be less than 256, though longer arrays may be read using either multiple ARRAYREADs or by leaving off this optional parameter. If the count exceeds the *Maxlength*, the program will exit the ARRAYREAD command and jump to *Label*.

An assortment of string-parsing modifiers is available for use within the item list of this command. These modifiers are capable of extracting data from input strings to various variable types:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar*n*{*c*}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{*n*}	Wait for character string

See section 2.10 for details on string-parsing modifiers.

ARRAYREAD is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
' Get first 2 bytes from array
ARRAYREAD A,[B0,B1]

' Skip 2 chars and grab a 4 digit decimal number
ARRAYREAD A,[SKIP 2,DEC4 W0]

' Find "x" in array A and then read a string
ARRAYREAD A,20,tlabel,[WAIT("x"),STR ar\10]
```

5.5 ARRAYWRITE

ARRAYWRITE ArrayVar, {Maxlength, Label,}**[**Item...**]**

Write one or more *Item*s to byte array *ArrayVar* using SEROUT2 modifiers. ARRAYWRITE allows the writing of formatted data to a byte array which can then be output by other compiler commands, such as I2CWRITE, to write to a serial LCD, for example.

An optional *Maxlength* and *Label* may be included to allow the program to limit the number of characters written to the array so as not to exceed its allocated length. *Maxlength* must be less than 256, though longer arrays may be written using either multiple ARRAYWRITEs or by leaving off this optional parameter. If the count exceeds the *Maxlength*, the program will exit the ARRAYWRITE command and jump to *Label*.

An assortment of string-formatting modifiers is available for use within the item list of this command. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

ARRAYWRITE is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
' Send the ASCII value of B0 followed by a period
' and 2 digit ASCII value of B1
ARRAYWRITE A,[DEC B0,".",DEC2 B1]

' Send "B0 =" followed by the binary value of B0
ARRAYWRITE A,20,tlabel,["B0=",IBIN8 B0]
```

5.6 ASM..ENDASM

```
ASM
    ;Assembly Language Code
ENDASM
```

The ASM and ENDASM instructions tells PBP that the code between these two lines is in assembly language and should not be interpreted as PICBASIC PRO statements. You can use these two instructions to mix assembly language code with BASIC statements.

The maximum size for an assembler text section is 8K characters. This is the maximum size for the actual source, including comments, not the generated code. If the text block is larger than this, you must break it into multiple ASM..ENDASM sections or simply include it in a separate file.

ASM resets the bank-selection in RAM to 0. You must ensure that the bank-select is reset to 0 before ENDASM, if the assembly language code has altered it.

ENDASM must not appear in a comment in the assembly language section of the program. As the compiler cannot discern what is happening in the assembly section, an ENDASM anywhere in an ASM section will cause the compiler to revert to BASIC parsing.

See section 7.1. In-Line Assembly Language for more information.

```
ASM
    bsf PORTA, 0 ; Set bit 0 on PORTA
    bcf PORTB, 0 ; Clear bit 0 on PORTB
ENDASM
```

Related Commands:

```
@
CALL
```

5.7 BRANCH

```
BRANCH Index,[Label{,Label...}]
```

BRANCH is a legacy command retained for backward compatibility. Replacement with ON GOTO is recommended.

BRANCH causes the program to jump to a different location based on a variable index.

Index selects one of a list of *Label*s. Execution resumes at the indexed *Label*. For example, if *Index* is zero, the program jumps to the first *Label* specified in the list, if *Index* is one, the program jumps to the second *Label*, and so on. If *Index* is greater than or equal to the number of *Label*s, no action is taken and execution continues with the statement following the BRANCH. Up to 255 (256 for PIC18) *Label*s may be used in a BRANCH.

For 12- and 14-bit core and PIC17 devices, *Label* must be in the same code page as the BRANCH instruction. If you cannot be sure they will be in the same code page (if you receive a "crossing code page boundary" warning), use BRANCHL instead.

For PIC18 devices, the *Label* must be within 1K of the BRANCH instruction as it uses a relative jump. If the *Label* is out of this range, use BRANCHL.

```
BRANCH B4,[dog,cat,fish]
' Same as:
' If B4=0 Then dog (goto dog)
' If B4=1 Then cat (goto cat)
' If B4=2 Then fish (goto fish)
```

Related Commands:

```
ON GOTO
ON GOSUB
BRANCHL
```

5.8 BRANCHL

```
BRANCHL Index,[Label{,Label...}]
```

BRANCHL is a legacy command retained for backward compatibility. Replacement with ON GOTO is recommended.

BRANCHL (BRANCH long) works very similarly to BRANCH in that it causes the program to jump to a different location based on a variable index. The main difference is that it can jump to a *Label* that is in a different code page than the BRANCHL instruction for 12- and 14-bit core and PIC17 devices, or further away than 1K for PIC18 devices. It also generates code that is about twice the size as code generated by the BRANCH instruction. If you are sure the labels are in the same page as the BRANCH instruction or if the microcontroller does not have more than one code page, using BRANCH instead of BRANCHL will minimize memory usage. BRANCHL is a different syntax of ON GOTO.

Index selects one of a list of *Label*s. Execution resumes at the indexed *Label*. For example, if *Index* is zero, the program jumps to the first *Label* specified in the list, if *Index* is one, the program jumps to the second *Label*, and so on. If *Index* is greater than or equal to the number of *Label*s, no action is taken and execution continues with the statement following the BRANCHL. Up to 127 (1024 for PIC18) *Label*s may be used in a BRANCHL.

```
BRANCHL B4,[dog,cat,fish]
' Same as:
' If B4=0 Then dog (goto dog)
' If B4=1 Then cat (goto cat)
' If B4=2 Then fish (goto fish)
```

Related Commands:

```
ON GOTO
ON GOSUB
BRANCH
```

5.9 BUTTON

```
BUTTON Pin, Down, Delay, Rate, BVar, Action, Label
```

Read *Pin* and optionally perform debounce and auto-repeat. *Pin* is automatically made an input. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

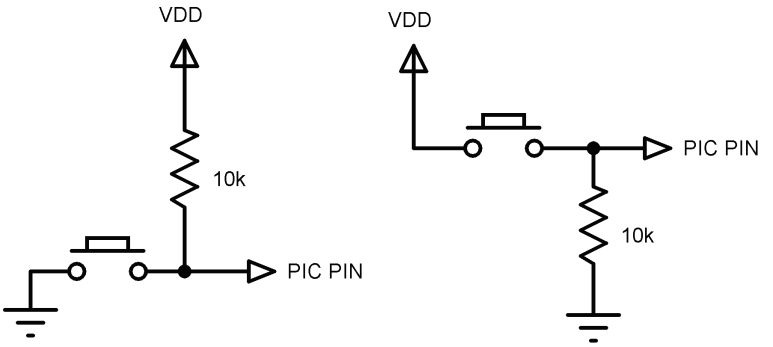
Down State of pin when button is pressed (0..1).

Delay Cycle count before auto-repeat starts (0..255). If 0, no debounce or auto-repeat is performed. If 255, debounce, but no auto-repeat, is performed.

Rate Auto-repeat rate (0..255).

BVar Byte-sized variable used internally for delay/repeat countdown. It must be initialized to 0 prior to use and not used elsewhere in the program.

Action State of button to act on (0 if not pressed, 1 if pressed). *Label* Execution resumes at this label if *Action* is true.




```
' Goto notpressed if button not pressed on Pin2
BUTTON PORTB.2,0,100,10,B2,0,notpressed
```

BUTTON needs to be used within a loop for auto-repeat to work properly.

BUTTON accomplishes debounce by delaying program execution for a period of milliseconds to wait for the contacts to settle down. The default debounce delay is 10ms. To change the debounce to another value, use DEFINE:

```
' Set button debounce delay to 50ms
DEFINE BUTTON_PAUSE 50
```

Be sure that `BUTTON_PAUSE` is all in upper case. The maximum delay for 12-bit core devices is 65ms.

Button is a complex command. If auto-repeat and debounce is not required, it is easier to simply read the state of the pin in an IF..THEN:

```
If PORTB.2 = 1 Then notpressed
```

The example program on the following page uses BUTTON to monitor three switches and toggles the state of a separate LED for each switch. Each switch is equipped with delayed auto-repeat that works independently of the other two switches. This example is written for the PIC16F887.

In the example, the BUTTON commands are written in this form:

```
BUTTON button1, 0, 40, 5, B1, 0, chk2
```

Decoding the parameters in order, the function of this command is:

- monitor the button1 pin, which…
- goes to a zero state when the button is pressed
- delay 40 loops before auto-repeat
- auto-repeat every 5 loops while pressed
- use the B1 variable to track loops
- act when the button is *not* pressed
- action is to jump to the chk2 label

BUTTON

```
button1 VAR PORTB.4
button2 VAR PORTB.5
button3 VAR PORTB.6

LED1 VAR PORTB.0
LED2 VAR PORTB.1
LED3 VAR PORTB.2

B1   VAR BYTE   ' Working buffer 1 for button command
B2   VAR BYTE   ' Working buffer 2 for button command
B3   VAR BYTE   ' Working buffer 3 for button command

   ANSEL = %00000000 ' Make AN0-AN7 digital
   ANSELH= %00000000 ' Make AN8-AN13 digital


   CLEAR        ' Clear buffers
   PORTB = 0    ' LEDs off

   TRISB = %11110000    ' Set portb 0-3 outputs, 4-7 inputs
   OPTION_REG.7 = 0     ' Enable PORTB pull-ups

chk1:
   PAUSE 25               ' Pause once for each loop

   ' Check Button 1 (Skip to 2 if Not Pressed)
   BUTTON button1, 0, 40, 5, B1, 0, chk2
   TOGGLE LED1  ' Toggle LED if pressed

chk2:
   ' Check Button 2 (Skip to 3 if Not Pressed)
   BUTTON button2, 0, 40, 5, B2, 0, chk3
   TOGGLE LED2  ' Toggle LED if pressed

chk3:
   ' Check Button 3 (Skip to 1 if Not Pressed)
   BUTTON button3, 0, 40, 5, B3, 0, chk1
   TOGGLE LED3  ' Toggle LED if pressed
   GoTo chk1    ' Do it forever
```

5.10 CALL

```
CALL Label
```

Execute the assembly language subroutine named *_Label*.

GOSUB is normally used to execute a PICBASIC PRO subroutine. The main difference between GOSUB and CALL is that with CALL, *Label*'s existence is not checked until assembly time. A *Label* in an assembly language section can be accessed using CALL that is otherwise inaccessible to PBP. The Assembly *Label* should be preceded by an underscore (_).

See section 7.1 In-Line Assembly Language and section 7.5 Hardware Stack for more information.

```
CALL pass                    ' Execute assembly language
                             subroutine named _pass
```

Related Commands:

```
@
ASM..ENDASM
```

5.11 CLEAR

```
CLEAR
```

CLEAR writes zeros to all the RAM locations in each bank. This intention is to initialize all declared variables with a value of zero.

When a PIC MCU is powered up, the RAM memory may read random data values. PBP does not automatically clear these values. CLEAR is a coding shortcut to accomplish a global initialization when needed, but it is expensive in terms of execution time. Rather than using CLEAR, consider initializing each variable individually, as needed.

CLEAR does not affect registers (SFRs) in the PIC MCU.

CLEAR does not zero bank 0 registers on 12-bit core devices.

```
CLEAR    ' Clear all variables to 0
```

5.12 CLEARWDT

```
CLEARWDT
```

Clear the Watchdog Timer.

The watchdog timer, when enabled, will reset the microcontroller after a specified amount of time if it is ignored by the executing program code. This functions as a safeguard against "lock-ups" by automatically resetting the device if the program stops running. By default, PBP automatically clears and restarts the watchdog timer periodically so that the watchdog reset never happens.

The CLEARWDT command will manually clear the watchdog timer.

```
CLEARWDT                    ' Clear Watchdog Timer
```

A DEFINE can be used to that instructs PBP not to clear the watchdog automatically. This will allow you to manually handle the watchdog with CLEARWDT commands in critical sections of your program. It can also save a bit of code space if you plan to disable the watchdog entirely.

```
DEFINE NO_CLRWDT 1          ' Don't insert CLRWDTs
```

The Watchdog Timer is used in conjunction with the SLEEP and NAP instructions to wake the PIC MCU after a certain period of time.

5.13 COUNT

```
COUNT Pin, Period, Var
```

Count the number of pulses that occur on *Pin* during the *Period* and stores the result in *Var*. *Pin* is automatically made an input. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

The resolution of *Period* is in milliseconds. It tracks the oscillator frequency based on the DEFINEd OSC.

COUNT checks the state of *Pin* in a tight loop and counts the low to high transitions. With a 4MHz oscillator it checks the pin state every 20us. With a 20MHz oscillator it checks the pin state every 4us. From this, it can be determined that the highest frequency of pulses that can be counted is 25KHz with a 4MHz oscillator and 125KHz with a 20MHz oscillator, if the frequency has a 50% duty cycle (the high time is the same as the low time).

```
' Count # of pulses on Pin1 in 100 milliseconds
COUNT PORTB.1,100,W1

' Determine frequency on a pin
COUNT PORTA.2, 1000, W1    ' Count for 1 second
Serout PORTB.0,N2400,[W1]
```

5.14 DATA

```
{Label} DATA {@Location,}Constant{,Constant...}
```

Store constants in on-chip non-volatile EEPROM when the device is first programmed. If the optional *Location* value is omitted, the first **DATA** statement starts storing at address 0 and subsequent statements store at the following locations. If the *Location* value is specified, it denotes the starting location where these values are stored. An optional *Label* (not followed by a colon) can be assigned to the starting EEPROM address for later reference by the program.

Constant can be a numeric constant or a string constant. Only the least significant byte of numeric values are stored unless the WORD or LONG (PBPL only) modifier is used. Strings are stored as consecutive bytes of ASCII values. No length or terminator is automatically added.

DATA only works with microcontrollers with on-chip EEPROM (Data Space). It will not work on devices with on-chip I2C interfaced serial EEPROM like the PIC12CE67x and PIC16CE62x parts. Since EEPROM is non-volatile memory, the data will remain intact even if the power is turned off.

The data is stored in the EEPROM space only once at the time the microcontroller is programmed, not each time the program is run. WRITE can be used to set the values of the on-chip EEPROM at runtime. READ is used to retrieve these stored DATA values at runtime.

```
' Store 10, 20 and 30 starting at location 4
DATA @4,10,20,30

' Assign a label to a word at the next location
dlabel DATA word $1234     ' Stores $34, $12

' Assign a label to a long at the next location
label DATA long $12345678  ' Stores $78, $56, $34,$12 (PBPL
                           only)
' Skip 4 locations and store 10 zeros
DATA (4),0(10)
```

5.15 DEBUG

DEBUG *Item*{,*Item*...}

Send one or more *Item*s on a predefined pin at a predefined baud rate in standard asynchronous format using 8 data bits, no parity and 1 stop bit (8N1). The pin is automatically made an output.

An assortment of string-formatting modifiers is available for use within the item list of this command. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

DEBUG is one of several built-in asynchronous serial functions. It is the smallest and fastest of the software generated serial routines. It can be used to send debugging information (variables, program position markers, etc.) to a terminal program like Hyperterm. It can also be used anytime serial output is desired on a fixed pin at a fixed baud rate.

The serial pin and baud rate are specified using DEFINEs:

```
' Set Debug pin port
DEFINE DEBUG_REG PORTB

' Set Debug pin bit
DEFINE DEBUG_BIT 0

' Set Debug baud rate
DEFINE DEBUG_BAUD 2400

' Set Debug mode: 0 = true, 1 = inverted
DEFINE DEBUG_MODE 1
```

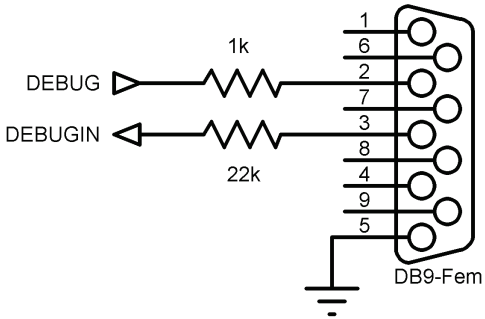
DEBUG assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to any different oscillator value.

In some cases, the transmission rates of DEBUG instructions may present characters too quickly to the receiving device. A DEFINE adds character pacing to the serial output transmissions. This allows additional time between the characters as they are transmitted. The character pacing DEFINE allows a delay of up to 65,535 microseconds (65.535 milliseconds) between each character transmitted.

For example, to pause 1 millisecond between the transmission of each character:

```
DEFINE DEBUG_PACING 1000
```

While single-chip RS-232 level converters are common and inexpensive, thanks to current RS-232 implementation and the excellent I/O specifications of the PIC MCU, most applications may not require level converters. Rather, inverted TTL (DEBUG_MODE 1) may be used. A current limiting resistor is suggested (RS-232 is suppose to be short-tolerant).




```
DEBUG "B0=",DEC B0,10       ' Send the text "B0=" followed
                            by the decimal value of B0 and a
                            linefeed out serially
```

5.16 DEBUGIN

DEBUGIN {*Timeout*, *Label*,}**[***Item*{,*Item*...}**]**

Receive one or more *Item*s on a predefined pin at a predefined baud rate in standard asynchronous format using 8 data bits, no parity and 1 stop bit (8N1). The pin is automatically made an input.

An optional *Timeout* and *Label* may be included to allow the program to continue if a character is not received within a certain amount of time. *Timeout* is specified in 1 millisecond units. If the serial input pin stays idle during the *Timeout* time, the program will exit the DEBUGIN command and jump to *Label*.

An assortment of string-parsing modifiers is available for use within the item list of this command. These modifiers are capable of extracting data from input strings to various variable types:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar*n*{*c*}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{*n*}	Wait for character string

See section 2.10 for details on string-parsing modifiers.

DEBUGIN is one of several built-in asynchronous serial functions. It is the smallest and fastest of the software generated serial routines. It can be used to receive debugging information from a terminal program like Hyperterm. It can also be used anytime serial input is desired on a fixed pin at a fixed baud rate.

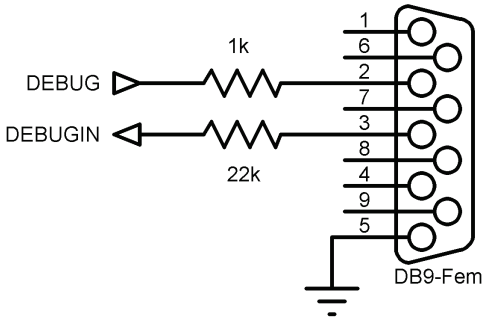
The serial pin and baud rate are specified using DEFINEs:

```
' Set Debugin pin port
DEFINE DEBUGIN_REG PORTB

' Set Debugin pin bit
DEFINE DEBUGIN_BIT 0

' Set Debugin baud rate (same as Debug baud)
DEFINE DEBUG_BAUD 2400

' Set Debugin mode: 0 = true, 1 = inverted
DEFINE DEBUGIN_MODE 1
```

If any of these DEFINEs are not included in a program, the DEBUGIN port, pin or mode is set to the same values as they are for DEBUG. The DEBUGIN baud rate is always the same as DEBUG's. It cannot be DEFINEd differently.

DEBUGIN assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to any different oscillator value.

While single-chip RS-232 level converters are common and inexpensive, thanks to current RS-232 implementation and the excellent I/O specifications of the PIC MCU, most applications may not require level converters. Rather, inverted TTL (DEBUGIN_MODE 1) may be used. A current limiting resistor is necessary to dissipate the higher and sometimes negative RS-232 voltage.



DEBUGIN

```
' Wait until the character "A" is received serially and put
                          next character into B0
DEBUGIN [WAIT("A"),B0]
' Skip 2 chars and grab a 4 digit decimal number
DEBUGIN [SKIP 2,DEC4 B0]
' Wait for value with timeout
DEBUGIN 100, timesup, [B0]
```

5.17 DO..LOOP

```
DO {UNTIL Condition} {WHILE Condition}
    Statement...
LOOP {UNTIL Condition} {WHILE Condition}
```

Repeatedly execute *Statement*s in a loop. An optional **UNTIL** or **WHILE** may be added to check a *Condition*. Tests using the UNTIL keyword will cause the loop to terminate when the condition becomes true. Tests using the WHILE keyword will cause the loop to terminate when the condition becomes false.

If the test condition is written on the line with the DO keyword (at the top of the loop), the test will be performed before the loop executes. If the test condition results in termination of the loop, execution will continue at the line after the LOOP keyword, even if the code within the loop has not executed.

If the test condition is written on the line with the LOOP keyword (at the bottom of the loop), the test will first be performed after the loop executes. The code within the loop will always execute at least one time, even if the test condition calls for termination of the loop on its first iteration.

The EXIT command, when executed within a DO loop, will force the loop to terminate.

DO..LOOP

```
DO
    PWM PORTC.2,127,100
LOOP


i = 1
DO
SEROUT 0,N2400,[”No:”,#i,13,10]
    i = i + 1
LOOP UNTIL i > 10


i = 1
DO WHILE i <= 10
    SEROUT 0,N2400,[”No:”,#i,13,10]
    i = i + 1
LOOP


i = 1
DO
    SEROUT 0,N2400,[”No:”,#i,13,10]
    i = i + 1
    IF PORTB.0 = 0 THEN EXIT
LOOP WHILE i <= 10
```

5.18 DTMFOUT

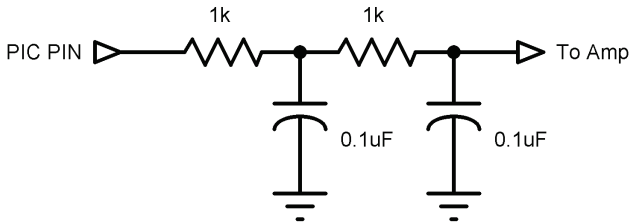
```
DTMFOUT Pin,{Onms, Offms,}[Tone{,Tone...}]
```

Produce DTMF touch *Tone* sequence on *Pin*. *Pin* is automatically made an output. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

Onms is the number of milliseconds to sound each tone and *Offms* is the number of milliseconds to pause between each tone. If they are not specified, *Onms* defaults to 200ms and *Offms* defaults to 50ms.

Tones are numbered 0-15. *Tones* 0-9 are the same as on a telephone keypad. *Tone* 10 is the * key, *Tone* 11 is the # key and *Tones* 12-15 correspond to the extended keys A-D.

DTMFOUT uses FREQOUT to generate the dual tones. FREQOUT generates tones using a form of pulse width modulation. The raw data coming out of the pin looks pretty scary. Some kind of filter is usually necessary to smooth the signal to a sine wave and get rid of some of the harmonics that are generated:



DTMFOUT works best with a 20MHz or 40MHz oscillator. It can also work with a 10MHz or 8MHz oscillator and even at 4MHz, although it will start to get very hard to filter and be of fairly low amplitude. Any other frequency may not be used with DTMFOUT.

DTMFOUT is not supported on PIC MCUs that use the 12-bit instruction set due to RAM and stack constraints.

```
' Send DTMF tones for 212 on Pin1
DTMFOUT PORTB.1,[2,1,2]
```

5.19 EEPROM

```
EEPROM {Location,}[Constant{,Constant...}]
```

This command is included for compatibility with other languages. The DATA command is recommended instead.

Store constants in on-chip EEPROM. If the optional *Location* value is omitted, the first EEPROM statement starts storing at address 0 and subsequent statements store at the following locations. If the *Location* value is specified, it denotes the starting location where these values are stored.

Constant can be a numeric constant or a string constant. Only the least significant byte of numeric values are stored. Strings are stored as consecutive bytes of ASCII values. No length or terminator is automatically added.

EEPROM only works with microcontrollers with on-chip EEPROM (Data Space). It will not work on devices with on-chip I2C interfaced serial EEPROM like the PIC12CE67x and PIC16CE62x parts. Since EEPROM is non-volatile memory, the data will remain intact even if the power is turned off.

The data is stored in the EEPROM space only once at the time the microcontroller is programmed, not each time the program is run. WRITE can be used to set the values of the on-chip EEPROM at runtime. READ is used to retrieve these stored DATA values at runtime.

```
' Store 10, 20 and 30 starting at location 4
EEPROM 4,[10,20,30]
```

5.20 END

```
END
```

Stop program execution and enter low power mode. All of the I/O pins remain in their current state. END works by executing a Sleep instruction continuously in a loop.

Care should be taken not to execute END while hardware peripherals such as a serial USART could be operating. END will suspend operation of such peripherals. If you need to suspend program operation without shutting down the peripherals, use STOP instead.

```
END
```

5.21 ERASECODE

```
ERASECODE Block
```

Some flash PIC MCUs, like the PIC18F series, require a portion of the code space to be erased before it can be rewritten with WRITECODE. On these devices, an erase is performed a block at a time. An erase block may be 32 words (64 bytes) or another size, depending on the device. This size is usually larger than the write block size. See the Microchip data sheet for information on the size of the erase block for the particular PIC MCU you are using.

The first location of the block to be erased is specified by *Block*. For PIC18F devices, *Block* is a byte address rather than a word address. Be careful not to specify a *Block* that contains program code.

Note that the *Block* address used in the ERASECODE command must coincide with a block starting address as defined by Microchip. If you use an address that is not a starting address, you may get unexpected results. If a PIC18 target device has an erase block size of 64 bytes, then the *Block* address should be an exact multiple of 64 (0, 64, 128, … 3200, 3264, etc.).

For 12-bit instruction set devices that support flash data memory, like the PIC12F519 and PIC16F526, ERASECODE must be used to erase the rows of memory before it can be rewritten using WRITE.

If only a portion of a block is to be changed, for example only the first byte in the block, the entire block must be read before it is erased and all of the data rewritten, including the new data and the original data that needs to be preserved.

Flash program writes must be enabled in the configuration for the PIC MCU at device programming time for ERASECODE to be able to erase.

Using this instruction on devices that do not support block erase may cause a compilation error.

```
ERASECODE $1000             ' Erase code block starting at
                            location $1000
```

5.22 EXIT

```
EXIT
```

EXIT jumps to the line after the end of the current block structure and continues program execution from there. This allows the current FOR..NEXT or other loop construct to be left without having to satisfy a specific condition. As none of the block structures in PBP use the stack, there are no stack concerns when using EXIT.

Loop and conditional structures that can be terminated using EXIT are:

DO..LOOP
FOR..NEXT
IF..THEN
WHILE..WEND
REPEAT..UNTIL

```
FOR x = 0 TO 255
                                IF (x = 27) THEN EXIT
NEXT x
```

5.23 FOR..NEXT

FOR *Count* **=** *Start* **TO** *End* {**STEP** {**-**} *Inc*}{*Body*}**NEXT** {*Count*}

The FOR..NEXT loop allows programs to execute a number of statements (the *Body*) some number of times using a variable as a counter. Due to its complexity and versatility, FOR..NEXT is best described step by step:

1) The value of Start is assigned to the index variable, Count. Count can be a variable of any type.

2) The Body is executed. The Body is optional and can be omitted (perhaps for a delay loop).

3) The value of Inc is added to (or subtracted from if "-" is specified) Count. If no STEP clause is defined, Count is incremented by one.

4) If Count has not passed End or overflowed the variable type, execution returns to Step 2.

If the loop needs to *Count* to more than 255, a word- or long-sized (PBPL only) variable must be used.

```
FOR i = 1 TO 10             ' Count from 1 to 10
    SEROUT 0,N2400,[#i," "]    ' Send each number toPin0
                            serially
NEXT i                      ' Go back to and do next count
SEROUT 0,N2400,[10]         ' Send a linefeed
FOR B2 = 20 TO 10 STEP -2   ' Count from 20 to 10 by 2
    SEROUT 0,N2400,[#B2," "]   ' Send each number to Pin0
                            serially
NEXT B2                     ' Go back to and do next count
SEROUT 0,N2400,[10]         ' Send a linefeed
```

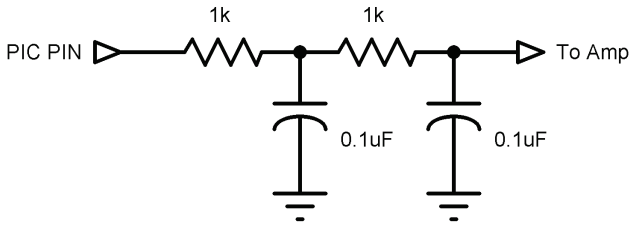
5.24 FREQOUT

```
FREQOUT Pin, Onms, Frequency1{,Frequency2}
```

Produce the *Frequency*(s) on *Pin* for *Onms* milliseconds. *Pin* is automatically made an output. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

One or two different frequencies from 0 to 32767 Hertz may be produced at a time.

FREQOUT generates tones using a form of pulse width modulation. The raw data coming out of the pin looks pretty scary. Some kind of filter is usually necessary to smooth the signal to a sine wave and get rid of some of the harmonics that are generated:



FREQOUT works best with a 20MHz or 40MHz oscillator. It can also work with a 10MHz or 8MHz oscillator and even at 4MHz, although it will start to get very hard to filter and be of fairly low amplitude. Any other frequency will cause FREQOUT to generate a frequency that is a ratio of the actual oscillator used and 20MHz.

FREQOUT is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
' Send 1KHz tone on Pin1 for 2 seconds
FREQOUT PORTB.1,2000,1000

' Send 350Hz / 440Hz (Dial Tone) for 2 seconds
FREQOUT PORTB.1,2000,350,440
```

5.25 GOSUB

```
GOSUB Label
```

Jump to the subroutine at *Label* saving its return address on the stack. Unlike GOTO, when a RETURN statement is reached after executing a GOSUB, execution resumes with the statement following that last executed GOSUB statement.

An unlimited number of subroutines may be used in a program. Subroutines may also be nested. In other words, it is possible for a subroutine to GOSUB to another subroutine. Such subroutine nesting must be restricted to no more than four nested levels for 12- and 14-bit core devices, 12 levels for 14-bit enhanced core and PIC17 parts and 27 levels for PIC18 parts. Interrupts cause additional locations to be used on the stack , reducing the number of possible nested GOSUBs.

See section 7.5 Hardware Stack for more information.

```
GOSUB flash                 'Execute subroutine named flash


flash:
    HIGH led                'Turn on LED
    PAUSE 500               'Pause 500mS
    LOW led                 'Turn off LED
RETURN                      'Go back to main routine that
                            called us
```

5.26 GOTO

```
GOTO Label
```

Program execution continues with the statements at *Label*.

```
GOTO send                    ' Jump to statement labeled send
                             ...

send:
    SEROUT 0,N2400,["Hi"]    ' Send "Hi" out Pin0 serially
```

5.27 HIGH

HIGH *Pin*

Make the specified *Pin* high. *Pin* is automatically made an output. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
HIGH 0                      ' Make Pin0 an output and set it
                            high (~5 volts)
HIGH PORTA.0                ' Make PORTA, pin 0 an output
                            and set it high (~5 volts)
led Var PORTB.0             ' Define LED pin
HIGH led                    ' Make LED pin an output and set
                            it high (~5 volts)
```

Alternatively, if the pin is already an output, a much quicker and shorter way (from a generated code standpoint) to set it high would be:

```
PORTB.0 = 1                 ' Set PORTB pin 0 high
```

5.28 HPWM

```
HPWM Channel, Dutycycle, Frequency
```

Output a pulse width modulated pulse train using PWM hardware available on some PIC MCUs. It can run continuously in the background while the program is executing other instructions.

Channel specifies which hardware PWM channel to use. Some devices have between 1 and 5 PWM *Channel*s that can be used with HPWM. The Microchip data sheet for the particular device shows the fixed hardware pin for each *Channel*. For example, for a PIC16F877a, *Channel* 1 is CCP1 which is pin PORTC.2. *Channel* 2 is CCP2 which is pin PORTC.1.

Some devices can be configured to select different pins for some PWM output channels. The following DEFINEs allow you to specify alternative output pins so that the HPWM command will function correctly. (The available pin selection is specified in the Microchip datasheet for the target device. These DEFINEs only serve to let PBP know how you have configured the microcontroller.)

```
DEFINE  CCP1_REG  PORTC    'Channel-1 port
DEFINE  CCP1_BIT  2        'Channel-1 bit
DEFINE  CCP2_REG  PORTC    'Channel-2 port
DEFINE  CCP2_BIT  1        'Channel-2 bit
DEFINE  CCP3_REG  PORTG    'Channel-3 port
DEFINE  CCP3_BIT  0        'Channel-3 bit
DEFINE  CCP4_REG  PORTG    'Channel-4 port
DEFINE  CCP4_BIT  3        'Channel-4 bit
DEFINE  CCP5_REG  PORTG    'Channel-5 port
DEFINE  CCP5_BIT  4        'Channel-5 bit
```

Dutycycle specifies the on/off (high/low) ratio of the signal. It ranges from 0 to 255, where 0 is off (low all the time) and 255 is on (high) all the time. A value of 127 gives a 50% duty cycle (square wave).

Frequency is the desired frequency of the PWM signal. On devices with 2 channels, the *Frequency* must be the same on both channels. Not all frequencies are available at all oscillator settings. For the non-long versions of PBP (PBP and PBPW), the highest frequency at any oscillator speed is 32767Hz. The lowest usable HPWM *Frequency* at each oscillator setting is shown in the following table:

HPWM

OSC	14-bit core and PIC18	PIC17
4MHz	245Hz	3907Hz
8MHz	489Hz	7813Hz
10MH z	611Hz	9766Hz
12MH z	733Hz	11719H z
16MH z	977Hz	15625H z
20MH z	1221Hz	19531H z
24MH z	1465Hz	23437H z
25MH z	1527Hz	24415H z
32MH z	1953Hz	31249H z
33MH z	2015Hz	32227H z
40MH z	2441Hz	na
48MH z	2929Hz	na
64MH z	3905Hz	na

After an HPWM command, the CCP control register is left in PWM mode. If the CCP pin is to be used as a normal I/O pin after an HPWM command, the CCP control register will need to be set to PWM off. See the Microchip data sheet for the particular device for more information.

```
HPWM 1,127,1000          ' Send a 50% duty cycle PWM
                         signal at 1kHz
HPWM 1,64,2000           ' Send a 25% duty cycle PWM
                         signal at 2kHz
```

5.29 HSERIN

```
HSERIN {ParityLabel,} {Timeout, Label,}[Item{,...}]
```

Receive one or more *Item*s from the hardware serial port on devices that support asynchronous serial communications in hardware.

HSERIN is one of several built-in asynchronous serial functions. It can only be used with devices that have a hardware USART. See the device data sheet for information on the serial input pin and other parameters. The serial parameters and baud rate are specified using DEFINEs:

```
' Set receive register to receiver enabled
DEFINE HSER_RCSTA 90h
' Set transmit register to transmitter enabled
DEFINE HSER_TXSTA 20h
' Set baud rate
DEFINE HSER_BAUD 2400

' Set SPBRG, SPBRGH directly
' (better to set HSER_BAUD instead)
DEFINE HSER_SPBRG 25
DEFINE HSER_SPBRGH 0
```

HSER_RCSTA, HSER_TXSTA, HSER_SPBRG, and HSER_SPBRGH simply set each respective PIC MCU register, RCSTA, TXSTA, SPBRG and SPBRGH to the hexadecimal value DEFINEd, once, at the beginning of the program. See the Microchip data sheet for the device for more information on each of these registers.

The TXSTA register BRGH bit (bit 2) controls the high speed mode for the baud rate generator. Certain baud rates at certain oscillator speeds require this bit to be set to operate properly. To do this, set HSER_TXSTA to 24h instead of 20h. All baud rates at all oscillator speeds may not be supported by the device. See the Microchip data sheet for the hardware serial port baud rate tables and additional information.

HSERIN assumes a 4MHz oscillator when calculating the baud rate. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value.

An optional *Timeout* and *Label* may be included to allow the program to continue if a character is not received within a certain amount of time.

Timeout is specified in 1 millisecond units. If no character is received during the *Timeout* time, the program will exit the HSERIN command and jump to *Label*.

HSERIN

The serial data format defaults to 8N1, 8 data bits, no parity bit and 1 stop bit. 7E1 (7 data bits, even parity, 1 stop bit) or 7O1 (7data bits, odd parity, 1 stop bit) can be enabled using one of the following DEFINEs:

```
' Use only if even parity desired
DEFINE HSER_EVEN 1
' Use only if odd parity desired
DEFINE HSER_ODD 1
' Use 8 bits + parity
DEFINE HSER_BITS 9
```

The parity setting, along with all of the other HSER DEFINEs, affect both HSERIN and HSEROUT.

An optional *ParityLabel* may be included in the statement. The program will continue at this location if a character with a parity error is received. It should only be used if parity is enabled using one of the preceding DEFINEs.

As the hardware serial port only has a 2 byte input buffer, it can easily overflow if characters are not read from it often enough. When this happens, the USART stops accepting new characters and needs to be reset. This overflow error can be reset by toggling the CREN bit in the RCSTA register. A DEFINE can be used to automatically clear this error. However, you will not know that an error has occurred and characters may have been lost.

```
DEFINE HSER_CLROERR 1
```

To manually clear an overrun error:

```
RCSTA.4 = 0
RCSTA.4 = 1
```

Since the serial reception is done in hardware, it is not possible to set the levels to an inverted state to eliminate an RS-232 driver. Therefore a suitable driver should be used with HSERIN.

On devices with 2 hardware serial ports, HSERIN will only use the first port. The second port may read using HSERIN2.

An assortment of string-parsing modifiers is available for use within the item list of this command. These modifiers are capable of extracting data from input strings to various variable types:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar*n*{*c*}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{*n*}	Wait for character string

See section 2.10 for details on string-parsing modifiers.

```
HSERIN [B0,DEC W1]
HSERIN 100, timesup, [B0]
```

5.30 HSERIN2

HSERIN2 {ParityLabel,}{Timeout, Label,}**[**Item{,...}**]**

Receive one or more *Item*s from the second hardware serial port on devices that support asynchronous serial communications in hardware.

HSERIN2 works the same as HSERIN with the exception that is uses the second hardware serial port on devices that have 2 ports such as the PIC18F8720 It can only be used with devices that have 2 hardware USARTs. See the device data sheet for information on the serial output pin and other parameters and the above section on HSERIN for more command details. The serial parameters and baud rate are specified using DEFINEs:

```
' Set receive register to receiver enabled
DEFINE HSER2_RCSTA 90h
' Set transmit register to transmitter enabled
DEFINE HSER2_TXSTA 20h
' Set baud rate
DEFINE HSER2_BAUD 2400
' Set SPBRG2, SPBRGH2 directly
' (better to set HSER2_BAUD instead)
DEFINE HSER2_SPBRG 25
DEFINE HSER2_SPBRGH 0
' Use only if even parity desired
DEFINE HSER2_EVEN 1
' Use only if odd parity desired
DEFINE HSER2_ODD 1
' Use 8 bits + parity
DEFINE HSER2_BITS 9
' Automatically clear overflow errors
DEFINE HSER2_CLROERR 1

HSERIN2 [B0,DEC W1]
HSERIN2 100, timesup, [B0]
```

5.31 HSEROUT

HSEROUT [*Item*{,*Item...*}]

Send one or more *Item*s to the hardware serial port on devices that support asynchronous serial communications in hardware.

HSEROUT is one of several built-in asynchronous serial functions. It can only be used with devices that have a hardware USART. See the device data sheet for information on the serial output pin and other parameters. The serial parameters and baud rate are specified using DEFINEs:

```
' Set receive register to receiver enabled
DEFINE HSER_RCSTA 90h
' Set transmit register to transmitter enabled
DEFINE HSER_TXSTA 20h
' Set baud rate
DEFINE HSER_BAUD 2400
' Set SPBRG, SPBRGH directly
' (better to set HSER_BAUD instead)
DEFINE HSER_SPBRG 25
DEFINE HSER_SPBRGH 0
```

HSER_RCSTA, HSER_TXSTA, HSER_SPBRG, and HSER_SPBRGH simply set each respective PIC MCU register, RCSTA, TXSTA, SPBRG and SPBRGH to the hexadecimal value DEFINEd, once, at the beginning of the program. See the Microchip data sheet for the device for more information on each of these registers.

The TXSTA register BRGH bit (bit 2) controls the high speed mode for the baud rate generator. Certain baud rates at certain oscillator speeds require this bit to be set to operate properly. To do this, set HSER_TXSTA to 24h instead of 20h. All baud rates at all oscillator speeds may not be supported by the device. See the Microchip data sheet for the hardware serial port baud rate tables and additional information.

HSEROUT assumes a 4MHz oscillator when calculating the baud rate. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value.

The serial data format defaults to 8N1, 8 data bits, no parity bit and 1 stop bit. 7E1 (7 data bits, even parity, 1 stop bit) or 7O1 (7data bits, odd parity, 1 stop bit) can be enabled using one of the following DEFINEs:

HSEROUT

```
' Use only if even parity desired
DEFINE HSER_EVEN 1
' Use only if odd parity desired
DEFINE HSER_ODD 1
' Use 8 bits + parity
DEFINE HSER_BITS 9
```

The parity setting, along with all of the other HSER DEFINEs, affect both HSERIN and HSEROUT.

Since the serial transmission is done in hardware, it is not possible to set the levels to an inverted state to eliminate an RS-232 driver. Therefore a suitable driver should be used with HSEROUT.

On devices with 2 hardware serial ports, HSEROUT will only use the first port. The second port may be accessed using HSEROUT2.

An assortment of string-formatting modifiers is available for use within the item list of this command. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

```
HSEROUT [DEC B0,10]          ' Send the decimal value of B0
                             followed by a line feed out the
                             hardware USART
```

5.32 HSEROUT2

HSEROUT2 [*Item*{,*Item...*}**]**

Send one or more *Item*s to the second hardware serial port on devices that support asynchronous serial communications in hardware.

HSEROUT2 works the same as HSEROUT with the exception that is uses the second hardware serial port on devices that have 2 ports such as the PIC18F8720. It can only be used with devices that have 2 hardware USARTs. See the device data sheet for information on the serial output pin and other parameters and the above section on HSEROUT for more command details. The serial parameters and baud rate are specified using DEFINEs:

```
' Set receive register to receiver enabled
DEFINE HSER2_RCSTA 90h
' Set transmit register to transmitter enabled
DEFINE HSER2_TXSTA 20h
' Set baud rate
DEFINE HSER2_BAUD 2400
' Set SPBRG2, SPBRGH2 directly
' (better to set HSER2_BAUD instead)
DEFINE HSER2_SPBRG 25
DEFINE HSER2_SPBRGH 0
' Use only if even parity desired
DEFINE HSER2_EVEN 1
' Use only if odd parity desired
DEFINE HSER2_ODD 1
' Use 8 bits + parity
DEFINE HSER2_BITS 9

HSEROUT2 [DEC B0,10]        ' Send the decimal value of B0
                            followed by a linefeed out the
                            hardware USART
```

5.33 I2CREAD

```
I2CREAD DataPin, ClockPin, Control,{Address,}[Var{,Var...}]{,Label}
```

Send *Control* and optional *Address* bytes out the *ClockPin* and *DataPin* and store the byte(s) received into *Var*. *ClockPin* and *DataPin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

I2CREAD is a software-based command and does not require that the target device have I2C capability. The *ClockPin* and *DataPin* parameters may be set to any digital I/O pins, and may be different in different commands within the same program.

I2CREAD and I2CWRITE can be used to read and write data to a serial EEPROM with a 2-wire I^2C interface such as the Microchip 24LC01B and similar devices. This allows data to be stored in external non-volatile memory so that it can be maintained even after the power is turned off. These commands operate in the I^2C master mode and may also be used to talk to other devices with an I^2C interface like temperature sensors and A/D converters.

For 12-bit core PIC MCUs only, the I^2C clock and data pins are fixed at compile time by DEFINEs. They still must be specified in the I2CREAD statements, though this information is ignored by the compiler.

```
DEFINE I2C_SCL PORTA,1      ' For 12-bit core only
DEFINE I2C_SDA PORTA,0      ' For 12-bit core only
```

The upper 7 bits of the *Control* byte contain the control code along with chip select or additional address information, depending on the particular device. The low order bit is an internal flag indicating whether it is a read or write command and should be kept clear.

This format for the *Control* byte is different than the format used by the original PICBASIC Compiler. Be sure to use this format with PBP I^2C operations.

For example, when communicating with a 24LC01B, the control code is %1010 and the chip selects are unused so the *Control* byte would be %10100000 or $A0. Formats of *Control* bytes for some of the different parts follows:

Device	Capacity	Control	Address size
24LC01 B	128 bytes	%1010xxx0	1 byte
24LC02 B	256 bytes	%1010xxx0	1 byte
24LC04 B	512 bytes	%1010xxb0	1 byte
24LC08 B	1K bytes	%1010xbb0	1 byte
24LC16 B	2K bytes	%1010bbb0	1 byte
24LC32 B	4K bytes	%1010ddd0	2 bytes
24LC65	8K bytes	%1010ddd0	2 bytes

```
bbb = block select (high order address) bits
ddd = device select bits
xxx = don't care
```

The *Address* size sent (byte or word) is determined by the size of the variable that is used. If a byte-sized variable is used for the *Address*, an 8-bit address is sent. If a word-sized variable is used, a 16-bit address is sent. Be sure to use the proper sized variable for the device you wish to communicate with. Constants should not be used for the *Address* as the size can vary dependent on the size of the constant. Also, expressions should not be used as they can cause an improper *Address* size to be sent.

Once *Control* and/or *Address* has been sent to the device, the data specified between the square brackets is read from the device. If a word-or long-sized *Var* is specified, the bytes are read and stored into the *Var* highest byte first, followed by the lower byte(s). This order is different than the way variables are normally stored, low byte first.

A modifier, STR, may be included before the variable name. This can load an entire array (string) at once. If STR is specified, the following variable must be the name of a word or byte array, followed by a backslash (\) and a count:

```
a Var Byte[8]
addr Var Byte
    addr = 0
    I2CREAD PORTC.4,PORTC.3,$a0,addr,[STR a\8]
```

If a word- or long-sized array is specified, the bytes that comprise each element are read lowest byte first. This is the opposite of how simple words and longs are read and is consistent with the way the compiler normally stores word- and long-sized variables.

If the optional *Label* is included, this label will be jumped to if an acknowledge is not received from the I^2C device. The I^2C instructions can be used to access the on-chip serial EEPROM on the PIC12CE and PIC16CE devices. Simply specify the

I2CREAD

pin names for the appropriate internal lines as part of the I²C command and place the following DEFINE at the top of the program:

```
DEFINE I2C_INTERNAL 1
```

For the PIC12CE67x devices, the data line is GPIO.6 and the clock line is GPIO.7. For the PIC16CE62x devices, the data line is EEINTF.1 and the clock line is EEINTF.2. See the Microchip data sheets for these devices for more information.

The timing of the I²C instructions is set so that standard speed devices(100kHz) will be accessible at clock speeds up to 8MHz. Fast mode devices (400kHz) may be used up to 20MHz. If it is desired to access a standard speed device at above 8MHz, the following DEFINE should be added to the program:

```
DEFINE I2C_SLOW 1
```

Because of memory and stack constraints, this DEFINE for 12-bit core PIC MCUs does not do anything. Low-speed (100 kHz) I2C devices may be used up to 4MHz. Above 4MHz, high-speed (400kHz) devices should be used.

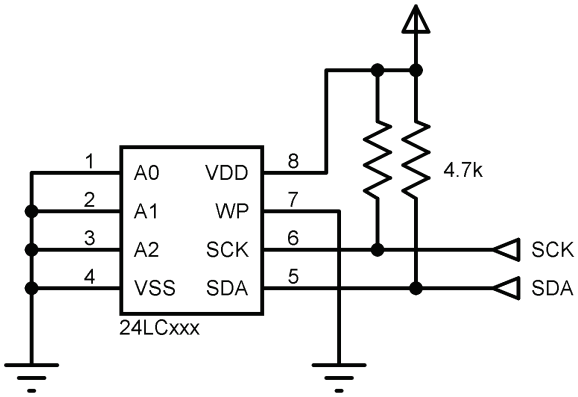
Transfer on the I2C bus can be paused by the receiving device by its holding the clock line low (not supported on 12-bit core PIC MCUs). To enable this the following DEFINE should be added to the program:

```
DEFINE I2C_HOLD 1
```

The I²C clock and data lines should be pulled up to Vcc with a 4.7K resistor per the following schematic as they are both run in a bidirectional open-collector manner.

To make the I2C clock line bipolar instead of open-collector the following DEFINE may be added to the program:

```
DEFINE I2C_SCLOUT 1
```




```
addr Var Byte
cont Con %10100000

addr = 17                   ' Set address to 17

' Read data at address 17 into B2
I2CREAD PORTA.0,PORTA.1,cont,addr,[B2]
```

See the Microchip “Non-Volatile Memory Products Data Book” for more information on these and other devices that may be used with the I2CREAD and I2CWRITE commands.

5.34 I2CWRITE

```
I2CWRITE DataPin, ClockPin, Control, {Address,}[Value{,Value...}]{,Label}
```

I2CWRITE sends *Control* and optional *Address* out the I^2C *ClockPin* and *DataPin* followed by *Value*. *ClockPin* and *DataPin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

I2CWRITE is a software-based command and does not require that the target device have I2C capability. The *ClockPin* and *DataPin* parameters may be set to any digital I/O pins, and may be different in different commands within the same program.

For 12-bit core PIC MCUs only, the I^2C clock and data pins are fixed at compile time by DEFINEs. They still must be specified in the I2CWRITE statements, though this information is ignored by the compiler.

```
DEFINE I2C_SCL PORTA,1      ' For 12-bit core only
DEFINE I2C_SDA PORTA,0      ' For 12-bit core only
```

The *Address* size sent (byte or word) is determined by the size of the variable that is used. If a byte-sized variable is used for the *Address*, an 8-bit address is sent. If a word-sized variable is used, a 16-bit address is sent. Be sure to use the proper sized variable for the device you wish to communicate with. Constants should not be used for the *Address* as the size can vary dependent on the size of the constant. Also, expressions should not be used as they can cause an improper *Address* size to be sent.

When writing to a serial EEPROM, it is necessary to wait 10ms (device dependent - check its data sheet) for the write to complete before attempting communication with the device again. If a subsequent I2CREAD or I2CWRITE is attempted before the write is complete, the access will be ignored.

While a single I2CWRITE statement may be used to write multiple bytes at once, doing so may violate the above write timing requirement for serial EEPROMs. Some serial EEPROMS let you write multiple bytes into a single page before necessitating the wait. Check the data sheet for the specific device you are using for these details. The multiple byte write feature may also be useful with I^2C devices other than serial EEPROMs that don't have to wait between writes.

If a word- or long-sized *Value* is specified, the bytes are sent highest byte first, followed by the lower byte(s). This order is different than the way variables are normally stored, low byte first.

A modifier, STR, may be included before the variable name. This can be used to write an entire array (string) at once and take advantage of a serial EEPROM's page mode. The data must fit into a single SEEPROM page. The page size is dependent on the particular SEEPROM device. If STR is specified, the following variable must be the name of a word or byte array, followed by a backslash (\) and a count:

```
a Var Byte[8]
addr Var Byte
addr = 0
I2CWRITE PORTC.4,PORTC.3,$a0,addr,[STR a\8]
```

If a word- or long-sized array is specified, the bytes that comprise each element are written lowest byte first. This is the opposite of how simple words and longs are written and is consistent with the way the compiler normally stores word- and long-sized variables.

If the optional Label is included, this label will be jumped to if an acknowledge is not received from the I2C device. The I2C instructions can be used to access the on-chip serial EEPROM on the PIC12CE and PIC16CE devices. Simply specify the pin names for the appropriate internal lines as part of the I^2C command and place the following DEFINE at the top of the program:

```
DEFINE I2C_INTERNAL 1
```

For the PIC12CE67x devices, the data line is GPIO.6 and the clock line is GPIO.7. For the PIC16CE62x devices, the data line is EEINTF.1 and the clock line is EEINTF.2. See the Microchip data sheets for these devices for more information.

The timing of the I^2C instructions is set so that standard speed devices(100kHz) will be accessible at clock speeds up to 8MHz. Fast mode devices (400kHz) may be used up to 20MHz. If it is desired to access a standard speed device at above 8MHz, the following DEFINE should be added to the program:

```
DEFINE I2C_SLOW 1
```

Because of memory and stack constraints, this DEFINE for 12-bit core PIC MCUs does not do anything. Low-speed (100 kHz) I2C devices may be used up to 4MHz. Above 4MHz, high-speed (400kHz) devices should be used.

Transfer on the I2C bus can be paused by the receiving device by its holding the clock line low (not supported on 12-bit core PIC MCUs). To enable this the following DEFINE should be added to the program:

I2CWRITE

```
DEFINE I2C_HOLD 1
```

To make the I2C clock line bipolar instead of open-collector the following DEFINE may be added to the program:

```
DEFINE I2C_SCLOUT 1
```

See the I2CREAD command above for the rest of the story.

```
addr Var Byte
cont Con %10100000

addr = 17 ' Set address to 17

' Send the byte 6 to address 17
I2CWRITE PORTA.0,PORTA.1,cont,addr,[6]

Pause 10 ' Wait 10ms for write to

completeaddr = 1 ' Set address to 1

' Send the byte in B2 to address 1
I2CWRITE PORTA.0,PORTA.1,cont,addr,[B2]

Pause 10 ' Wait 10ms for write to complete
```

5.35 IF..THEN

```
IF Comp {AND/OR Comp...} THEN Label

IF Comp {AND/OR Comp...} THEN Statement...

IF Comp {AND/OR Comp...} THEN
    Statement...
 {ELSEIF Comp {AND/OR Comp...} THEN
    Statement...}
 {ELSE
    Statement...}
ENDIF
```

Performs one or more comparisons. Each *Comp* term can relate a variable to a constant or other variable and includes one of the comparison operators listed previously.

IF..THEN evaluates the comparison terms for true or false. If the condition evaluates to true, the operation after the THEN is executed. If it evaluates to false, the operation after the THEN is not executed. Comparisons that evaluate to 0 are considered false. Any other value is considered true.

For PBPW, all values in comparisons are treated as unsigned. IF..THEN cannot be used to check if a number is less than 0. Using PBPL, signed comparisons, including less than zero, may be performed.

It is essential to use parenthesis to specify the order in which the operations should be tested. Otherwise, operator precedence will determine it for you and the result may not be as expected.

IF..THEN can operate as a single-line or code, or as a multi-line block structure.

If written as a single line, a label may be written after the THEN keyword. The IF statement will jump to the label if the condition evaluates as true:

```
IF PORTB.0 = 0 THEN pushd  ' If the condition is true, jump
                           to label pushd
```

Single line mode can also be used to execute a command statement, or multiple, concatenated command statements.

```
IF PORTB.0 = 0 THEN  HIGH PORTC.0
```

In the multi-line form, IF..THEN can conditionally execute a group of *Statement*s following the THEN. This is the traditional form found in many programming languages. This form requires that the THEN keyword be the last word on the line.

IF..THEN

The *Statement*s must be placed on separate lines and followed by an optional ELSEIF or ELSE and required ENDIF to complete the structure.

Only one block of code will be executed, even if multiple ELSEIF conditions evaluate as true. The first condition that evaluates as true will cause subsequent conditionals to be ignored.

```
IF B0 = 20 THEN
    led = 1
ELSEIF B0 = 40 THEN
    led = 1
ELSE
    led = 0
ENDIF
```

More Examples:

```
IF B0 <> 10 THEN
    B0 = B0 + 1
    B1 = B1 - 1
ENDIF

IF B0 = 20 THEN
    led = 1
ELSE
    led = 0
ENDIF

IF B0 >= 40 THEN old

IF PORTB.0 THEN itson

IF (B0 = 10) AND (B1 = 20) THEN mainloop

IF B0 <> 10 THEN B0 = B0 + 1: B1 = B1 - 1
```

5.36 INPUT

```
INPUT Pin
```

Makes the specified *Pin* an input. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
INPUT 0                     ' Make Pin0 an input
INPUT PORTA.0               ' Make PORTA, pin 0 an input
```

Alternatively, the pin may be set to an input in a much quicker and shorter way (from a generated code standpoint):

```
TRISB.0 = 1                 ' Set PORTB, pin 0 to an input
```

All of the pins on a port may be set to inputs by setting the entire TRIS register at once:

```
TRISB = %11111111           ' Set all of PORTB to inputs
```

5.37 LCDIN

```
LCDIN {Address,}[Var{,Var...}]
```

Read LCD RAM at *Address* and store data to *Var*.

LCDs have RAM onboard that is used for character memory. Most LCDs have more RAM available that is necessary for the displayable area. This RAM can be written using the LCDOUT instruction. The LCDIN instruction allows this RAM to be read.

CG (character generator) RAM runs from address $40 to $7f. Display data RAM starts at address $80. See the data sheet for the specific LCD for these addresses and functions.

It is necessary to connect the LCD read/write line to a PIC MCU pin so that it may be controlled to select either a read (LCDIN) or write (LCDOUT) operation. Two DEFINEs control the pin address:

```
DEFINE LCD_RWREG PORTE      ' LCD read/write port
DEFINE LCD_RWBIT 2          ' LCD read/write pin bit
```

See **LCDOUT** for information on connecting an LCD to a PIC MCU.

```
LCDIN [B0]
```

5.38 LCDOUT

LCDOUT *Item*{,Item...}

Display *Item*s on an intelligent Liquid Crystal Display. PBP supports LCD modules with a Hitachi 44780 controller or equivalent. These LCDs usually have a 14- or 16-pin single- or dual-row header at one edge.

An assortment of string-formatting modifiers is available for use within the item list of this command. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

A program should wait for up to half a second before sending the first command to an LCD. It can take quite a while for an LCD to start up.

The LCD is initialized the first time any character or command is sent to it using LCDOUT. If it is powered down and then powered back up for some reason during operation, an internal flag can be reset to tell the program to reinitialize it the next time it uses LCDOUT:

```
FLAGS = 0
```

Commands are sent to the LCD by sending a $FE followed by the command. Some useful commands are listed in the following table:

LCDOUT

Command	Operation
$FE, $01	Clear display
$FE, $02	Return home
$FE, $0C	Cursor off
$FE, $0E	Underline cursor on
$FE, $0F	Blinking cursor on
$FE, $10	Move cursor left one position
$FE, $14	Move cursor right one position
$FE, $80	Move cursor to beginning of first line
$FE, $C0	Move cursor to beginning of second line
$FE, $94	Move cursor to beginning of third line
$FE, $D4	Move cursor to beginning of fourth line

Note that there are commands to move the cursor to the beginning of the different lines of a multi-line display. For most LCDs, the displayed characters and lines are not consecutive in display memory - there can be a break in between locations. For most 16x2 displays, the first line starts at $80 and the second line starts at $C0. The command:

```
LCDOUT $FE, $80 + 4
```

sets the display to start writing characters at the forth position of the first line. 16x1 displays are usually formatted as 8x2 displays with a break between the memory locations for the first and second 8 characters. 4line displays also have a mixed up memory map, as shown in the table above.

See the data sheet for the particular LCD device for the character memory locations and additional commands..

```
LCDOUT $FE,1,"Hello"          ' Clear display and show "Hello"
LCDOUT $FE,$C0,"World"        ' Jump to second line and show
                              "World"
LCDOUT B0,#B1                 ' Display B0 and decimal ASCII
                              value of B1
```

The LCD may be connected to the PIC MCU using either a 4-bit bus or an 8-bit bus. If an 8-bit bus is used, all 8 bits must be on one port. If a 4-bit bus is used, the top 4 LCD data bits must be connected to either the bottom 4 or top 4 bits of one port. Enable and Register Select may be connected to any port pin. R/W may be tied to ground if the LCDIN command is not used.

PBP assumes the LCD is connected to specific pins unless told otherwise using DEFINEs. It assumes the LCD will be used with a 4-bit bus with data lines DB4 - DB7 connected to PIC MCU PORTA.0 - PORTA.3, Register Select to PORTA.4 and Enable to PORTB.3.

It is also preset to initialize the LCD to a 2 line display.

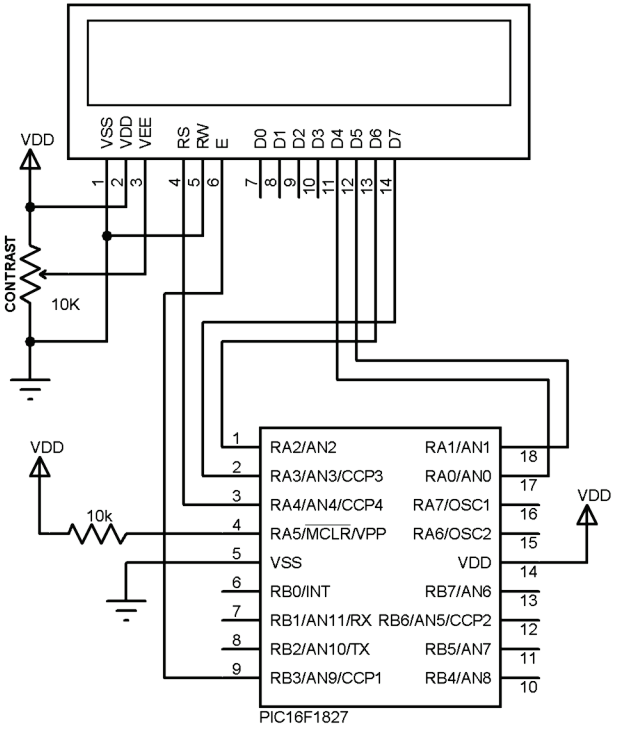
To change this setup, place one or more of the following DEFINEs, all in upper-case, at the top of your PICBASIC PRO program:

```
' Set LCD Data port
DEFINE LCD_DREG PORTA
' Set starting Data bit (0 or 4) if 4-bit bus
DEFINE LCD_DBIT 0
' Set LCD Register Select port
DEFINE LCD_RSREG PORTA
' Set LCD Register Select bit
DEFINE LCD_RSBIT 4
' Set LCD Enable port
DEFINE LCD_EREG PORTB
' Set LCD Enable bit
DEFINE LCD_EBIT 3
' Set LCD bus size (4 or 8 bits)
DEFINE LCD_BITS 4
' Set number of lines on LCD
DEFINE LCD_LINES 2
' Set command delay time in us
DEFINE LCD_COMMANDUS 1500
' Set data delay time in us
DEFINE LCD_DATAUS 44
```

The settings above represent the default values. If you omit the DEFINEs (not recommended) these values will be used.

LCDOUT

The following schematic shows one way to connect an LCD to a PIC MCU, using the default DEFINE settings (from the previous page) for the PIC16F1827:

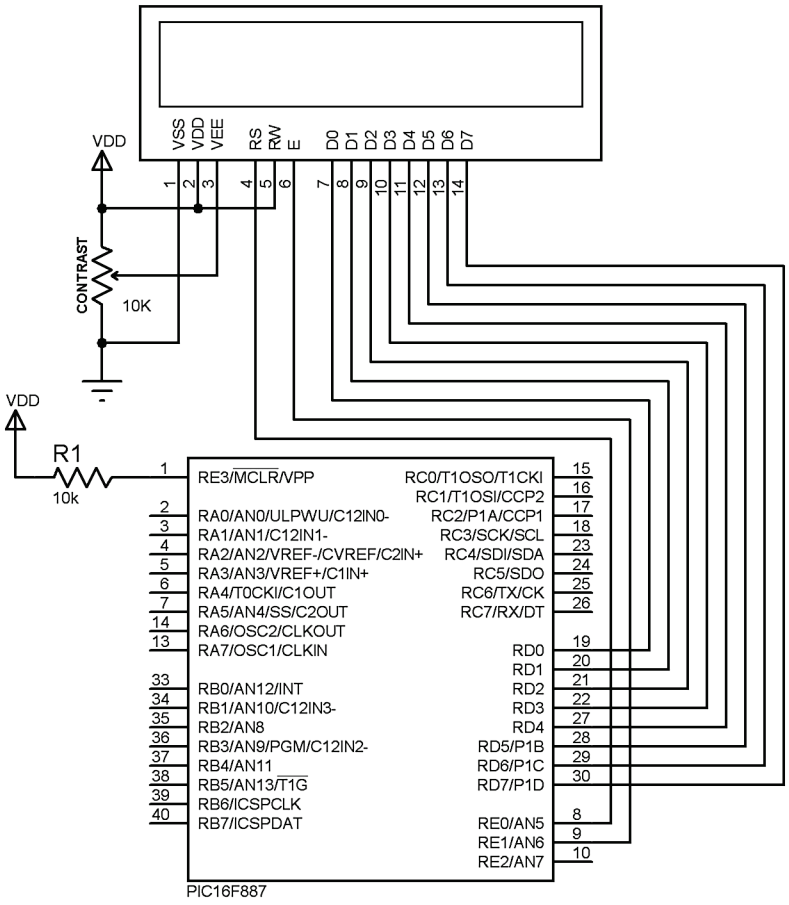


Note that most of the pins used to connect the LCD in the above diagram have the additional function of analog conversion inputs on the 16F1827 (AN0-AN4, and AN9). For proper operation of the LCDOUT command, these pins must be configured as digital I/O with following register settings in the program code:

```
ANSELA = %00000000          ' Set PORTA pins to digital I/O
ANSELB = %00000000          ' Set PORTB pins to digital I/O
```

The need to configure the pins for digital I/O is common to most PIC microcontrollers, but the actual register settings will differ from device to device. Consult the datasheet for the specific device for the correct settings.

The following schematic demonstrates how the LCD would be connected with 8 data lines instead of 4. See the code example on the following page for the DEFINEs and register settings that will make this connection scheme work on the PIC16F887.



LCDOUT

Program code example to configure the LCD connection shown on the preceding page:

```
' Configure LCDOUT for 8-bit connection on a PIC16F887

DEFINE LCD_DREG PORTD      ' PORTD is LCD data port
DEFINE LCD_DBIT 0          ' PORTD.0 is the data LSB
DEFINE LCD_RSREG PORTE     ' RS is connected to PORTE.0
DEFINE LCD_RSBIT 0
DEFINE LCD_EREG PORTE      ' E is connected to PORTE.1
DEFINE LCD_EBIT 1
DEFINE LCD_BITS 8          ' 8 lines of data are used
DEFINE LCD_LINES 2         ' It is a 2-line display
DEFINE LCD_COMMANDUS 1500  ' Use 1500uS command delay
DEFINE LCD_DATAUS 44       ' Use 44uS data delay


' Initialize ANSEL to allow use of PORTE pins for LCD
ANSEL = %00000000          ' Configure AN0-AN7 as digital
                           I/O
```

5.39 {LET}

```
{LET} Var = Value
```

Assign a *Value* to a *Var*iable. The *Value* may be a constant, another variable or the result of an expression. Refer to the previous section on operators for more information. The keyword LET itself is optional.

```
LET B0 = B1 * B2 + B3       'Calculate value for B0

B0 = B1 * B2 + B3           'Identical result
```

5.40 LOOKDOWN

```
LOOKDOWN Search,[Constant{,Constant...}],Var
```

The LOOKDOWN statement searches a list of 8-bit *Constant* values for the presence of the *Search* value. If found, the list-location of the matching constant is stored in *Var*. Thus, if the value is found first in the list, *Var* is set to zero. If second in the list, *Var* is set to one. And so on. If not found, *Var* remains unchanged.

The constant list can be a mixture of numeric and string constants. Each character in a string is treated as a separate constant with the character's ASCII value. Array variables with a variable index may not be used in LOOKDOWN although array variables with a constant index are allowed. Up to 255 (256 for PIC18) constants are allowed in the list.

```
SERIN 1,N2400,B0            ' Get hexadecimal character from
                            Pin1 serially

' Convert hexadecimal character in B0 to decimal value B1
LOOKDOWN B0,["0123456789ABCDEF"],B1

SEROUT 0,N2400,[#B1]        ' Send decimal value to Pin0
                            serially
```

5.41 LOOKDOWN2

```
LOOKDOWN2 Search,{Test}[Value{,Value...}],Var
```

The LOOKDOWN2 statement searches a list of *Values* for the presence of the *Search* value. If found, the index of the matching constant is stored in *Var*. Thus, if the value is found first in the list, *Var* is set to zero. If second in the list, *Var* is set to one. And so on. If not found, *Var* remains unchanged.

The optional parameter *Test* can be used to perform a test for other than equal to ("=") while searching the list. For example, the list could be searched for the first instance where the *Search* parameter is greater than the *Value* by using ">" as the *Test* parameter. If *Test* is left out, "=" is assumed.

The *Value* list can be a mixture of 8- and 16-bit (and 32-bit for PBPL) numeric and string constants and variables. Each character in a string is treated as a separate constant equal to the character's ASCII value. Expressions may not be used in the *Value* list, although they may be used as the *Search* value.

Array variables with a variable index may not be used in LOOKDOWN2 although array variables with a constant index are allowed. Up to 85 (256 for PIC18) values are allowed in the list.

LOOKDOWN2 generates code that is about 3 times larger than LOOKDOWN. If the search list is made up only of 8-bit constants and strings, use LOOKDOWN.

```
LOOKDOWN2 W0,[512,W1,1024],B0
LOOKDOWN2 W0,>[1000,100,10],B0
```

5.42 LOOKUP

```
LOOKUP Index,[Constant{,Constant...}],Var
```

The LOOKUP statement can be used to retrieve values from a table of 8bit constants. If *Index* is zero, *Var* is set to the value of the first *Constant*. If *Index* is one, *Var* is set to the value of the second *Constant*. And so on. If *Index* is greater than or equal to the number of entries in the constant list, *Var* remains unchanged.

The constant list can be a mixture of numeric and string constants. Each character in a string is treated as a separate constant equal to the character's ASCII value. Array variables with a variable index may not be used in LOOKUP although array variables with a constant index are allowed. Up to 255 (1024 for PIC18) constants are allowed in the list.

```
For B0 = 0 To 5             ' Count from 0 to 5
    LOOKUP B0,[“Hello!”],B1 ' Get character number B0 from
                            string to variableB1
    SEROUT 0,N2400,[B1]     ' Send character in B1 to Pin0
                            serially
Next B0                     ' Do next character
```

5.43 LOOKUP2

```
LOOKUP2 Index,[Value{,Value...}],Var
```

The **LOOKUP2** statement can be used to retrieve entries from a table of *Values*. If *Index* is zero, *Var* is set to the first *Value*. If *Index* is one, *Var* is set to the second *Value*. And so on. If *Index* is greater than or equal to the number of entries in the list, and *Var* remains unchanged.

The *Value* list can be a mixture of 8-bit and 16-bit (and 32-bit for PBPL) numeric and string constants and variables. Each character in a string is treated as a separate constant equal to the character's ASCII value. Expressions may not be used in the *Value* list, although they may be used as the *Index* value.

Array variables with a variable index may not be used in LOOKUP2 although array variables with a constant index are allowed. Up to 85 (1024 for PIC18) values are allowed in the list.

LOOKUP2 generates code that is about 3 times larger than LOOKUP. If the *Value* list is made up of only 8-bit constants and strings, use LOOKUP.

```
LOOKUP2 B0,[256,512,1024],W1
```

5.44 LOW

LOW *Pin*

Make the specified *Pin* low. *Pin* is automatically made an output. *Pin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
LOW 0                       ' Make Pin0 an output and set it
                            low (0 volts)
LOW PORTA.0                 ' Make PORTA, pin 0 an output
                            and set it low (0 volts)
led Var PORTB.0             ' Define LED pin
LOW led                     ' Make LED pin an output and set
                            it low (0 volts)
```

Alternatively, if the pin is already an output, a much quicker and shorter way (from a generated code standpoint) to set it low would be:

```
PORTB.0 = 0                 ' Set PORTB, pin 0 low
```

5.45 NAP

NAP Period

Places the microcontroller into low power mode for a short period of time. During this NAP, power consumption is reduced. To achieve minimum current draw it may be necessary to turn off other peripherals on the device, such as the ADC, before executing the NAP command. See the Microchip data sheet for the specific device for information about these register settings.

Period	Delay (Approx.)	
	PIC12F, PIC16F	PIC12F1, PIC16F1
0	18 mS	1 mS
1	36 mS	2 mS
2	72 mS	4 mS
3	144 mS	8 mS
4	288 mS	16 mS
5	576 mS	32 mS
6	1.152 Second	64 mS
7	2.304 Seconds	128 mS
8		256 mS
9		512 mS
10		1 Second
11		2 Seconds
12		4 Seconds
13		8 Seconds
14		16 Seconds
15		32 Seconds
16		64 Seconds
17		128 Seconds
18		256 Seconds

The *Period* is used to set the Watchdog timer prescaler for devices that have a prescaler including the 12- and 14-bit core devices.

The PIC18 devices use a postscaler set at programming time to configure the Watchdog timeout period. The compiler will disregard the *Period* set in the NAP instruction for the 16bit core devices.

The listed *Period*s for the 12- and 14-bit core devices are only approximate because the timing derived from the Watchdog Timer is R/C driven and can vary greatly from chip to chip and over temperature.

NAP puts the processor to sleep for one Watchdog Timer period. If the Watchdog Timer is not enabled, the processor will sleep forever or until an enabled interrupt or

NAP

reset is received. For this reason, NAP is suitable for placing the device in low-power mode indefinitely and waking the device with an interrupt.

For complete details on the workings of low-power modes and interrupts, you will need to refer to the Microchip datasheet for the specific device that you are using. In most PIC MCUs, only a reset or an enabled interrupt event will wake the part.

A reset, of course, will cause the program to restart from the beginning.

Interrupt behavior is dependent on the interrupt-control register settings. Upon wake, a jump to an interrupt vector will occur if the global interrupt bit is enabled. If the global interrupt bit is not enabled, program execution will resume on the line after the NAP command.

```
NAP 7                   ' Low power pause for about 2.3
                        seconds on a PIC16F887
NAP 11                  ' Low power pause for about 2
                        seconds on a PIC16F1827
```

5.46 ON GOSUB

```
ON Index GOSUB Label{,Label...}
```

ON GOSUB causes the program to jump to a different subroutine based on a variable index. Once the subroutine is complete and a RETURN is encountered, the program continues execution at the line following the ON GOSUB.

Index selects one of a list of *Label*s. A subroutine call is made to the indexed *Label*. For example, if *Index* is zero, the program does a GOSUB to the first *Label* specified in the list, if *Index* is one, the program does a GOSUB to the second *Label*, and so on. If *Index* is greater than or equal to the number of *Label*s, no action is taken and execution continues with the statement following the ON GOSUB. Up to 127 (1024 for PIC18) *Label*s may be used in a ON GOSUB.

An unlimited number of subroutines may be used in a program. Subroutines may also be nested. In other words, it is possible for a subroutine to GOSUB to another subroutine. Such subroutine nesting must be restricted to no more than four nested levels for 14-bit core devices, 12 levels for 14-bit enhanced core and PIC17 parts and 27 levels for PIC18 parts. Interrupts cause additional locations to be used on the stack, reducing the number of possible nested GOSUBs. See the section on interrupts later in the manual for more information.

ON GOSUB is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
ON B4 GOSUB dog, cat, fish
' Same as:
'   IF B4=0 THEN GOSUB dog : Goto after
'   IF B4=1 THEN GOSUB cat : Goto after
'   IF B4=2 THEN GOSUB fish
'after:
```

5.47 ON GOTO

```
ON Index GOTO Label{,Label...}
```

ON GOTO causes the program to jump to a different location based on a variable index. It can jump to a *Label* that is in a different code page than the ON GOTO instruction for 12- and 14-bit core and PIC17 devices, or further away than 1K for PIC18 devices. It generates code that is about twice the size as code generated by the BRANCH instruction. If you are sure the labels are in the same page as the BRANCH instruction or if the microcontroller does not have more than one code page, using BRANCH instead of ON GOTO will minimize memory usage. ON GOTO is a different syntax of BRANCHL.

Index selects one of a list of *Label*s. Execution resumes at the indexed *Label*. For example, if *Index* is zero, the program jumps to the first *Label* specified in the list, if *Index* is one, the program jumps to the second *Label*, and so on. If *Index* is greater than or equal to the number of *Label*s, no action is taken and execution continues with the statement following the ON GOTO. Up to 127 (1024 for PIC18) *Label*s may be used in a ON GOTO.

```
ON B4 GOTO dog, cat, fish
' Same as:
'  If B4=0 Then dog (goto dog)
'  If B4=1 Then cat (goto cat)
'  If B4=2 Then fish (goto fish)
```

5.48 OUTPUT

```
OUTPUT Pin
```

Make the specified *Pin* an output. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
OUTPUT 0                    ' Make Pin0 an output
OUTPUT PORTA.0              ' Make PORTA, pin 0 an output
```

Alternatively, the pin may be set to an output in a much quicker and shorter way (from a generated code standpoint):

```
TRISB.0 = 0 ' Set PORTB, pin 0 to an output
```

All of the pins on a port may be set to outputs by setting the entire TRIS register at once:

```
TRISB = %00000000           ' Set all of PORTB to outputs
```

5.49 OWIN

```
OWIN Pin, Mode,[Item...]{,Label}
```

Optionally send a reset pulse to a one-wire device and then read one or more bits or bytes of data from it, optionally ending with another reset pulse.

Pin may be a constant, 0 - 15, or a variable that contains a number 0 15 (e.g. B0) or a pin name (e.g. PORTA.0).

Mode specifies whether a reset is sent before and/or after the operation and the size of the data items, either bit or byte.

Some *Mode* examples would be: *Mode* of %000 (decimal 0) means no reset and byte-sized data, *Mode* of %001 (decimal 1) means reset before data and byte-sized data, *Mode* of %100 (decimal 4) means no reset and bit-sized data.

Item is one or more variables or modifiers separated by commas. The allowable modifiers are STR for reading data into a byte array variable and SKIP for skipping a number of input values.

The SKIP and STR modifiers are not supported for the 12-bit core PIC MCUs because of RAM and stack size limits.

If a device is not present, OWIN can jump to an optional *Label*.

```
OWIN PORTC.0,%000,[STR temperature\2,SKIP 4,
count_remain, count_per_c]
```

This statement would receive bytes from a one-wire device on PORTC pin 0 with no reset pulse being sent. It would receive 2 bytes and put them into the byte array temperature, skip the next 4 bytes and then read the final 2 bytes into separate variables.

5.50 OWOUT

```
OWOUT Pin, Mode,[Item...]{,Label}
```

Optionally send a reset pulse to a one-wire device and then writes one or more bits or bytes of data to it, optionally ending with another reset pulse.

Pin may be a constant, 0 - 15, or a variable that contains a number 0 15 (e.g. B0) or a pin name (e.g. PORTA.0).

Mode specifies whether a reset is sent before and/or after the operation and the size of the data items, either bit or byte.

Mode bit number	Effect
0	1 = send reset pulse before data
1	1 = send reset pulse after data
2	0 = byte-sized data, 1 = bit-sized data

Some *Mode* examples would be: *Mode* of %000 (decimal 0) means no reset and byte-sized data, *Mode* of %001 (decimal 1) means reset before data and byte-sized data, *Mode* of %100 (decimal 4) means no reset and bit-sized data.

Item is one or more constants, variables or modifiers separated by commas. The allowable modifiers are STR for sending data from a byte array variable and REP for sending a number of repeated values.

The REP and STR modifiers are not supported for the 12-bit core PIC MCUs because of RAM and stack size limits.

If a device is not present, OWOUT can jump to an optional *Label*.

```
OWOUT PORTC.0,%001,[$cc, $be]
```

This statement would send a reset pulse to a one-wire device on PORTC pin 0 followed by the bytes $cc and $be.

5.51 PAUSE

```
PAUSE Period
```

Pause the program for *Period* milliseconds. *Period* is 16-bits using PBP and PBPW, so delays can be up to 65,535 milliseconds (a little over a minute). Using PBPL, *Period* is 32-bits. This will allow delays of over 49 days. Long values are interpreted as unsigned. This may result in a longer pause than expected. If a long variable is used and it could go negative, it should be limited to greater than or equal to 0 using a function like MAX, for example.

Unlike the other delay functions (NAP and SLEEP), PAUSE doesn't put the microcontroller into low power mode. Thus, PAUSE consumes more power but is also much more accurate. It has the same accuracy as the system clock.

DEFINE OSC must be used in order for PBP to accurately calculate and generate code for PAUSE. If no DEFINE OSC is placed in the program, PBP will assume that the system clock will operate at 4MHz and calibrate the generated code accordingly.

```
PAUSE 1000 ' Delay for 1 second
```

5.52 PAUSEUS

```
PAUSEUS Period
```

Pause the program for *Period* microseconds. *Period* is 16-bits, so delays can be up to 65,535 microseconds. Unlike the other delay functions (NAP and SLEEP), PAUSEUS doesn't put the microcontroller into low power mode. Thus, PAUSEUS consumes more power but is also much more accurate.

Because PAUSEUS takes a minimum number of cycles to operate, depending on the frequency of the oscillator, delays of less than a minimum number of microseconds are not possible using PAUSEUS. To obtain shorter delays, use an assembly language routine.

OSC	Minimum delay	Minimum delay PIC18
3 (3.58)	20us	20us**
4	24us	19us**
8	12us	9us**
10	8us	7us**
12	7us	5us**
16	5us	4us**
20	3us	3us**
24	3us	2us**
25,32,33	2us*	2us**
40,48,64	-	1us**

* PIC17 only. ** PIC18 only

DEFINE OSC must be used in order for PBP to accurately calculate and generate code for PAUSEUS. If no DEFINE OSC is placed in the program, PBP will assume that the system clock will operate at 4MHz and calibrate the generated code accordingly.

```
PAUSEUS 1000 ' Delay for 1 millisecond
```

5.53 PEEK

```
PEEK Address, Var
```

Read the microcontroller register at the specified *Address* and stores the result in *Var*. Special PIC MCU features such as A/D converters and additional I/O ports may be read using PEEK.

If *Address* is a constant, the contents of this register number are placed into *Var*. If *Address* is the name of a special function register, e.g. PORTA, the contents of this register will be placed into *Var*. If *Address* is a RAM location, the value of the RAM location will first be read, then the contents of the register specified by that value will be placed into *Var*.

However, all of the PIC MCU registers can be and should be accessed without using PEEK and POKE. All of the PIC MCU registers are considered 8-bit variables by PICBASIC PRO and may be used as you would any other byte-sized variable. They can be read directly or used directly in equations.

```
B0 = PORTA ' Get current PORTA pin states to B0
```

5.54 PEEKCODE

```
PEEKCODE Address, Var
```

Read a value from the code space at the specified *Address* and store the result in *Var*.

PEEKCODE can be used to read data stored in the code space of a PIC MCU. It executes a call to the specified *Address* and places the returned value in *Var*. The specified location should contain a retlw and the data value. POKECODE may be used to store this value at the time the device is programmed.

```
PEEKCODE $3FF, OSCCAL       'Get OSCCAL value for
                            PIC12C671/12CE673
PEEKCODE $7FF, OSCCAL       'Get OSCCAL value for
                            PIC12C672/12CE674
```

5.55 POKE

```
POKE Address, Value
```

Write *Value* to the microcontroller register at the specified *Address*. Special PIC MCU features such as A/D converters and additional I/O ports may be written using POKE.

If *Address* is a constant, *Value* is placed into this register number. If *Address* is the name of a special function register, e.g. PORTA, *Value* will be placed into this register. If *Address* is a RAM location, the contents of the RAM location will first be read, then *Value* is placed into the register specified by those contents.

However, all of the PIC MCU registers can be and should be accessed without using PEEK and POKE. All of the PIC MCU registers are considered 8-bit variables by PICBASIC PRO and may be used as you would any other byte-sized variable. They can be written directly or used directly in equations.

```
TRISA = 0                   ' Set PORTA to all outputs
PORTA.0 = 1                 ' Set PORTA bit 0 high
```

5.56 POKECODE

POKECODE {@Address,}Value{,Value...}

Store *Value*s to the code space at the current program address or optional specified *Address* at the time the microcontroller is programmed.

Note that POKECODE is a specialized command intended for use in circumstances under which standard methods won't serve. LOOKUP and LOOKUP2 are usually a better choice for constructing lookup tables in code space.

POKECODE can be used to generate tables in the code space of the PIC MCU. It generates a return with the data in W. This data can be accessed using the PEEKCODE instruction.

If the optional *Address* is not specified, data storage will be located immediately after the preceding program instruction written.

To avoid interruption of program flow, POKECODE should be the last line of your program. It should be placed after the END or STOP command.

```
POKECODE 10, 20, 30          ' Store 10, 20, and 30in code
                             space
Generates:
    retlw 10
    retlw 20
    retlw 30

POKECODE @$7ff, $94          ' Set OSCCAL value for
                             PIC12C672/12CE674
Generates:
    org 7ffh
    retlw 94h
```

5.57 POT

```
POT Pin, Scale, Var
```

Reads a potentiometer (or some other resistive device) on *Pin*. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

> Note that POT originated as a means to read an analog input on PIC MCUs that lacked analog conversion capability. These days, analog conversion is considered a standard feature on modern PIC MCUs. If the PIC is equipped with analog conversion, it is highly recommended that ADCIN be used instead of POT.

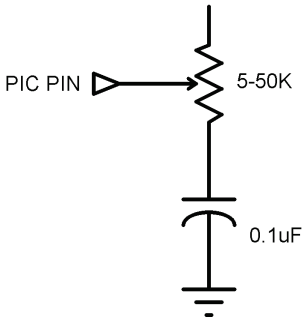
The resistance is measured by timing the discharge of a capacitor through the resistor (typically 5K to 50K). *Scale* is used to adjust for varying RC constants. For larger RC constants, *Scale* should be set low (a minimum value of one). For smaller RC constants, *Scale* should be set to its maximum value (255). If *Scale* is set correctly, *Var* should be zero near minimum resistance and 255 near maximum resistance.

Unfortunately, *Scale* must be determined experimentally. To do so, set the device under measure to maximum resistance and read it with *Scale* set to 127. Adjust Scale until the Pot command returns 254. If 255, decrease the scale. If 253 or lower, increase the scale. (Note: This is similar to the process performed by the Alt-P option of the BS1 environment).

Use the following code to automate the process. Make sure that you set the pot to maximum resistance.

```
B0 Var Byte
scale Var Byte
For scale = 1 To 255
    POT 0,scale,B0
    If (B0 > 253) Then calibrated
Next scale
SEROUT 2,0,["Increase R or C.",10,13]
Stop
calibrated:
    SEROUT 2,0,["Scale= ",#scale,10,13]
```

Potentiometer wiring example:



5.58 PULSIN

```
PULSIN Pin, State, Var
```

Measures pulse width on *Pin*. If *State* is zero, the width of a low pulse is measured. If *State* is one, the width of a high pulse is measured. The measured width is placed in *Var*. If the pulse edge never happens or the width of the pulse is too great to measure, *Var* is set to zero.

Pin is automatically made an input. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The resolution of PULSIN is dependent upon the oscillator frequency. If a 4MHz oscillator is used, the pulse width is returned in 10us increments. If a 20MHz oscillator is used, the pulse width will have a 2us resolution. Defining an OSC value has no effect on PULSIN. The resolution always changes with the actual oscillator speed.

PULSIN normally waits a maximum of 65535 counts before it determines there is no pulse. If it is desired to wait fewer or more counts before it stops looking for a pulse or the end of a pulse, a DEFINE can be added:

```
DEFINE PULSIN_MAX 1000
```

This DEFINE also affects RCTIME in the same manner.

```
' Measure high pulse on Pin4 stored in W3
PULSIN PORTB.4,1,W3
```

5.59 PULSOUT

```
PULSOUT Pin, Period
```

Generates a pulse on *Pin* of specified *Period*. The pulse is generated by toggling the pin twice, thus the initial state of the pin determines the polarity of the pulse. *Pin* is automatically made an output. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The resolution of PULSOUT is dependent upon the oscillator frequency. If a 4MHz oscillator is used, the *Period* of the generated pulse will be in 10us increments. If a 20MHz oscillator is used, *Period* will have a 2us resolution. Defining an OSC value has no effect on PULSOUT. The resolution always changes with the actual oscillator speed.

```
' Send a pulse 1mSec long (at 4MHz) to Pin5
PULSOUT PORTB.5,100
```

PULSOUT is a legacy command that is included for compatibility with other languages. Consider the following example for a timed pulse on PORTB.5 using PAUSEUS:

```
' Send a high pulse 1mSec long (at any defined osc) to Pin5
' The pin should be set as an output with "OUTPUT PORTB.5"

PORTB.5 = 1                 ' Set the pin high
PAUSEUS 1000                ' Pause for 1mS
PORTB.5 = 0                 ' Set the pin low
```

The advantages to this method are:

The time is set in uS and PBP will automatically adjust to achieve this with any system-clock frequency that is defined with DEFINE OSC.

The active state of the pulse is not dependent on the state of the pin before the command is executed. The active state is specified and less prone to accidental inversion.

5.60 PWM

```
PWM Pin, Duty, Cycle
```

Outputs a pulse width modulated pulse train on *Pin*. Each cycle of PWM consists of 256 steps. The *Duty* cycle for each PWM cycle ranges from 0 (0%) to 255 (100%). This PWM cycle is repeated *Cycle* times. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

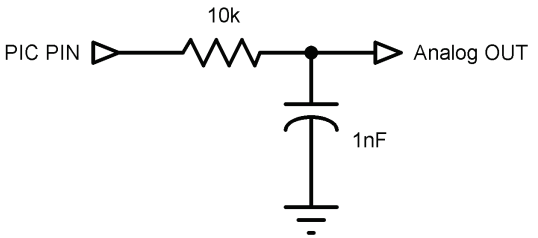
PWM is a software-based command and does not require that the target device have PWM capability. The output pin may be set to any digital I/O pin, and may be different in different PWM commands within the same program.

The *Cycle* time of PWM is dependent upon the oscillator frequency. If a 4MHz oscillator is used, each *Cycle* is about 5ms long. If a 20MHz oscillator is used, each *Cycle* is about 1ms in length. Defining an OSC value has no effect on PWM. The *Cycle* time always changes with the actual oscillator speed.

If you want continuous PWM output and the PIC MCU has PWM hardware, HPWM may be used instead of PWM. See the section on for HPWM more information about it.

Pin is made an output just prior to pulse generation and reverts to an input after generation stops. The PWM output on a pin looks like so much garbage, not a beautiful series of square waves. A filter of some sort is necessary to turn the signal into something useful. An RC circuit can be used as a simple D/A converter:

```
PWM PORTB.7,127,100          ' Send a 50% duty cycle PWM
                             signal out Pin7 for100 cycles
```



5.61 RANDOM

```
RANDOM Var
```

Perform one iteration of pseudo-randomization on *Var*. *Var* should be a 16-bit variable. Array variables with a variable index may not be used in RANDOM although array variables with a constant index are allowed. *Var* is used both as the seed and to store the result. The pseudo-random algorithm used has a walking length of 65535 (only zero is not produced).

RANDOM is not a true random-number generator. It performs a complex math operation on the seed value, resulting in a "seemingly random" result. The same seed value will always yield exactly the same result. If the result is used for the seed value in subsequent iterations of RANDOM, the result is a predictable repeating sequence of numbers.

```
RANDOM W4                    ' Randomize value in W4
```

5.62 RCTIME

```
RCTIME Pin, State, Var
```

RCTIME measures the time a *Pin* stays in a particular *State*. It is basically half a PULSIN. *Pin* is automatically made an input. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

RCTIME may be used to read a potentiometer (or some other resistive device). Resistance can be measured by discharging and timing the charge (or vice versa) of a capacitor through the resistor (typically 5K to 50K).

The resolution of RCTIME is dependent upon the oscillator frequency. If a 4MHz oscillator is used, the time in state is returned in 10us increments. If a 20MHz oscillator is used, the time in state will have a 2us resolution. Defining an OSC value has no effect on RCTIME. The resolution always changes with the actual oscillator speed.

If the pin never changes state, 0 is returned. RCTIME normally waits a maximum of 65535 counts before it determines there is no change of state. If it is desired to wait fewer or more counts before it stops looking for this change, a DEFINE can be added:

```
DEFINE PULSIN_MAX 1000
```

This DEFINE also affects PULSIN in the same manner.

```
Low PORTB.3                 ' Discharge cap to start
Pause 10                    ' Discharge for 10ms
RCTIME PORTB.3,0,W0         ' Read potentiometer on Pin3
```

5.63 READ

READ *Address*,{**WORD**}{**LONG**}*Var* {,*Var...*}

Read bytes, words and longs (if PBPL used) from the on-chip EEPROM at the specified *Address* and stores the result in *Var*. This instruction may only be used with a PIC MCU that has on-chip EEPROM (Data Space).

READ will not work on devices with on-chip I2C interfaced serial EEPROM like the PIC12CE67x and PIC16CE62x parts. Use the I2CREAD instruction instead.

```
READ 5,B0                   ' Put the value at EEPROM
                            location 5 into B0
READ 0,Word W1,Word W2,B6
READ 10,Long L0             ' PBPL only
```

5.64 READCODE

```
READCODE Address, Var
```

Read the value at location *Address* in code space into *Var*. Some PIC16F and PIC18 devices allow program code to be read at run-time. This may be useful for additional data storage or to verify the validity of the program code. For PIC16F devices, 14-bit-sized data can be read from word code space *Addresse*s.

For PIC18 devices, byte or word-sized data can be read from byte (rather than word) code space *Addresse*s. The listing file may be examined to determine program addresses.

```
READCODE $100,w             ' Put the code word at location
                            $100 into W
```

5.65 REPEAT..UNTIL

```
REPEAT
    Statement...
UNTIL Condition
```

This command has been deprecated. Use DO..LOOP instead.

REPEATedly execute *Statement*s UNTIL the specified *Condition* is true. When the *Condition* is true, execution continues at the statement following the UNTIL. *Condition* may be any comparison expression.

```
i = 0
REPEAT
    PORTB.0[i] = 0
    i = i + 1
UNTIL i > 7
```

5.66 RESUME

RESUME {*Label*}

Pick up where program left off after handling an interrupt. RESUME is similar to RETURN but is used at the end of a PICBASIC PRO interrupt handler.

If the optional *Label* is used, program execution will continue at *Label* instead of where it was when it was interrupted. This can, however, cause problems with the stack. If the device has a stack pointer that is not accessible by the program, like a PIC16F877A, any other return addresses on the stack will no longer be accessible. If the stack pointer is accessible as it is on the 14-bit enhanced core and the PIC18 devices, it is cleared to 0 before the jump to *Label* is executed. If you would rather manipulate the stack pointer yourself, the following DEFINE keeps the compiler from clearing it:

```
DEFINE NO_CLEAR_STKPTR 1
```

See ON INTERRUPT for more information.

```
clockint:
    seconds = seconds + 1  ' Count time
RESUME                     ' Return to program after
                           interrupt
error:
    High errorled          ' Turn on error LED
RESUME restart             ' Resume somewhere else
```

5.67 RETURN

```
RETURN
```

Return from subroutine. RETURN resumes execution at the statement following the GOSU**B** which called the subroutine.

```
GOSUB sub1                  ' Go to subroutine labeled sub1
                            ...
sub1:
    SEROUT 0,N2400,["Lunch"]   ' Send "Lunch" out Pin0
                            serially
RETURN                      ' Return to main program after
                            GOSUB
```

5.68 REVERSE

```
REVERSE Pin
```

If *Pin* is an input, it is made an output. If *Pin* is an output, it is made an input. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
OUTPUT 4                    ' Make Pin4 an output
REVERSE 4                   ' Change Pin4 to an input
```

5.69 SELECT CASE

```
SELECT CASE Var
    CASE Expr1 {, Expr...}Statement...
    CASE Expr2 {, Expr...}Statement...
    {CASE ELSE Statement...}
END SELECT
```

CASE statements are sometimes easier to use than multiple IF..THENs. These statements are used to compare a variable with different values or ranges of values, and take action based on the value.

The *Variable* to be used in all of the comparisons is specified in the SELECT CASE statement. Each CASE is followed by the *Statement*s to be executed if the CASE is true.

IS may be used to specify a comparison other than equal to. Note that "IS" comparisons may only be performed with relation to the *Variable* specified in the SELECT CASE statement. Additional expressions and compound expressions will result in unexpected behavior.

```
SELECT CASE x
    CASE IS (PORTB.0 = 0)       ' NOT VALID
```

CASEs are tested and evaluated in the order in which they are written within the SELECT CASE structure. The first CASE that is evaluated as true will execute, and the program will resume execution on the line after END SELECT. Only one CASE will execute, even if multiple CASE statements evaluate as true.

If none of the CASEs are true, the *Statement*s under the optional CASE ELSE statement are executed. An END SELECT closes the SELECT CASE.

```
SELECT CASE x
    CASE 1
          y = 10
    CASE 2, 3
          y = 20
    CASE IS > 5
          y = 100
    CASE ELSE
          y = 0
END SELECT
```

5.70 SERIN

```
SERIN Pin, Mode,{Timeout, Label,}{[Qual...],}{Item...}
```

Receive one or more *Item*s on *Pin* in standard asynchronous format using 8 data bits, no parity and one stop bit (8N1). SERIN is similar to the BS1 SERIN command with the addition of a *Timeout*. *Pin* is automatically made an input. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The *Mode* names (e.g. T2400) are defined in the file MODEDEFS.BAS. To use them, add the line:

```
Include "modedefs.bas"
```

to the top of the PICBASIC PRO program. BS1DEFS.BAS and BS2DEFS.BAS already includes MODEDEFS.BAS. Do not include it again if one of these files is already included. The *Mode* numbers may be used without including this file.

Mode	*Mode* No.	Baud Rate	State
T2400	0	2400	True
T1200	1	1200	
T9600	2	9600	
T300	3	300	
N2400	4	2400	Inverted
N1200	5	1200	
N9600	6	9600	
N300	7	300	

An optional *Timeout* and *Label* may be included to allow the program to continue if a character is not received within a certain amount of time. *Timeout* is specified in 1 millisecond units. If the serial input pin stays in the idle state during the *Timeout* time, the program will exit the SERIN command and jump to *Label*.

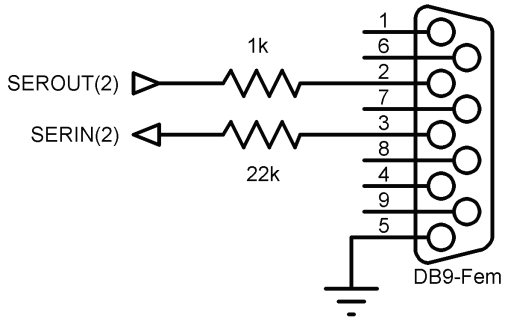
The list of data items to be received may be preceded by one or more qualifiers enclosed within brackets. SERIN must receive these bytes in exact order before receiving the data items. If any byte received does not match the next byte in the qualifier sequence, the qualification process starts over (i.e. the next received byte is compared to the first item in the qualifier list). A *Qualifier* can be a constant, variable or a string constant. Each character of a string is treated as an individual qualifier.

Once the qualifiers are satisfied, SERIN begins storing data in the variables associated with each *Item*. If the variable name is used alone, the value of the

received ASCII character is stored in the variable. If variable is preceded by a pound sign (#), SERIN converts a decimal value in ASCII and stores the result in that variable. All non-digits received prior to the first digit of the decimal value are ignored and discarded. The non-digit character which terminates the decimal value is also discarded. The decimal value received may not be greater than 65535, even when a long variable is specified.

SERIN assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value.

While single-chip RS-232 level converters are common and inexpensive, the excellent I/O specifications of the PIC MCU allow most applications to run without level converters. Rather, inverted input (N300..N9600) can be used in conjunction with a current limiting resistor.




```
' Wait until the character "A" is received serially on Pin1
                          and put next character into B0
SERIN 1,N2400,["A"],B0
```

5.71 SERIN2

```
SERIN2 DataPin{\FlowPin},Mode,{ParityLabel,}{Timeout, Label,}[Item...]
```

Receive one or more *Item*s on *Pin* in standard asynchronous format. SERIN2 is similar to the BS2 SERIN command. *DataPin* is automatically made an input. The optional *FlowPin* is automatically made an output. *DataPin* and *FlowPin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The optional flow control pin, *FlowPin*, may be included to help keep data from overrunning the receiver. If it is used, *FlowPin* is automatically set to the enabled state to allow transmission of each character. This enabled state is determined by the polarity of the data specified by *Mode*.

Mode is used to specify the baud rate and operating parameters of the serial transfer. The low order 13 bits select the baud rate. Bit 13 selects parity or no parity. Bit 14 selects inverted or true level. Bit-15 is not used.

The baud rate bits specify the bit time in microseconds - 20. To find the value for a given baud rate, use the equation:

(1000000 / baud) - 20

Some standard baud rates are listed in the following table.

Baud Rate	Bits 0 - 12
300	3313
600	1646
1200	813
2400	396
4800	188
9600*	84
19200*	32
38400*	6

*Oscillator faster than 4MHz may be required.

Bit 13 selects parity (bit 13 = 1) or no parity (bit 13 = 0). Normally, the serial transmissions are 8N1 (8 data bits, no parity and 1 stop bit). If parity is selected, the data is received as 7E1 (7 data bits, even parity and 1 stop bit). To receive odd parity instead of even parity, include the following DEFINE in the program:

```
DEFINE SER2_ODD 1
```

Bit 14 selects the level of the data and flow control pins. If bit 14 = 0, the data is received in true form for use with RS-232 drivers. If bit14 = 1, the data is received inverted. This mode can be used to avoid installing RS232 drivers.

Some examples of *Mode* are: *Mode* = 84 (9600 baud, no parity, true), *Mode* = 16780 (2400 baud, no parity, inverted), *Mode* = 27889 (300 baud, even parity, inverted). Section 8.6 shows more *Mode* examples.

If *ParityLabel* is included, this label will be jumped to if a character with bad parity is received. It should only be used if parity is selected (bit 13 = 1).

An optional *Timeout* and *Label* may be included to allow the program to continue if a character is not received within a certain amount of time. *Timeout* is specified in 1 millisecond units. If the serial input pin stays in the idle state during the *Timeout* time, the program will exit the SERIN2 command and jump to *Label*.

A DEFINE allows the use of data bits other than 8 (or 7 with parity). SER2_BITS data bits may range from 4 bits to 8 (the default if no DEFINE is specified). Enabling parity uses one of the number of bits specified.

Defining SER2_BITS to 9 allows 8 bits to be read and written along with a 9th parity bit.

With parity disabled (the default):

```
DEFINE SER2_BITS 4          ' Set Serin2 and Serout2 data
                            bits to 4
DEFINE SER2_BITS 5          ' Set Serin2 and Serout2 data
                            bits to 5
DEFINE SER2_BITS 6          ' Set Serin2 and Serout2 data
                            bits to 6
DEFINE SER2_BITS 7          ' Set Serin2 and Serout2 data
                            bits to 7
DEFINE SER2_BITS 8          ' Set Serin2 and Serout2 data
                            bits to 8 (default)
```

With parity enabled:

SERIN2

```
DEFINE SER2_BITS 5          ' Set Serin2 and Serout2 data
                            bits to 4
DEFINE SER2_BITS 6          ' Set Serin2 and Serout2 data
                            bits to 5
DEFINE SER2_BITS 7          ' Set Serin2 and Serout2 data
                            bits to 6
DEFINE SER2_BITS 8          ' Set Serin2 and Serout2 data
                            bits to 7 (default)
DEFINE SER2_BITS 9          ' Set Serin2 and Serout2 data
                            bits to 8
```

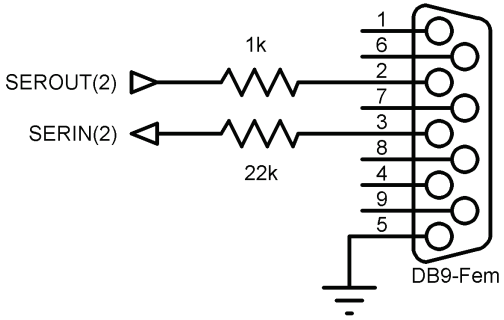
An assortment of string-parsing modifiers is available for use within the item list of this command. These modifiers are capable of extracting data from input strings to various variable types:

Input Modifiers for Parsing Strings	
Modifier	**Operation**
DEC{1..10}	Receive decimal digits
BIN{1..32}	Receive binary digits
HEX{1..8}	Receive upper case hexadecimal digits
SKIP *n*	Skip *n* received characters
STR ArrayVar*n*{*c*}	Receive string of *n* characters optionally ended in character *c*
WAIT ( )	Wait for sequence of characters
WAITSTR ArrayVar{*n*}	Wait for character string

See section 2.10 for details on string-parsing modifiers.

SERIN2 assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value. An oscillator speed faster than 4MHz may be required for reliable operation at 9600 baud and above.

While single-chip RS-232 level converters are common and inexpensive, thanks to current RS-232 implementation and the excellent I/O specifications of the PIC MCU, most applications don't require level converters. Rather, inverted TTL (*Mode* bit 14 = 1) can be used. A current limiting resistor is suggested (RS-232 is suppose to be short-tolerant).



SERIN2 is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
' Wait until the character "A" is received serially
' on Pin1 and put next character into B0
SERIN2 1,16780,[WAIT("A"),B0]
' Skip 2 chars and grab a 4 digit decimal number
SERIN2 PORTA.1,84,[SKIP 2,DEC4 B0]
SERIN2 PORTA.1\PORTA.0,84,100,tlabel,_
    [WAIT("x",b0),STR ar]
```

5.72 SEROUT

SEROUT Pin**,** Mode**, [**Item{**,**Item...}**]**

Sends one or more items to *Pin* in standard asynchronous format using 8 data bits, no parity and one stop (8N1). SEROUT is similar to the BS1 SEROUT command. *Pin* is automatically made an output. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The *Mode* names (e.g. T2400) are defined in the file MODEDEFS.BAS. To use them, add the line:

```
Include "modedefs.bas"
```

to the top of the PICBASIC PRO program. BS1DEFS.BAS and BS2DEFS.BAS already includes MODEDEFS.BAS. Do not include it again if one of these files is already included. The *Mode* numbers may be used without including this file.

Mode	*Mode* No.	Baud Rate	State
T2400	0	2400	Driven True
T1200	1	1200	
T9600	2	9600	
T300	3	300	
N2400	4	2400	Driven Inverted
N1200	5	1200	
N9600	6	9600	
N300	7	300	
OT2400	8	2400	Open True*
OT1200	9	1200	
OT9600	10	9600	
OT300	11	300	
ON2400	12	2400	Open Inverted*
ON1200	13	1200	
ON9600	14	9600	
ON300	15	300	

* Open modes not supported on 12-bit core PIC MCUs.

SEROUT supports three different data types which may be mixed and matched freely within a single SEROUT statement.

3) A string constant is output as a literal string of characters.
4) A numeric value (either a variable or a constant) will send the corresponding ASCII character. Most notably, 13 is carriage return and 10 is line feed.
5) A numeric value preceded by a pound sign (#) will send the ASCII representation of its decimal value, up to 65535. For example, if W0 =

123, then #W0 (or #123) will send “1", “2”, ”3".

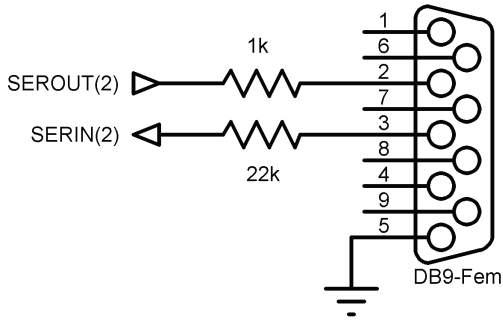
SEROUT assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value.

In some cases, the transmission rates of SEROUT instructions may present characters too quickly to the receiving device. A DEFINE adds character pacing to the serial output transmissions. This allows additional time between the characters as they are transmitted. The character pacing DEFINE allows a delay of 1 to 65,535 microseconds (.001 to 65.535 milliseconds) between each character transmitted.

For example, to pause 1 millisecond between the transmission of each character:

```
DEFINE CHAR_PACING 1000
```

While single-chip RS-232 level converters are common and inexpensive, thanks to current RS-232 implementation and the excellent I/O specifications of the PIC MCU, most applications don't require level converters. Rather, inverted TTL (N300..N9600) can be used. A current limiting resistor is suggested (RS-232 is suppose to be short-tolerant).




```
SEROUT 0,N2400,[#B0,10]     ' Send the ASCII value of B0
                            followed by a linefeed out Pin0
                            serially
```

5.73 SEROUT2

```
SEROUT2 DataPin{\FlowPin},Mode,{Pace,} {Timeout,Label,}[Item...]
```

Send one or more *Item*s to *DataPin* in standard asynchronous serial format. **SEROUT2** is similar to the BS2 SEROUT command. *DataPin* is automatically made an output. The optional *FlowPin* is automatically made an input. *DataPin* and *FlowPin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

The optional flow control pin, *FlowPin*, may be included to help keep data from overrunning the receiver. If it is used, the serial data will not be sent until *FlowPin* is in the proper state. This state is determined by the polarity of the data specified by *Mode*.

An optional *Timeout* and *Label* may be included to allow the program to continue if *FlowPin* does not change to the enabled state within a certain amount of time. *Timeout* is specified in units of 1 millisecond. If *FlowPin* stays disabled during the *Timeout* time, the program will exit the **SEROUT2** command and jump to *Label*.

In some cases, the transmission rates of **SEROUT2** instructions may present characters too quickly to the receiving device. It may not be desirable to use an extra pin for flow control. An optional *Pace* can be used to add character pacing to the serial output transmissions. This allows additional time between the characters as they are transmitted. The character pacing allows a delay of 1 to 65,535 milliseconds between each character transmitted.

Mode is used to specify the baud rate and operating parameters of the serial transfer. The low order 13 bits select the baud rate. Bit 13 selects parity or no parity. Bit 14 selects inverted or true level. Bit 15 selects whether it is driven or open.

The baud rate bits specify the bit time in microseconds - 20. To find the value for a given baud rate, use the equation:

(1000000 / baud) - 20

Some standard baud rates are listed in the following table.

Baud Rate	Bits 0 - 12
300	3313
600	1646
1200	813
2400	396
4800	188
9600*	84
19200*	32
38400*	6

*Oscillator faster than 4MHz may be required.

Bit 13 selects parity (bit 13 = 1) or no parity (bit 13 = 0). Normally, the serial transmissions are 8N1 (8 data bits, no parity and 1 stop bit). If parity is selected, the data is sent as 7E1 (7 data bits, even parity and 1 stop bit). To transmit odd parity instead of even parity, include the following **DEFINE** in the program:

```
DEFINE  SER2_ODD  1
```

Bit 14 selects the level of the data and flow control pins. If bit 14 = 0, the data is sent in true form for use with RS-232 drivers. If bit14 = 1, the data is sent inverted. This mode can be used to avoid installing RS-232 drivers.

Bit 15 selects whether the data pin is always driven (bit 15 = 0), or is open in one of the states (bit 15 = 1). The open mode can be used to chain several devices together on the same serial bus.

See Section 8.6 for a table of *Mode* examples.

A DEFINE allows the use of data bits other than 8 (or 7 with parity). SER2_BITS data bits may range from 4 bits to 8 (the default if no DEFINE is specified). Enabling parity uses one of the number of bits specified. Defining SER2_BITS to 9 allows 8 bits to be read and written along with a 9th parity bit.

With parity disabled (the default):

SEROUT2

```
DEFINE SER2_BITS 4          ' Set Serin2 and Serout2 data
                            bits to 4
DEFINE SER2_BITS 5          ' Set Serin2 and Serout2 data
                            bits to 5
DEFINE SER2_BITS 6          ' Set Serin2 and Serout2 data
                            bits to 6
DEFINE SER2_BITS 7          ' Set Serin2 and Serout2 data
                            bits to 7
DEFINE SER2_BITS 8          ' Set Serin2 and Serout2 data
                            bits to 8 (default)
```

With parity enabled:

```
DEFINE SER2_BITS 5          ' Set Serin2 and Serout2 data
                            bits to 4
DEFINE SER2_BITS 6          ' Set Serin2 and Serout2 data
                            bits to 5
DEFINE SER2_BITS 7          ' Set Serin2 and Serout2 data
                            bits to 6
DEFINE SER2_BITS 8          ' Set Serin2 and Serout2 data
                            bits to 7 (default)
DEFINE SER2_BITS 9          ' Set Serin2 and Serout2 data
                            bits to 8
```

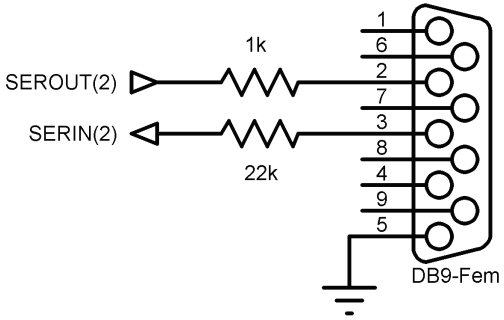
An assortment of string-formatting modifiers is available for use within the item list of this command. These modifiers can be used to format string output that includes numeric values converted from variables:

Output Modifiers for Formatting Strings	
Modifier	Operation
{I}{S}DEC{1..10}	Send decimal digits
{I}{S}BIN{1..32}	Send binary digits
{I}{S}HEX{1..8}	Send hexadecimal digits
REP *char*\count	Send character *c* repeated *n* times
STR ArrayVar{*count*}	Send string of *n* characters

See section 2.11 for details on string-formatting modifiers.

SEROUT2 assumes a 4MHz oscillator when generating its bit timing. To maintain the proper baud rate timing with other oscillator values, be sure to DEFINE the OSC setting to the new oscillator value. An oscillator speed faster than 4MHz may be required for reliable operation at 9600 baud and above.

While single-chip RS-232 level converters are common and inexpensive, thanks to current RS-232 implementation and the excellent I/O specifications of the PIC MCU, most applications don't require level converters. Rather, inverted TTL (*Mode* bit 14 = 1) can be used. A current limiting resistor is suggested (RS-232 is suppose to be short-tolerant).



SEROUT2 is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

```
' Send the ASCII value of B0 followed by a linefeed out
' Pin0 serially at 2400 baud
SEROUT2 0,16780,[DEC B0,10]
' Send "B0 =" followed by the binary value of B0 out
' PORTA pin 1 serially at 9600 baud
SEROUT2 PORTA.1,84,["B0=", IHEX4 B0]
```

5.74 SHIFTIN

```
SHIFTIN DataPin, ClockPin, Mode,[Var{\Bits}...]
```

Clock *ClockPin*, synchronously shift in bits on *DataPin* and store the data received into *Var*. *ClockPin* and *DataPin* may be a constant, 015, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

SHIFTIN is a software-based command and does not require that the target device have synchronous serial capability. The *ClockPin* and *DataPin* parameters may be set to any digital I/O pins, and may be different in different commands within the same program.

Bits optionally specifies the number of bits to be shifted in. If it is not specified, 8 bits are shifted in, independent of the variable type. The *Bits* shifted in are always the low order bits, regardless of the *Mode* used, LSB or MSB.

The *Mode* names (e.g. MSBPRE) are defined in the file MODEDEFS.BAS. To use them, add the line:

```
Include "modedefs.bas"
```

to the top of the PICBASIC PRO program. BS1DEFS.BAS and BS2DEFS.BAS already includes MODEDEFS.BAS. Do not include it again if one of these files is already included. The *Mode* numbers may be used without including this file.. Some *Mode*s do not have a name.

Mode	*Mode* No.	Operation
MSBPRE	0	Shift data in highest bit first, Read data before sending clock. Clock idles low.
LSBPRE	1	Shift data in lowest bit first, Read data before sending clock. Clock idles low.
MSBPOST	2	Shift data in highest bit first, Read data after sending clock. Clock idles low.
LSBPOST	3	Shift data in lowest bit first, Read data after sending clock. Clock idles low.
	4	Shift data in highest bit first, Read data before sending clock. Clock idles high.
	5	Shift data in lowest bit first, Read data before sending clock. Clock idles high.
	6	Shift data in highest bit first, Read data after sending clock. Clock idles high.
	7	Shift data in lowest bit first, Read data after sending clock. Clock idles high.

For *Mode*s 0-3, the clock idles low, toggles high to clock in a bit, and then returns low. For *Mode*s 4-7, the clock idles high, toggles low to clock in a bit, and then returns high.

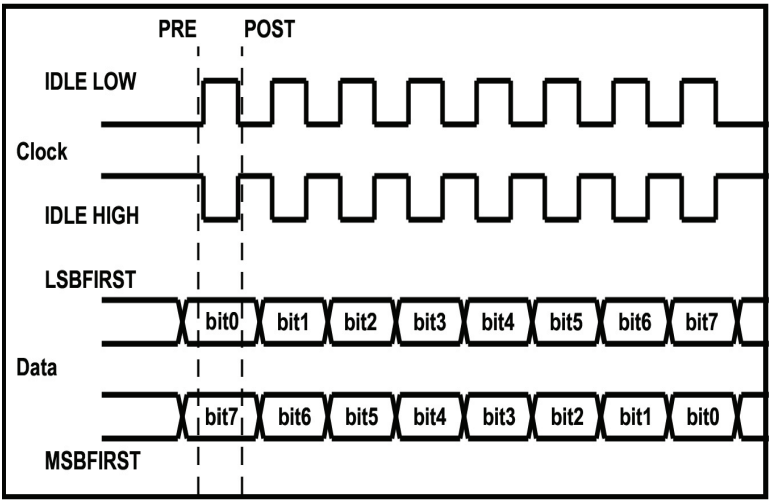
The shift clock runs at about 50kHz, dependent on the oscillator. The active state is held to a minimum of 2 microseconds. A DEFINE allows the active state of the clock to be extended by an additional number of microseconds up to 65,535 (65.535 milliseconds) to slow the clock rate. The minimum additional delay is defined by the PAUSEUS timing. See its section for the minimum for any given oscillator. This DEFINE is not available on 12-bit core PIC MCUs.

SHIFTIN

For example, to slow the clock by an additional 100 microseconds:

```
DEFINE SHIFT_PAUSEUS 100
```

The following diagram shows the relationship of the clock to the data for the various modes:



Examples:

```
SHIFTIN 0,1,MSBPRE,[B0,B1\4]
```

SPI communications may be accomplished with SHIFTIN/SHIFTOUT. A Chip-Select (CS) pin must be defined and manipulated manually before and after the commands:

```
CS  VAR PORTA.5             ' Chip select pin
CS = 0                      ' Enable serial EEPROM
' Send read command and address
SHIFTOUT SI, SCK, MSBFIRST, [$03, addr.byte1, addr.byte0]
SHIFTIN SO, SCK, MSBPRE, [B0]  ' Read data
CS = 1                      ' Disable
```

5.75 SHIFTOUT

```
SHIFTOUT DataPin, ClockPin, Mode, [Var{\Bits}...]
```

Synchronously shift out *Var* on *ClockPin* and *DataPin*. *ClockPin* and *DataPin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

SHIFTOUT is a software-based command and does not require that the target device have synchronous serial capability. The *ClockPin* and *DataPin* parameters may be set to any digital I/O pins, and may be different in different commands within the same program.

\Bits optionally specifies the number of bits to be shifted out. If it is not specified, 8 bits are shifted out, independent of the variable type. The *Bits* shifted out are always the low order bits, regardless of the *Mode* used, LSB or MSB. Up to 32 *Bits* can be shifted out of a single (long) variable. If more than 32 *Bits* are required, multiple variables or constants may be included between the square brackets.

The *Mode* names (e.g. LSBFIRST) are defined in the file MODEDEFS.BAS. To use them, add the line:

```
Include "modedefs.bas"
```

to the top of the PICBASIC PRO program. BS1DEFS.BAS and BS2DEFS.BAS already includes MODEDEFS.BAS. Do not include it again if one of these files is already included. The *Mode* numbers may be used without including this file. Some *Mode*s do not have a name.

Mode	*Mode* No.	Operation
LSBFIRST	0	Shift data out lowest bit first. Clock idles low.
MSBFIRST	1	Shift data out highest bit first. Clock idles low.
	4	Shift data out lowest bit first. Clock idles high.
	5	Shift data out highest bit first. Clock idles high.

For *Mode*s 0-1, the clock idles low, toggles high to clock in a bit, and then returns low. For *Mode*s 4-5, the clock idles high, toggles low to clock in a bit, and then returns high.

The shift clock runs at about 50kHz, dependent on the oscillator. The active state is held to a minimum of 2 microseconds. A DEFINE allows the active state of the clock to be extended by an additional number of microseconds up to 65,535 (65.535 milliseconds) to slow the clock rate. The minimum additional delay is

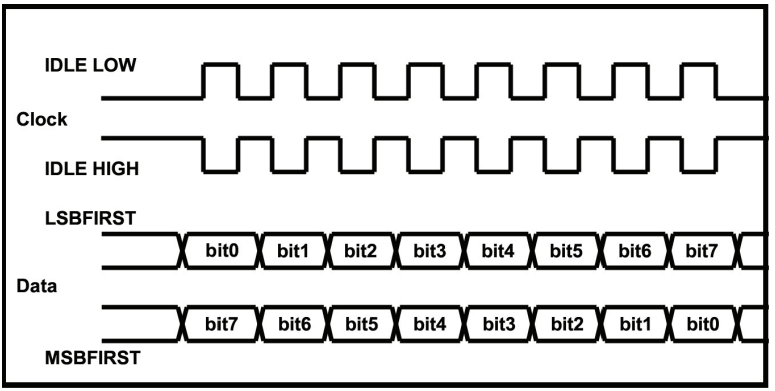
SHIFTOUT

defined by the PAUSEUS timing. See its section for the minimum for any given oscillator. This DEFINE is not available on 12-bit core PIC MCUs.

For example, to slow the clock by an additional 100 microseconds:

```
DEFINE SHIFT_PAUSEUS 100
```

The following diagram shows the relationship of the clock to the data for the various modes:



Examples:

```
SHIFTOUT 0,1,MSBFIRST,[B0,B1]
SHIFTOUT PORTA.1,PORTA.2,1,[wordvar\4]
SHIFTOUT PORTC.1,PORTB.1,4,[$1234\16, $56]
```

SPI communications may be accomplished with SHIFTIN/SHIFTOUT. A Chip-Select (CS) pin must be defined and manipulated manually before and after the commands:

```
CS  VAR PORTA.5             ' Chip select pin
CS = 0                      ' Enable serial EEPROM
' Send read command and address
SHIFTOUT SI, SCK, MSBFIRST, [$03, addr.byte1, addr.byte0]
SHIFTIN SO, SCK, MSBPRE, [B0]  ' Read data
CS = 1                      ' Disable
```

5.76 SLEEP

```
SLEEP Period
```

Place microcontroller into low power mode for *Period* seconds. *Period* is 16-bits using PBPW, so delays can be up to 65,535 seconds (just over 18 hours). For PBPL, *Period* is 32-bits so delays can be quite, quite long.

To achieve minimum current draw it may be necessary to turn off other peripherals on the device, such as the ADC, before executing the SLEEP command. See the Microchip data sheet for the specific device for information about these register settings.

SLEEP wakes up periodically using the Watchdog Timer to check to see if its time is up. If time is not up, it goes back to sleep until the next Watchdog Timer timeout and checks again. If a program is sleeping and waiting for some other event to wake it up, such as an interrupt, it may be more desirable to use the NAP command as it does not operate in SLEEP's looped fashion.

SLEEP uses the Watchdog Timer so it is independent of the actual oscillator frequency. The granularity is about 2 seconds and may vary based on device specifics and temperature. This variance is unlike the BASIC Stamp. The change was necessitated because when the PIC MCU executes a Watchdog Timer reset, it resets many of the internal registers to predefined values. These values may differ greatly from what your program may expect. By running the SLEEP command uncalibrated, this issue is sidestepped.

```
SLEEP 60                    ' Sleep for about 1 minute
```

5.77 SOUND

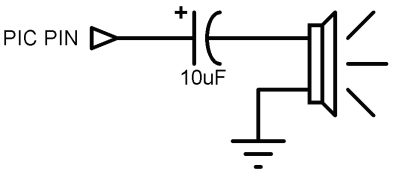
```
SOUND Pin, [Note, Duration{,Note, Duration...}]
```

Generates tone and/or white noise on the specified *Pin*. *Pin* is automatically made an output. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

Note 0 is silence. *Notes* 1-127 are tones. *Notes* 128-255 are white noise. Tones and white noises are in ascending order (i.e. 1 and 128 are the lowest frequencies, 127 and 255 are the highest). *Note* 1 is about 78.74Hz and *Note* 127 is about 10,000Hz.

Duration is 0-255 and determines how long the *Note* is played in about 12 millisecond increments. *Note* and *Duration* needn't be constants.

SOUND outputs TTL-level square waves. Thanks to the excellent I/O characteristics of the PIC MCU, a speaker can be driven through a capacitor. The value of the capacitor should be determined based on the frequencies of interest and the speaker load. Piezo speakers can be driven directly.




```
SOUND PORTB.7,[100,10,50,10]
' Send 2 sounds consecutively toPin7
```

5.78 STOP

```
STOP
```

Stop program execution by executing an endless loop. This does not place the microcontroller into low power mode. The microcontroller is still working as hard as ever. It is just not getting much done.

```
STOP                    ' Stop program dead in its
                        tracks
```

5.79 SWAP

```
SWAP Variable, Variable
```

Exchange the values between 2 variables. Usually, it is a tedious process to swap the value of 2 variables. SWAP does it in one statement without using any intermediate variables. It can be used with bit, byte, word and long variables. Array variables with a variable index may not be used in SWAP although array variables with a constant index are allowed.

```
Temp = B0
B0 = B1                    ' Old way
B1 = temp
SWAP B0, B1                ' One line way
```

5.80 TOGGLE

```
TOGGLE Pin
```

Invert the state of the specified *Pin*. *Pin* is automatically made an output. *Pin* may be a constant, 0 - 15, or a variable that contains a number 0 - 15 (e.g. B0) or a pin name (e.g. PORTA.0).

```
Low 0                       ' Start Pin0 as low
TOGGLE 0                    ' Change state of Pin0 to high
```

5.81 USBIN

```
USBIN Endpoint, Buffer, Countvar, Label
```

Get any available USB data for the *Endpoint* and place it in the *Buffer*. *Buffer* must be a byte array of suitable length to contain the data. *Countvar* should be set to the size of the buffer before USBIN is executed. It will contain the number of bytes transferred to the buffer. *Label* will be jumped to if no data is available.

This instruction may only be used with a PIC MCU that has an on-chip USB port such as the low-speed PIC16C745 and 765, and the full-speed PIC18F2550 and 4550.

The USB and USB18 subdirectories contain the modified Microchip USB libraries as well as example programs. USB programs require several additional files to operate (which are in the USB or USB18 subdirectory), some of which will require modification for your particular application. See the text file in the subdirectory for more information on the USB commands. The USB subdirectory is for the low-speed PIC16C devices and the USB18 subdirectory is for the full-speed PIC18F devices.

USB communications is much more complicated than synchronous (SHIFTIN and SHIFTOUT) and asynchronous (SERIN, SEROUT and so forth) communications. There is much more to know about USB operation that can possibly be described here. The USB information on the Microchip web site needs to be studied. Also, the book "USB Complete" by Jan Axelson may be helpful.

```
cnt = 8
USBIN 1, buffer, cnt, idleloop
```

5.82 USBINIT

USBINIT

USBINIT needs to be one of the first statements in a program that uses USB communications. It will initialize the USB portion of the PIC MCU.

This instruction may only be used with a PIC MCU that has an on-chip USB port such as the low-speed PIC16C745 and 765, and the full-speed PIC18F2550 and 4550.

The USB and USB18 subdirectories contain the modified Microchip USB libraries as well as example programs. USB programs require several additional files to operate (which are in the USB or USB18 subdirectory), some of which will require modification for your particular application. See the text file in the subdirectory for more information on the USB commands. The USB subdirectory is for the low-speed PIC16C devices and the USB18 subdirectory is for the full-speed PIC18F devices.

USB communications is much more complicated than synchronous (SHIFTIN and SHIFTOUT) and asynchronous (SERIN, SEROUT and so forth) communications. There is much more to know about USB operation that can possibly be described here. The USB information on the Microchip web site needs to be studied. Also, the book "USB Complete" by Jan Axelson may be helpful.

```
USBINIT
```

5.83 USBOUT

```
USBOUT Endpoint, Buffer, Count, Label
```

Take *Count* number of bytes from the array variable *Buffer* and send them to the USB *Endpoint*. If the USB buffer does not have room for the data because of a pending transmission, no data will be transferred and program execution will continue at *Label*.

This instruction may only be used with a PIC MCU that has an on-chip USB port such as the low-speed PIC16C745 and 765, and the full-speed PIC18F2550 and 4550.

The USB and USB18 subdirectories contain the modified Microchip USB libraries as well as example programs. USB programs require several additional files to operate (which are in the USB or USB18 subdirectory), some of which will require modification for your particular application. See the text file in the subdirectory for more information on the USB commands. The USB subdirectory is for the low-speed PIC16C devices and the USB18 subdirectory is for the full-speed PIC18F devices.

USB communications is much more complicated than synchronous (SHIFTIN and SHIFTOUT) and asynchronous (SERIN, SEROUT and so forth) communications. There is much more to know about USB operation that can possibly be described here. The USB information on the Microchip web site needs to be studied. Also, the book "USB Complete" by Jan Axelson may be helpful.

```
USBOUT 1, buffer, 4, outloop
```

5.84 USBSERVICE

```
USBSERVICE
```

USBSERVICE needs to be executed repeatedly in the program. Since the USB code provided for the full-speed PIC18F devices is polled rather than interrupt driven, USBSERVICE needs to be executed at least every 10ms throughout the program. If it is not, the device may drop off the USB bus.

When interacting with Windows, at the beginning of the program after USBINIT, it is required that USBSERVICE be polled at about 250 us per loop. Even 1ms may be too slow. It can take up to 5 seconds to complete the initial interaction to get to the state of usb_device_state == CONFIGURED_STATE, but many times it will complete much more quickly. Then, you have to continue to poll USBSERVICE to complete the passing of the HID data to the host. Doing it for another 0.5 seconds seems to be adequate.

This instruction may only be used with a PIC MCU that has an on-chip full-speed USB port such as the PIC18F2550 and 4550.

The USB18 subdirectory contains the modified Microchip USB libraries as well as example programs. USB programs require several additional files to operate (which are in the USB18 subdirectory), some of which will require modification for your particular application. See the text file in the subdirectory for more information on the USB commands.

USB communications is much more complicated than synchronous (SHIFTIN and SHIFTOUT) and asynchronous (SERIN, SEROUT and so forth) communications. There is much more to know about USB operation that can possibly be described here. The USB information on the Microchip web site needs to be studied. Also, the book "USB Complete" by Jan Axelson may be helpful.

```
USBSERVICE
```

5.85 WHILE..WEND

```
WHILE Condition Statement...
WEND
```

This command has been deprecated. Use DO..LOOP instead.

Repeatedly execute *Statement*s WHILE *Condition* is true. When the *Condition* is no longer true, execution continues at the statement following the WEND. *Condition* may be any comparison expression.

```
i = 1
WHILE i <= 10
    SEROUT 0,N2400,["No:",#i,13,10]
    i = i + 1
WEND
```

5.86 WRITE

WRITE *Address*,{**WORD**}{**LONG**}*Value* {,*Value...*}

Write byte, word or long (if PBPL used) *Value*s to the on-chip EEPROM at the specified *Address*. This instruction may only be used with a PIC MCU that has on-chip EEPROM (Data Space).

WRITE is used to set the values of the on-chip EEPROM at runtime. To set the values of the on-chip EEPROM at device programming-time, use the DATA or EEPROM statement.

Each WRITE is self-timed and may take up to 10 milliseconds to execute on a PIC MCU.

For 12-bit core devices that support flash data memory, like the PIC12F519 and PIC16F526, ERASECODE must be used to erase the rows of memory before it can be rewritten using WRITE. See ERASECODE for more information.

If interrupts are used in a program, they must be turned off (masked, not DISABLEd) before executing a WRITE, and turned back on (if desired) after the WRITE instruction is complete. An interrupt occurring during a WRITE may cause it to fail. The following DEFINE turns interrupts off and then back on within a WRITE command. Do not use this DEFINE if interrupts are not used in the program.

```
DEFINE WRITE_INT 1
```

WRITE will not work on devices with on-chip I2C interfaced serial EEPROM like the PIC12CE67x and PIC16CE62x parts. Use the I2CWRITE instruction instead.

```
WRITE 5, B0                 ' Send value in B0 to EEPROM
                            location 5
WRITE 0, Word W1, Word W2, B6
WRITE 10, Long L0           ' PBPL only
```

5.87 WRITECODE

```
WRITECODE Address,          Value
```

Write *Value* to the code space at location *Address*.

Some PIC16F and PIC18F devices allow program code to be written at run-time. While writing self-modifying code can be a dangerous technique, it does allow non-volatile data storage in devices that do not have on-chip EEPROM or when more than the 64 - 1024 bytes that on-chip EEPROM provides is not enough. However, one must be very careful not to write over active program memory.

Note that code space (program memory) has a finite lifespan estimated in number of writes. It is shorter lived than other types of memory like RAM and EEPROM (data memory). WRITECODE, if used, should be used sparingly so as not to "wear out" the memory in the device.

The listing file may be examined to determine program addresses.

For PIC16F devices, 14-bit-sized data can be written to word code space *Address*es.

For PIC18F devices, byte or word-sized data can be written to byte (rather than word) code space *Address*es. The variable size of *Value* determines the number of bytes written. Bit- and byte-sized variables write 1 byte. Word- and long-size variables write 2 bytes to 2 sequential locations.

For block accessed devices, like the PIC16F877a and PIC18F452, a complete block must be written at once. This write block size is different for different PIC MCUs

Note that block writes are not actually executed until the end location of the block is written to. If you write to random addresses within a block and neglect to write to the end location, the previously buffered data will not be written and will be lost.

See the Microchip data sheet for the particular device for information on the block size. Start addresses for will always be exact multiples of the block size, end addresses are calculated as *start address + (block size – 1)*.

Additionally, some flash PIC MCUs, like the PIC18F series, require a portion of the code space to be erased before it can be rewritten with WRITECODE. See the section on ERASECODE for more information.

If interrupts are used in a program, they must be turned off (masked, not DISABLEd) before executing a WRITECODE, and turned back on (if desired) after the WRITECODE instruction is complete. An interrupt occurring during a

WRITECODE may cause it to fail. The following DEFINE turns interrupts off and then back on within a WRITECODE command. Do not use this DEFINE if interrupts are not used in the program.

```
DEFINE WRITE_INT 1
```

Flash program writes must be enabled in the configuration for the PIC MCU at device programming time for WRITECODE to be able to write.

```
WRITECODE $100,w            ' Send value in W to code space
                            location $100
```

5.88 XIN

```
XIN DataPin, ZeroPin,{Timeout, Label,}[Var{,...}]
```

Receive X-10 data and store the House Code and Key Code in *Var*.

XIN is used to receive information from X-10 devices that can send such information. X-10 modules are available from a wide variety of sources under several trade names. An interface is required to connect the microcontroller to the AC power line. The TW-523 for two-way X-10 communications is required by XIN. This device contains the power line interface and isolates the microcontroller from the AC line. Since the X10 format is patented, this interface also covers the license fees.

DataPin is automatically made an input to receive data from the X-10 interface. *ZeroPin* is automatically made an input to receive the zero crossing timing from the X-10 interface. Both pins should be pulled up to 5 volts with 4.7K resistors. *DataPin* and *ZeroPin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

An optional *Timeout* and *Label* may be included to allow the program to continue if X-10 data is not received within a certain amount of time. *Timeout* is specified in AC power line half-cycles (approximately 8.33 milliseconds).

XIN only processes data at each zero crossing of the AC power line as received on *ZeroPin*. If there are no transitions on this line, XIN will effectively wait forever.

If *Var* is word-sized, each House Code received is stored in the upper byte of the word. Each received Key Code is stored in the lower byte of the word. If *Var* is a byte, only the Key Code is stored.

The House Code is a number between 0 and 15 that corresponds to the House Code set on the X-10 module A through P.

The Key Code can be either the number of a specific X-10 module or the function that is to be performed by a module. In normal practice, first a command specifying the X-10 module number is sent, followed by a command specifying the function desired. Some functions operate on all modules at once so the module number is unnecessary. Hopefully, later examples will clarify things. Key Code numbers 0-15 correspond to module numbers 1-16.

These Key Code numbers are different from the actual numbers sent and received by the X10 modules. This difference is to match the Key Codes in the BS2. To remove this Stamp translation, the following DEFINE may be used:

```
DEFINE XINXLAT_OFF 1
```

XIN is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

XOUT below lists the functions as well as the wiring information.

```
housekey Var Word

mainloop:                   ' Get X-10 data
    XIN PORTA.2,PORTA.0,[housekey]
    ' Display X-10 data on LCD
    LCDOUT $fe,1,"House=",#housekey.byte1,_
         "Key=",#housekey.byte0
Goto mainloop               ' Do it forever
' Check for X-10 data, go to nodata if none
XIN PORTA.2,PORTA.0,1,nodata,[housekey]
```

5.89 XOUT

```
XOUT DataPin, ZeroPin, [HouseCode\KeyCode{\Repeat}{,...}]
```

Send *HouseCode* followed by *KeyCode*, *Repeat* number of times in X10 format. If the optional *Repeat* is left off, 2 times (the minimum) is assumed. *Repeat* is usually reserved for use with the Bright and Dim commands.

XOUT is used to send control information to X-10 modules. These modules are available from a wide variety of sources under several trade names. An interface is required to connect the microcontroller to the AC power line. Either the PL-513 for send only, or the TW-523 for two-way X-10 communications are required. These devices contain the power line interface and isolate the microcontroller from the AC line. Since the X-10 format is patented, these interfaces also cover the license fees.

DataPin is automatically made an output to send data to the X-10 interface. *ZeroPin* is automatically made an input to receive the zero crossing timing from the X-10 interface. It should be pulled up to 5 volts with a 4.7K resistor. *DataPin* and *ZeroPin* may be a constant, 0-15, or a variable that contains a number 0-15 (e.g. B0) or a pin name (e.g. PORTA.0).

XOUT only processes data at each zero crossing of the AC power line as received on *ZeroPin*. If there are no transitions on this line, XOUT will effectively wait forever.

HouseCode is a number between 0 and 15 that corresponds to the House Code set on the X-10 module A through P. The proper *HouseCode* must be sent as part of each command.

The *KeyCode* can be either the number of a specific X-10 module or the function that is to be performed by a module. In normal practice, first a command specifying the X-10 module number is sent, followed by a command specifying the function desired. Some functions operate on all modules at once so the module number is unnecessary. Hopefully, later examples will clarify things. *KeyCode* numbers 0-15 correspond to module numbers 1-16.

The *KeyCode* (function) names (e.g. unitOn) are defined in the file MODEDEFS.BAS. To use them, add the line:

```
Include "modedefs.bas"
```

to the top of the PICBASIC PRO program. BS1DEFS.BAS and BS2DEFS.BAS already includes MODEDEFS.BAS. Do not include it again if one of these files is already included. The *KeyCode* numbers may be used without including this file.

KeyCode	KeyCode No.	Operation
unitOn	%10010	Turn module on
unitOff	%11010	Turn module off
unitsOff	%11100	Turn all modules off
lightsOn	%10100	Turn all light modules on
lightsOff	%10000	Turn all light modules off
bright	%10110	Brighten light module
dim	%11110	Dim light module

These *Keycode* numbers are different from the actual numbers sent and received by the X10 modules. This difference is to match the *Keycode*s in the BS2. To remove this Stamp translation, the following **DEFINE** may be used:

```
DEFINE XOUTXLAT_OFF 1
```

XOUT is not supported on 12-bit core PIC MCUs due to RAM and stack constraints.

Wiring to the X-10 interfaces requires 4 connections. Output from the X10 interface (zero crossing and receive data) are open-collector and require a pull up resistor of around 4.7K to 5 volts. Wiring tables for each interface is shown below:

PL-513 Wiring

Wire No.	Wire Color	Connection
1	Black	Zero crossing output
2	Red	Zero crossing common
3	Green	X-10 transmit common
4	Yellow	X-10 transmit input

XOUT

TW-523 Wiring

Wire No.	Wire Color	Connection
1	Black	Zero crossing output
2	Red	Common
3	Green	X-10 receive output
4	Yellow	X-10 transmit input

```
House VAR BYTE
Unit VAR BYTE

Include "modedefs.bas"

house = 0                   ' Set house to 0 (A)
unit = 8                    ' Set unit to 8 (9)
' Turn on unit 8 in house 0
XOUT PORTA.1,PORTA.0,[house\unit, house\unitOn]

' Turn off all the lights in house 0
XOUT PORTA.1,PORTA.0,[house\lightsOff]

' Blink light 0 on and off every 10 seconds
XOUT PORTA.1,PORTA.0,[house\0]

loop:
XOUT PORTA.1,PORTA.0,[house\unitOn]
Pause 10000                 ' Wait 10 seconds

XOUT PORTA.1,PORTA.0,[house\unitOff]
Pause 10000                 ' Wait 10 seconds

Goto loop
```

Chapter 6: Interrupts

Interrupts

The term Interrupt refers to the practice of suspending execution of program code when a predetermined event takes place. The main program is "frozen", while program execution is routed to an Interrupt Service Routine (ISR) that performs some task in response to the event that has been detected. When the ISR completes its duties, program execution is returned to the interrupted process, which should continue undisturbed.

Interrupts can be triggered by external events like a button press or a sensor input. They can also be triggered by an internal process like a timer overflowing or a conversion being completed.

When planning a design using interrupts, thought should be given to which functions should be performed in the interrupt service routine and which should be the responsibility of the main program. In most cases, it is desirable to keep the interrupt routine as short as possible. If the execution time of the ISR is longer than one iteration of the main program loop, you may want to rethink your design. Sometimes the project will benefit from a reversal of duties, where the functions of the main program are moved to an interrupt and vice versa.

The details of available interrupts differ from on device to another. You must consult the datasheet for the specific device you are using. In general, you will find the following types of interrupt triggers for various chips:

- Change to the state of an input pin
- Change to the state of an input port
- Overflow of an internal timer register
- Overflow of a counter register
- Completion of an analog conversion
- Change in a comparator result
- Reception of serial data
- Completion of a serial data send
- Completion of a timed event capture
- Various failures and error conditions

Interrupts are a necessity for many embedded designs, but it's best not to use them without real need. Interrupts will always add a layer of complexity to your program that can make debugging more difficult. Interrupts should not be feared, but you should accept that a bit of effort may be required to make them work as desired.

Note that the interrupt flag bits (the bits that indicate when a particular interrupt has occurred) continue to function even when interrupts are disabled. This is a valuable resource, as you can check and clear the flag bits manually in your program. Your program can test for an interrupt event, without actually enabling interrupts.

6.1 Interrupts Using ON INTERRUPT

PBP's ON INTERRUPT offers a simplified system of handling interrupts. It acts as a layer of automatic checking for the hardware interrupt indicators and directs your program execution to an interrupt-handling subroutine (written in BASIC) that you specify. ON INTERRUPT offers an easy way to deal with interrupts, but with a possible delay (latency) in its response to the interrupt trigger. More on latency can be found later in this section.

This method involves the use of the following commands and directives. They are listed here with reference to the section in this manual where descriptions can be found.

```
4.1   DISABLE
4.3   DISABLE INTERRUPT
4.4   ENABLE
4.6   ENABLE INTERRUPT
4.8   ON INTERRUPT
5.66  RESUME
```

Details about the workings of the actual interrupt triggers, their control registers, and their flag bits can be found in the Microchip datasheet for the specific MCU that you are compiling for.

6.1.1 In Practice

To use the ON INTERRUPT method, the following steps must be performed:

- Place the ON INTERRUPT directive
- Enable the GIE bit and the appropriate Interrupt Enable bit(s).
- Place the interrupt handler routine in a section of program where interrupts are disabled, and within it:
    - Execute code
    - Clear interrupt flags
    - Finish with a RESUME command

A short example follows that uses the "external interrupt" to toggle the state of an LED, while the main program flashes a different LED.

This example will also demonstrate the latency that is associated with ON INTERRUPT. If the interrupt trigger occurs during execution of one of the "PAUSE 500" statements, nothing will happen until the command finishes. This could result in up to 500mS delay before seeing the effect of the interrupt trigger.

Interrupts

```
ON INTERRUPT GOTO myint     ' Interrupt handler is myint,
                            enable interrupt-checking for
                            lines below this point.
INTCON = %10010000          ' Enable GIE and RB0 interrupt

mainloop:
  HIGH led1                 ' LED1 on
  PAUSE 500                 ' Wait a half second
  LOW led1                  ' LED2 off
  PAUSE 500                 ' Wait a half second
GOTO mainloop               ' Loop forever


DISABLE                     ' Disable interrupt-checking for
                            all routines placed below this
                            line.
myint:
  TOGGLE led2               ' Toggle LED2 when interrupted
  INTCON.1 = 0              ' Clear interrupt flag
RESUME                      ' Return to main program
```

If you wish to handle multiple interrupt triggers, each with separate handling routines, you should check the interrupt flags when entering the interrupt handler. Execute the appropriate section of code to handle the trigger that brought program execution to the handler routine.

Notice in the above example that ON INTERRUPT is immediately followed by the setting of the INTCON register and the GIE bit, before any code in the interrupt-enabled section of code is executed. Because the interrupt-checking code will perceive an interrupt event if GIE is clear, care should be taken to only enter the interrupt-enabled section of code (the code under the ON INTERRUPT directive) when GIE is set.

If, in the above example, you used a GOTO placed above the ON INTERRUPT directive to jump directly to the "mainloop" label without first setting the INTCON register, a false interrupt would be perceived and the program would immediately jump to the interrupt handler routine.

You can avoid this by placing ON INTERRUPT and the INTCON setting earlier in the program, so that interrupts are enabled before any jumps occur.

You can also write a safeguard in the first lines of the interrupt handler that checks the interrupt enable and flag bits to make sure that interrupt is real. Checking only the flag bit is not enough in this situation because flags are set upon their associated events, even when the interrupt is not enabled.

Here is an example that would perform this safety check in the "myint" routine in the above example:

```
myint:
  ' Execute only when enable and flag bits are both set.
  ' If either bit is clear (low), abort and return.
  IF (INTCON.5=0) OR (INTCON.1=0) THEN RESUME

  TOGGLE led2              ' Toggle LED2 when interrupted
  INTCON.1 = 0             ' Clear interrupt flag
RESUME                     ' Return to main program
```

6.1.2 How ON INTERRUPT Works

The ON INTERRUPT method is not quite the same as an Assembly Language interrupt method. When ON INTERRUPT is used, a short interrupt handler is placed at location 4 in the PIC MCU. This interrupt handler is simply a Return. What this does is send the program back to what it was doing before the interrupt occurred. It doesn't require any processor context saving.

What it doesn't do is re-enable Global Interrupts as happens using an Assembly Language RETFIE instruction. In this system, the Global Interrupts Enable bit (GIE) serves as a flag that can be checked during program execution. If GIE is disabled, it is known that an interrupt trigger occurred.

In sections of code where the ON INTERRUPT layer has been enabled, a call to a short subroutine is placed before each statement in the PICBASIC PRO. This short subroutine checks the state of the Global Interrupt Enable bit. If it is off, an interrupt is pending, so it vectors to the user's interrupt handler. If it is still set, the program continues with the next BASIC statement, after which, the GIE bit is checked again, and so forth.

Using ON INTERRUPT, PBP simply flags the interrupt event and immediately goes back to what it was doing. It does not immediately vector to your interrupt handler. Since the GIE bit is only checked before each PBP command begins, there could be considerable delay (latency) before the interrupt is handled. Interrupts that happen during execution of a PBP command are essentially ignored until the command finishes. Commands with long execution times may result in long latency in interrupt handling.

As an example, let's say that the PICBASIC PRO program just started execution of a Pause 10000 when an interrupt occurs. PBP will flag the interrupt and continue with the PAUSE. It could be up to 10 seconds later before the interrupt handler is

executed. If it is buffering characters from a serial port, many characters will be missed.

To minimize the problem, use only statements that don't take very long to execute. For example, instead of Pause 10000, use Pause 1 in a long FOR..NEXT loop. This will allow PBP to complete each statement more quickly and handle any pending interrupts.

If interrupt processing needs to occur more quickly than can be provided by ON INTERRUPT, interrupts in Assembly Language should be used.

When the RESUME statement is encountered at the end of the BASIC interrupt handler, it sets the GIE bit to re-enable interrupts and returns to where the program was before the interrupt occurred. If RESUME is given a label to jump to, execution will continue at that location instead. All previous return addresses will be lost in this case.

DISABLE stops PBP from inserting the call to the interrupt checker after each statement. This allows sections of code to execute without the possibility of being interrupted. ENABLE allows the insertion to continue.

A DISABLE should be placed before the interrupt handler so that it will not keep getting restarted by checking the GIE bit.

If it is desired to turn off interrupts for some reason after ON INTERRUPT is encountered, you must not turn off the GIE bit. Turning off this bit tells PBP that an interrupt has happened and it will execute the interrupt handler forever. Instead, clear the individual interrupt enable bit(s). In the example above, you could write:

```
INTCON.5 = 0                ' Disable external interrupt
                            (See the datasheet)
```

Note that the enable bit associated with the interrupt that you are using may be in a different register than INTCON. See the datasheet's section on Interrupts to gain understanding on the working of the interrupt that you wish to use.

6.2 Interrupts Using Assembly Language

Assembly Language Interrupt Handlers are the most responsive way to handle interrupt events. Latency with this method is virtually the same as with pure Assembly programs. Using this method, interrupts will suspend program execution even during execution of PBP commands.

As you might guess, using Assembly Language is a bit more involved than a purely BASIC program. We can't offer a full Assembly Language tutorial in this manual, but we'll try to give you the fundamental concerns for interrupt handlers. There is a bit more information in section 7.1 In-Line Assembly Language.

6.2.1 Checklist

The requirements for setting up an Assembly interrupt handler are:

- Use a DEFINE to specify the Assembly label that begins the routine
- Declare special variables for saving context (when appropriate)
- Set registers to enable the desired interrupts
- Place the handler routine at the beginning of your program as in-line Assembly, and within it:
    - Determine whether context saving code is required and include it appropriately
    - Execute Assembly code to handle the event
    - Clear interrupt flags
    - Restore context from variables
    - Return to main program with RETFIE instruction

6.2.2 DEFINEs

PBP offers a DEFINE to specify the name of the interrupt service routine label. The label refers to the Assembly Language label that marks the beginning of your service routine.

```
DEFINE  INTHAND  Label
```

For devices with multiple priority interrupts, PBP offers a single additional DEFINE that allows you to specify a second label for a second service routine. This routine will be used for low-priority interrupts.

```
DEFINE  INTLHAND  Label
```

6.2.3 Enabling Interrupts

Interrupts should be enabled without concern for PBP. In other words, enable interrupts as appropriate for a pure Assembly Language program.

This will most often consist of at least two bit-settings, one to enable the Global Interrupt Enable (GIE) and one to enable the specific interrupt that you desire to use. If the interrupt is a "peripheral" interrupt, there is an additional Peripheral Interrupt Enable bit (PIE) that must be set.

```
' For PIC18, enable the USART-receive interrupt:
INTCON = %11000000          ' Enable Global and Peripheral
                            interrupts
PIE1.5 = 1                  ' Enable USART receive interrupt
```

To disable and enable interrupts during program execution, the easiest method is to manipulate only the Global Interrupt Enable (GIE) bit:

```
INTCON.7 = 0                ' Disable interrupts
INTCON.7 = 1                ' Enable interrupts
```

Note that this is in direct conflict with the ON INTERRUPT method, for which you should never manipulate the GIE directly.

6.2.4 Placement of the Assembly Language Routine

It is customary to place the interrupt-handler code at the beginning of the executable program, after declaring variables, constants and aliases. There are various reasons for this, but an exhaustive explanation for all the device types

would contain a lot of unnecessary information. Suffice to say that it lessens the probability of code-page issues with some devices that are vulnerable to such things.

Since you don't want your interrupt handler to execute upon power-up or reset, precede the interrupt handler with a PBP GOTO to jump over it.

```
GOTO main                   ' Jump over interrupt handler

ASM
myint                       ; Start handler code
    ; code here
    RETFIE                  ; Return to main program
ENDASM

main:                       ' Start PBP program
```

6.2.5 Declaring Special Variables to Save Context

In order for program execution to return to the main program after handling an interrupt, there are some key register values that must be saved when leaving the main program and restored when returning. The data made up of these key registers is called the "context". Saving and restoring context allows the program to resume reliably after an interrupt event.

In the following sections, details will be found for each type of PIC microcontroller.

6.2.6 Access to PBP Variables from the Interrupt Handler

We've already touched on bank selection as an issue, not just in interrupt handlers, but in in-line Assembly Language overall. The thing to remember is that, through one method or another, the procedures listed here will always result in a BANK0 selection when your interrupt handler begins to execute.

This provides a very simple solution for accessing variables that have been declared in your PBP code from your interrupt handler. If you declare the variables in BANK0, they will automatically be accessible from your Assembly code, without any bank manipulation.

```
tick  VAR  BYTE  BANK0     ' Declare tick variable in BANK0
```

If the SYSTEM keyword is not used in the variable declaration, PBP will create the variable in Assembly with a prepended underscore character. "tick" will become

"_tick" when translated to Assembly. Therefore, if the variable is declared as above, you can increment it in your interrupt handler with the following.

```
incf  _tick, F          ; Increment tick variable
```

6.2.7 Time-Sensitive PBP Commands

When using an Assembly Language interrupt handler, you must remain aware that the execution of any PBP command in your program could be interrupted. Some PBP commands are time-critical. A software-based serial command must track precise baud timing in order to function. A PULSIN command must have a precise timebase to accurately measure a pulse.

In commands such as these, you should disable interrupts before the command begins and enable the interrupts after the command finishes.

```
INTCON.7 = 0
PULSIN PORTB.0, pulse_val
INTCON.7 = 1
```

6.3 Assembly Interrupts for PIC18 Devices

6.3.1 Interrupt Priorities

The PIC18 devices offer the capability of assigning two levels of priority to specific interrupt types. By default, low-priority interrupts are disabled and all interrupts are handled as high-priority. The use of low-priority interrupts represents an additional level of complexity. Make sure the practice is actually needed before enabling it.

In order to use low-priority interrupts, you must first enable them (in the BASIC portion of your program):

```
RCON.7 = 1                  ' Enable interrupt priorities
```

To assign which priority is used for each interrupt source, you use the IPR bits. Each bit in the IPR registers controls the priority for ONE interrupt source. Setting the bit makes it a High Priority and clearing the bit makes it Low Priority. To figure out which of the IPR bits to use, you must look them up in the datasheet.

IPR bits always default to High Priority, so you only need to change them for Low Priority if desired.

```
IPR1.5 = 0                  ' Set USART receive interrupt to
                            LOW priority
```

Under normal operation, INTCON.6 is the Peripheral Interrupt Enable bit (PEIE). When using low-priority interrupts, INTCON.6 becomes Low priority Global Interrupt Enable bit (GIEL). INTCON.7 then becomes the High Priority Global Interrupt Enable bit (GIEH)

GIEH enables all unmasked high-priority interrupts and GIEL enables all unmasked low priority interrupts. "unmasked" simply means that the individual Enable bit for that interrupt source is set to the enabled state. For example, the PIE1.5 bit (RCIE) enables the USART Receive interrupt. If that bit is 1 then the USART Receive interrupt is considered "unmasked".

Peripheral interrupts are always enabled since there is no longer a PEIE bit, but the individual peripheral interrupts must still be enabled to generate interrupts for those peripherals.

It's important to remember that a Low Priority interrupt can itself be interrupted by a High Priority interrupt. This can change expected timings or overwrite values if both routines use the same variables.

6.3.2 Saving and Restoring Context

If only high-priority interrupts are used on a PIC18 device, explicit save/restore methods are not usually required. The critical SFR values (WREG, STATUS, and BSR) are automatically saved in shadow registers, and the "retfie FAST" return method automatically restores the values. Other SFRs like the FSR registers, PCLATH:U, and PRODL:H should be saved and restored if your interrupt service routine changes them.

For high-priority interrupts, the handler code can be very simple:

```
ASM
highP_label                ; Label begins the routine
    clrf    BSR            ; set Bank to 0
    ; your assembly code goes here
    retfie FAST            ; Restore context and return
ENDASM
```

Low-priority interrupts may be interrupted by the occurrence of a high-priority interrupt. For this reason, explicit context save and restore is necessary in low-priority interrupt handler. This requires additional variables to be declared in the PBP program. Declare them as follows:

```
wsave VAR BYTE BANKA SYSTEM
ssave VAR BYTE SYSTEM
bsave VAR BYTE SYSTEM
```

The low-priority interrupt handler should save and restore context of critical SFRs WREG, STATUS, and BSR. Other SFRs like the FSR registers, PCLATH:U, and PRODL:H should be saved and restored if your interrupt handler code changes them. An example of a low-priority interrupt handler follows.

```
ASM
LowP_label                  ; Label begins the routine
    movwf   wsave           ; Save the Working register
                            (WREG)
    movff   STATUS, ssave   ; Save STATUS reg
    movff   BSR, bsave      ; Save Bank Select Register
                            (BSR)
    clrf    BSR             ; Set Bank to 0

    ; your assembly code goes here

    movff   ssave, STATUS   ; Restore STATUS
    movff   bsave, BSR      ; Restore Bank Select Register
                            (BSR)
    movff   WREG, wsave     ; Restore Working register
                            (WREG)
    retfie                  ; Return
ENDASM
```

6.3.3 Example High/Low Priority ISR Framework for PIC18

```
DEFINE INTHAND HP_ISR      ' Assign High Priority Interrupt
                           Service Routine label

DEFINE INTLHAND LP_ISR     ' Assign Low Priority Interrupt
                           Service Routine label

' These variables are only required when using
' Low-Priority interrupts.
wsave VAR BYTE BANKA SYSTEM
ssave VAR BYTE SYSTEM
bsave VAR BYTE SYSTEM

GOTO main                  ' Jump over interrupt routines

'----[High Priority interrupt service routines]---------
ASM
HP_ISR
   clrf    BSR             ; Set Bank to 0

   ; Your Assembly code goes here

   retfie FAST
ENDASM

'----[Low Priority interrupt service routines]----------
ASM
LP_ISR                     ; Label begins the routine
   movwf   wsave           ; Save WREG
   movff   STATUS, ssave   ; Save STATUS
   movff   BSR, bsave      ; Save BSR
   clrf    BSR             ; Set Bank to 0

   ; your assembly code goes here

   movff   ssave, STATUS   ; Restore STATUS
   movff   bsave, BSR      ; Restore BSR
   movff   WREG, wsave     ; Restore WREG
   retfie                  ; Return
ENDASM

main:                      ' Begin main program here
```

6.4 Assembly Interrupts for Enhanced 14-Bit Instruction Set

6.4.1 Saving and Restoring Context

For PIC MCUs that use the Enhanced 14-Bit instruction set (part number patterns 12F1xxx, 12LF1xxx, 16F1xxx, and 16LF1xxx), context save and restore is done automatically. You need not write any code for context save or restore.

6.4.2 Example ISR Framework for Enhanced 14-Bit

```
' Define interrupt handler label
DEFINE INTHAND myint

Goto main                   ' jump over interrupt handler

ASM
myint                       ; Context is saved automatically

   ; Your Assembly goes code here

   retfie                   ; Return with auto context
                            restore

ENDASM

main:                       ' Begin main program here
```

6.5 Assembly Interrupts for 14-Bit Instruction Set

6.5.1 Declaring Special Variables to Save Context

To accommodate context save and restore in these devices, a set of special variables must be declared in the PBP program. The names of the variables are:

wsave	For saving the W register
ssave	For saving the STATUS register
psave	For saving the PCLATH register

For **PIC12 and PIC16** devices that do not use the Enhanced 14-bit instruction set, it is necessary to reserve space for the "wsave" variable in a special section of RAM that is accessible regardless of bank-select bit settings. The reason for this requirement is that the W register value is saved upon the interrupt event, before any bank selection change is possible. It will be stored to the memory address where wsave is allocated, but the bank selection bits may point to a different bank.

Microchip has accommodated this for the devices that share the mid-range architecture. A few addresses in RAM at the end of banks 1 and higher will access the equivalent address in BANK0. This can be utilized by placing the wsave variable in one of these "access RAM" addresses within BANK0.

To determine the actual address, you must consult the datasheet for the specific device that you are using. In the datasheet, look for the section "Data Memory Organization". In that section, there should be a table of Special Function Registers that also shows General Purpose Registers at the bottom of each bank column.

In banks numbered greater than zero, you should see a small block that is labeled with something similar to "accesses 70h-7Fh". This means that the wsave variable should be placed in somewhere in the range of addresses 70h-7Fh.

See the following example taken from the PIC16F882 datasheet. The relevant information is highlighted near the bottom.

FIGURE 2-4: PIC16F882 SPECIAL FUNCTION REGISTERS

File Address	Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3
00h	Indirect addr. (1)	80h	Indirect addr. (1)	100h	Indirect addr. (1)	180h	Indirect addr. (1)
01h	TMR0	81h	OPTION_REG	101h	TMR0	181h	OPTION_REG
02h	PCL	82h	PCL	102h	PCL	182h	PCL
03h	STATUS	83h	STATUS	103h	STATUS	183h	STATUS
04h	FSR	84h	FSR	104h	FSR	184h	FSR
05h	PORTA	85h	TRISA	105h	WDTCON	185h	SRCON
06h	PORTB	86h	TRISB	106h	PORTB	186h	TRISB
07h	PORTC	87h	TRISC	107h	CM1CON0	187h	BAUDCTL
08h		88h		108h	CM2CON0	188h	ANSEL
09h	PORTE	89h	TRISE	109h	CM2CON1	189h	ANSELH
0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah	PCLATH
0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh	INTCON
0Ch	PIR1	8Ch	PIE1	10Ch	EEDAT	18Ch	EECON1
0Dh	PIR2	8Dh	PIE2	10Dh	EEADR	18Dh	EECON2(1)
0Eh	TMR1L	8Eh	PCON	10Eh	EEDATH	18Eh	Reserved
0Fh	TMR1H	8Fh	OSCCON	10Fh	EEADRH	18Fh	Reserved
10h	T1CON	90h	OSCTUNE	110h		190h	
11h	TMR2	91h	SSPCON2	111h		191h	
12h	T2CON	92h	PR2	112h		192h	
13h	SSPBUF	93h	SSPADD	113h		193h	
14h	SSPCON	94h	SSPSTAT	114h		194h	
15h	CCPR1L	95h	WPUB	115h		195h	
16h	CCPR1H	96h	IOCB	116h		196h	
17h	CCP1CON	97h	VRCON	117h		197h	
18h	RCSTA	98h	TXSTA	118h		198h	
19h	TXREG	99h	SPBRG	119h		199h	
1Ah	RCREG	9Ah	SPBRGH	11Ah		19Ah	
1Bh	CCPR2L	9Bh	PWM1CON	11Bh		19Bh	
1Ch	CCPR2H	9Ch	ECCPAS	11Ch		19Ch	
1Dh	CCP2CON	9Dh	PSTRCON	11Dh		19Dh	
1Eh	ADRESH	9Eh	ADRESL	11Eh		19Eh	
1Fh	ADCON0	9Fh	ADCON1	11Fh		19Fh	
20h	General Purpose Registers 96 Bytes	A0h	General Purpose Registers 32 Bytes	120h		1A0h	
		BFh					
		C0h					
		EFh		16Fh		1EFh	
7Fh	accesses 70h-7Fh	F0h FFh	accesses 70h-7Fh	170h 17Fh	accesses 70h-7Fh	1F0h 1FFh	accesses 70h-7Fh

Unimplemented data memory locations, read as '0'.

Note 1: Not a physical register.

With the clues gathered from the highlighted area of the table shown above, it can be determined that wsave can be placed at address 70h (written $70 in PBP):

```
wsave  VAR  BYTE $70  SYSTEM   ' wsave in access RAM
```

Please note that the appropriate address may change from device to device. Always consult the datasheet to avoid problems.

The only requirement for the remaining variables "ssave" and "psave" is that they be placed in BANK0. They do not need to be at any specific address. The following variable declarations, therefore, would work for the PIC16F882:

```
wsave  VAR BYTE $70   SYSTEM
ssave  VAR BYTE BANK0 SYSTEM
psave  VAR BYTE BANK0 SYSTEM
```

The "SYSTEM" keyword is used to remove the preceding underscore from the Assembly Language variable names. ("wsave" in PBP is also "wsave" in Assembly.)

6.5.2 Saving and Restoring Context

For PIC12 and PIC16 devices that do not use the Enhanced 14-bit instruction set, PBP will save context automatically if the device has more than 2K of code space (more than one code page). This is born of necessity because of the inner workings of these microcontrollers. For these devices that have 2K or less of code space, the context save needs to be done manually in your interrupt handler.

PBP inserts an Assembly Language constant for its own use that indicates the side of the code space. You can make use of this constant to conditionally insert the context-save code only when needed.

```
if CODE_SIZE <= 2          ; If less than 2K code space
; Save the state of critical registers (PIC12/PIC16)
   movwf  wsave            ; Save W
   swapf  STATUS,W         ; Swap STATUS to W (swap avoids
                           changing STATUS)
   clrf   STATUS           ; Clear STATUS
   movwf  ssave            ; Save swapped STATUS
   movf   PCLATH,W         ; Move PCLATH to W
   movwf  psave            ; Save PCLATH
endif
```

These lines of code should be the very first thing that executes in your interrupt handler. The function of this code is to save the W register, move the value of STATUS into W with a swap to avoid affecting the value, clear STATUS to select BANK0, and finally save the appropriate values to the ssave and psave variables.

The requirement for restoring context is not dependent upon the amount of code space for these devices. Restoration of context is always required. The steps of restoring are the reverse of saving. This insures that the bank selection is manipulated in such a way as to restore the values from the same banks in which

they were saved. If your interrupt handler code changed the bank selection bits to something other than BANK0, make sure you change them back to BANK0 before this code is executed.

```
; Restore the state of critical registers (PIC12/PIC16)
   movf   psave,W          ; restore PCLATH
   movwf  PCLATH
   swapf  ssave,W          ; restore STATUS
   movwf  STATUS
   swapf  wsave,F          ; restore W (swap avoids
                           changing STATUS)
   swapf  wsave,W
   retfie                  ; Return from interrupt
```

6.5.3 Example ISR Framework for the 14-Bit Instruction Set:

```
' Define interrupt handler label
DEFINE INTHAND myint

wsave  VAR BYTE $70   SYSTEM ;wsave in access RAM
ssave  VAR BYTE BANK0 SYSTEM
psave  VAR BYTE BANK0 SYSTEM

GOTO main                  ' Jump over the interrupt
                           handler

' Assembly language interrupt handler
ASM
myint

if CODE_SIZE <= 2          ; If less than 2K code space
; Save the state of critical registers (PIC12/PIC16)
   movwf  wsave            ; Save W
   swapf  STATUS,W         ; Swap STATUS to W (swap avoids
                           changing STATUS)
   clrf   STATUS           ; Clear STATUS
   movwf  ssave            ; Save swapped STATUS
   movf   PCLATH,W         ; Move PCLATH to W
   movwf  psave            ; Save PCLATH
endif

   ;Handler code here

; Restore the state of critical registers (PIC12/PIC16)
   movf   psave,W          ; restore PCLATH
   movwf  PCLATH
   swapf  ssave,W          ; restore STATUS
   movwf  STATUS
   swapf  wsave,F          ; restore W (swap avoids
                           changing STATUS)
   swapf  wsave,W
   retfie                  ; Return from interrupt

ENDASM

main:                      ' Begin main program here
```

Chapter 7: Advanced Techniques and Concepts

7.1 In-Line Assembly Language

In-line Assembly Language in your PBP program is only useful in specific circumstances. The practice is most commonly used for interrupt service routines. You should be reluctant to use Assembly Language, as it adds a layer of complexity that will make it more difficult to debug your program and to port your program to different PIC MCUs.

Note that Assembly Language is NOT REQUIRED to change the internal registers in the PIC MCU. Registers may be read and written at will, in BASIC, using PBP's Direct Register Access.

Before writing in-line Assembly Code, see section 7.2 Code Pages and RAM Banks. Assembly Language syntax is not covered in this manual. See the documentation provided with the assembler application and the device datasheet for syntax and programming information.

7.1.1 Inserting Assembly Code

PBP programs may contain a single line of assembly language preceded by an “at” symbol (**@**), or one or more lines of assembly code preceded by the **ASM** keyword and ended by the **ENDASM** keyword. Both keywords appear on their lines alone.

```
@   bsf     PORTA, 0
ASM
    bsf     STATUS,RP0
    bcf     TRISA, 0
    bcf     STATUS, RP0
ENDASM
```

The lines of assembly are copied verbatim into the assembly output file. This allows the PBP program to use all of the facilities of the assembler. This also, however, requires that the programmer have some familiarity with the PBP libraries. PBP’s notation conventions are similar to other commercial compilers and should come as no shock to programmers experienced enough to attempt in-line Assembly.

All identifier names defined in a PBP program are similarly defined in Assembly, but with the name preceded with an underscore (**_**). This allows access to user variables, constants, and even labeled locations, in assembly:

```
B0 Var Byte
ASM
    movlw 10
    movwf _B0
ENDASM
```

Thus, any name defined in assembly starting with an underscore has the possibility of conflicting with a PBP generated symbol.

PBP will not be aware of variables that you define in Assembly Language. To avoid conflict and allow PBP to effectively manage RAM allocation, variables should be declared in BASIC (even if they are only used in Assembly).

Just as underscored symbols have possible conflicts, so do symbols not starting with underscores. The problem is internal library identifiers. Luckily, most library identifiers contain a '**?**' or make reference to one of the working registers (such as **R0**). Avoiding such names should reduce problems. If you should have a name collision, the assembler will report the duplicate definitions as an error.

In BASIC code, comments may be denoted using either an apostrophe or semicolon. In Assembly Language, only a semicolon is recognized as a comment character.

```
' PICBASIC PRO comment
; Assembly Language comment
```

7.1.2 Placement of In-line Assembly

PBP statements execute in order of their appearance in the source. The organization of the code is as follows: Starting at location 0 (the reset vector) PBP inserts some startup code, followed by a jump to INIT. Next, the called-for library subroutines are stuffed in. At the end of the library is INIT, where any additional initialization is completed.

Finally, at the label MAIN, the compiled PICBASIC PRO statement code is added. The first executable line of program code appears in memory right behind the controller's startup and library code, right after the MAIN label.

The tendency of programmers is to place their own Assembly library functions either before or after their code. There are a couple of deciding factors as to where might be the best place to insert assembly language subroutines. If the entire program fits into one code page, place your assembly routines after your PBP code. If the program is longer than one code page, it could make more sense to put the assembly language routines at the beginning of the PBP program. This

should ensure them of being in the first code page so that you know where to find them. This is the way assembly language interrupt routines should be handled.

If the routines are placed at the front, use a (BASIC) **GOTO** to jump over the code to the first executable PBP statement. If you place the routines at the end of your program, take appropriate steps to make sure the routines do not execute unintentionally.

The actual code for the assembly language routines may be included in your program or in a separate file. If a routine is used by only one particular PICBASIC PRO program, it would make sense to include the assembler code within the PBP source file. This routine can then be accessed using the **CALL** command.

If it is used by several different PBP programs, a separate file containing the assembly routines can simply be included at the appropriate place in the PICBASIC PRO source:

```
ASM
  Include "myasm.inc"
ENDASM
```

7.2 Code Pages and RAM Banks

In some PIC MCUs, the program code space is divided into "pages". In all PIC MCUs (that we have seen to date), RAM is divided into "banks".

One of the advantages of using a high-level language like PBP is that these things are managed for you. If you use PBP's native methods for writing code, declaring and accessing variables, and accessing registers, you needn't give a thought to code-page and bank settings.

```
There is one command that is an exception to this.  PBP's
BRANCH command is not capable of jumps that cross code-page
boundaries.   If you see a warning during assembly that
indicates "crossing code-page boundary", make sure any BRANCH
commands are replaced with BRANCHL.
```

PBP also offers the capability of inserting Assembly Language into your program. When this technique is used, consideration must be given to bank and code-page selection.

We make the assumption that users who choose to use Assembly Language know that language. Therefore, we won't go into Assembly Language techniques in this manual. This section is provided to give Assembly Language programmers the information necessary to manage code-page and bank selection in their code.

The commands and directives that provide a transition between BASIC and Assembly Language are ASM/ENDASM, @, and to some extent #CONFIG/#ENDCONFIG. They are described in other parts of this manual.

When one of these commands is used to begin a block of Assembly Language code, the code-page selection is not changed by PBP. It must be set to point to the code-page in which the first instruction of the Assembly code is placed.

The implication here is that, unless an ASM block is placed at the beginning of the program, you don't know which code-page is selected when entering the Assembly Language. The Assembly code should check and maintain code-page selection as necessary, especially when executing branch or goto instructions.

The best way to simplify this situation is to always place ASM blocks at the beginning of the code. This will insure that the code starts in code-page 0. If you limit the Assembly to less than 2K of consumed code space, then all of the Assembly code will be contained in the first code-page. This is especially relevant to Assembly Language interrupt-handler code.

Advanced Techniques and Concepts

Banks in RAM are handled a bit more actively by PBP. Whenever a block of inline Assembly Language is entered, PBP sets the bank-select register to BANK0.

This comes into play when you access variables or registers with Assembly Language code. If you know that the entities you are accessing are in BANK0/BANKA, you needn't write bank-select instructions. Otherwise, you do.

When declaring variables in PBP, you can use a modifier to force PBP to place the variables in a specific bank. This is commonly used to place any variables that are accessed in Assembly Language in BANK0/BANKA.

```
tick  VAR  BYTE  BANK0     ' Place tick variable in BANK0
```

See section 2.6 Variables for more information.

7.3 RAM Allocation

In general, it is not necessary to know how RAM is allocated by PBP in the microcontroller. PBP takes care of all the details so the programmer doesn't have to. However there are times when this knowledge could be useful.

Variables are stored in the PIC MCU's RAM. Refer to the Microchip PIC MCU data books for the actual location of the start of the RAM registers for a given microcontroller.

The variables are assigned to RAM sequentially in a particular order. The order is LONG arrays first (if any), followed by WORD, BYTE and BIT arrays. Space is then allocated for LONGs, WORDs, BYTEs and individual BITs. BITs are packed into bytes as possible. This order makes the best use of available RAM. (For PIC18 devices, arrays are allocated last.)

Arrays must fit entirely within one RAM bank on 12-bit, 14-bit or PIC17 devices. Arrays may span banks on PIC18 devices. Byte-, word- and long-sized arrays are only limited in length by the amount of available memory on PIC18 devices. The compiler will assure that arrays, as well as simple variables, will fit in memory before successfully compiling.

You can suggest to PBP a particular bank to place the variable in:

```
penny  VAR WORD BANK0
nickel VAR BYTE BANK1
```

If specific bank requests are made, those are handled first. If there is not enough room in a requested bank, the first available space is used and a warning is issued.

You can even set specific addresses for variables. In most cases, it is better to let PBP handle the memory mapping for you. But in some cases, such as storage of the W register in an interrupt handler, it is necessary to define a fixed address. This may be done in a similar manner to bank selection:

```
wsave VAR BYTE $70
```

Several system variables, using about 24 bytes of RAM, are automatically allocated by the compiler for use by library subroutines. These variables are allocated in the file PBPPIC14.RAM and must be in bank 0 (bank A on PIC18 devices).

In the generated code, user variables are prepended with an underscore (_) while system variables have no underscore so that they do not interfere with each other.

```
R0 VAR WORD SYSTEM
```

BASIC Stamp variables B0 - B25 and W0 - W12 are not automatically allocated. It is best to create your own variables using the **VAR** instruction. However if you want these variables to be created for you, simply include the appropriate file, BS1DEFS.BAS or BS2DEFS.BAS, at the beginning of the PICBASIC PRO program. These variables allocate space separate and apart from any other variables you may later create. This is different than the BS2 where using the canned variables and user created variables can get you into hot water.

Additional temporary variables may be generated automatically by the compiler to help it sort out equations. A listing of these variables, as well as the entire memory map, may be seen in the generated .ASM or .LST file.

If there is not enough RAM memory available for the variables, an unable to fit variable in memory error message will be issued.

7.4 MPLAB® Development Environment

At the time of this writing, Microchip is in transition from MPLAB to MPLABX. To get the latest information and details for installing PBP as a language tool within these environments, see the support section of our website, www.melabs.com.

PBP may be installed as a language tool with Microchip's MPLAB IDE. This offers the use of PBP as a programming language while working in MPLAB and most debugging tools that are integrated in MPLAB will work at the source level. This means that you can set breakpoints and control the program execution in the BASIC program code, instead of Assembly Language.

MPLAB is a project-oriented environment. You will need to create a project in order to experience the Microchip workflow. Once a project is created with the PBP language tool selected, the Microchip debugging tools should work as described in Microchip's documentation.

7.4.1 Debugging Tool General Considerations

When using a hardware debugging tool like Microchip's ICD3 or Real ICE, there are associated limitations and resource requirements to consider. Software tools like MPLAB SIM are not subject to these requirements. The general considerations when using a Microchip hardware debugging tool with PBP are:

- The MCLR pin is reserved for debugging, so you cannot use this pin as digital I/O while debugging.
- The programming clock and data pins (RB6 and RB7 on many devices) are reserved for programming and in-circuit debugging. Therefore, other functions multiplexed on these pins will not be available during debug.
- One stack level is used by the debugger. This will reduce the stack levels available to your PBP program. See section 8.1.14 Hardware Stack for more information.

7.4.2 Debugging Tool Device-Specific Considerations

For each PIC MCU family, Microchip's in-circuit debugging tools (ICD3, Real ICE, etc.) require specific memory locations to be reserved for proper use. The exact requirements for each device family are detailed in the MPLAB help files for the debugging tool.

If you encounter a requirement for the first location of Program Memory to be reserved, you may use the following DEFINE in your PBP program. There is no

known harm in using this define, even if it isn't specifically called for, so you may safely add it if you aren't sure if it's needed.

```
DEFINE  ICD_USED  1         ' Place a nop in location-0 of
                            Program Memory
```

Most devices will require a few locations at the end of Program Memory and some specific RAM locations to be reserved. As an example, consider the following information found in the ICD2 help file for the PIC16F88.

Device	Program Memory Used	File Registers Used
PIC16F88	0xF00-0xFFF	0x070 0x0F0 0x170 0x1E7-0x1F0

For the PIC16F88, the **Program Memory requirements** are locations 0xF00 through 0xFFF (hex). If you look at the total program memory available for the PIC16F88, you will notice that these locations are at the very end of the available space. This is the norm for debugging requirements in PIC MCUs.

PBP doesn't offer a specific method of reserving locations at the end of code space because it isn't possible. If your program extends into these locations, reserving them would leave no place for the program code to be displaced to, resulting in errors. The only way to keep these locations free is to make sure that your program doesn't extend into them. This is rarely a problem, except when a program consumes every available location of code space.

The **RAM, or File Register, requirements** are a bit more involved. For the PIC16F88, we see that RAM locations 0x070, 0x0F0, 0x170, and the range 0x1E7 through 0x1F0 are required.

Reserving these RAM locations is simply a matter of assigning dummy variables that occupy the space. As long as you don't use these variables in your PBP program, the locations can be considered "reserved". In this case, we would reserve the locations with the code:

```
ICDRESERVED1    VAR     BYTE $70
ICDRESERVED9    VAR     BYTE(9) $1E7
```

You will notice that locations 0x0F0 and 0x170 are not included in the example. This is because those locations are not available to PBP as general-purpose RAM to begin with. Since they can't be used by PBP, they are inherently reserved. The status of these locations could be gleaned from the datasheet, but the shortcut is to

attempt to define them and then remove them if you receive a compile error – assuming that you haven't declared variables at these locations elsewhere in your program.

The ICDRESERVED9 variable is declared as an array, starting at location 0x1E7 and spanning 9 bytes. This reserves the range 0x1E7 through 0x1F0.

In the PBP install folder, you will find some files named icddefs*.bas. These are example files for reserving ICD resources for specific devices (listed in the comments within each file).

7.5 Hardware Stack

Each PIC MCU utilizes a hardware call stack to save return addresses. The stack is a small area of memory that functions as a list to which addresses are saved before calling a subroutine or interrupt handler. These saved addresses are then used to return to the previous address after the subroutine or interrupt handler executes. Each address is removed from the stack upon return, leaving room for a subsequent call.

The number of locations available for the stack is limited by a different amount for each instruction set family of PIC MCU. The limit is also referred to as the "depth" of the stack. PBP uses a few levels of stack to work its magic, leaving a limited number of stack levels available for the user's program.

Instruction Set	Total Stack	Available Stack
12-Bit	N/A - PBP creates	4
14-Bit	8	4
14-Bit Enhanced	16	12
16-Bit	31	26

When you use GOSUB to call a subroutine in your program, one level of stack will be occupied with a return address while the subroutine executes. That level will be vacated upon execution of the RETURN statement at the end of the routine.

If you leave the subroutine without executing a RETURN, an "orphaned" address will be left on the stack. If you enter a subroutine with some other method besides GOSUB, and a subsequent RETURN is then executed, an unexpected address is removed from the stack (and used to resume program execution). Either of these circumstances will leave the stack in a corrupted state. You may observe unexpected behavior that is seemingly random and very difficult to debug.

Make sure each GOSUB results in a RETURN being executed, and that your RETURNs can't be executed without a preceding GOSUB.

If you use GOSUB from within a subroutine that was called with a GOSUB, we call that a "nested" GOSUB. Two levels of stack will be occupied while the second subroutine executes. If you nest GOSUBS three levels deep, then 3 levels of stack must be available. Nesting too deeply and overrunning the available stack will cause the afore-mentioned unexpected behavior that is seemingly random and very difficult to debug.

Avoid nesting GOSUBs too deeply, especially in devices with a very limited stack depth.

Since interrupts utilize stack memory, you should consider an extra level of stack to be unavailable when you write a program the uses interrupts.

Debugging with a Microchip tool like the ICD3 will also use up one level of stack.

The directive ON INTERRUPT will enable interrupts and one level of stack will be consumed.

The only PBP commands that are cause for concern when nesting are GOSUB and CALL. All other PBP commands may be nested with no stack concerns and no practical limit.

7.6 Array Handling Mechanism

Array variables in PBP are written with square brackets ([]) to enable an index value to point to an element in an array.

```
my_array[15] = 0            ' Write zero to element-15 of
                            my_array
```

At first glance, this seems simple and straightforward, but there is a much larger story behind the use of indexes enclosed in brackets.

Actually, a better term than index would be "offset". You can write a bracketed value next to just about any memory entity in PBP and the value will be treated as an offset to the real memory-address of the entity.

```
my_var  VAR  BYTE           ' Declare a scalar byte variable

my_var[15] = 0              ' Write to a RAM location that
                            is offset 15 locations from
                            where my_var is allocated
```

7.6.1 The Danger

The techniques about to be discussed are not monitored by PBP during compilation or execution of the program. This means that you can write some crazy code that could totally wreck the RAM on the PIC MCU. PBP won't warn you or generate an error message.

The biggest possibility for trouble lies in the fact that PBP doesn't monitor (isn't even aware) of array variable sizes. When you declare an array in PBP and specify a size, all that really happens is that PBP skips a number of RAM locations after the base variable name is allocated.

```
my_array  VAR  WORD[16]     ' Allocates "my_array" as two
                            bytes, then skips (reserves) a
                            block of 30 bytes in RAM
```

Even if you blatantly write to a location that is beyond the size of an array you created, PBP won't complain.

```
my_array  VAR  WORD[16]

my_array[87] = 0            ' Not good
```

This will zero a RAM location outside of your declared array. It will probably wreck another variable in your program, and PBP won't say a word about it.

When accessing arrays using variables for index values, it is always good practice to place limits on the values to inhibit them from pointing to locations that aren't within the array.

```
my_array  VAR  WORD[16]     ' Declare array locations 0
                            through 15
IF x > 15 THEN error_1      ' Check the index variable to
                            see if it's within the array
my_array[x] = 0             ' Only allow access if index is
                            valid
```

If you're asking why PBP doesn't monitor such things, there are two good answers. The first is that it's impossible for PBP to know run-time values of index variables and the insertion of automatic validation code would consume a lot of resources. The second answer is that performing such checks would inhibit the cool stuff that follows.

7.6.2 Brackets Perform Offsets

Variable names (and alias names) in PBP represent two things to the compiler. Each name represents an address where the least-significant element is stored in RAM, and an entity-type that determines how PBP will treat the entity in subsequent encounters.

When writing any name that represents an entity in RAM (including SFRs), you can follow the name with brackets. The expression within the brackets will be treated as an offset in memory. For example, consider the following:

```
x = 15
FOO[x] = 0
```

Without knowing exactly how FOO is declared, all that we can truthfully state is that a location at address (FOO + 15) will be set to zero. The step value of the 15-address offset will be the same as the entity-type associated with the name FOO. If FOO is a BIT, a bit that is 15 bits higher in RAM will be set to zero. If FOO is a WORD, a word that is 15 words higher in RAM will be set to zero. (If the entity-type is BIT, the offset value is limited to 255.)

PBP doesn't' know and doesn't care whether you've declared FOO as an array. It simply sees the bracketed offset value and the entity-type and inserts code to calculate a new address.

This is only useful if you know what lies at the offset RAM location ahead of time. The best way to know is to *define something* ahead of time.

7.6.3 Sub-Arrays within Arrays

Consider the following variable declarations:

```
all_data VAR BYTE[48]      ' Array for all my data
samples  VAR all_data[0]   ' 16 bytes for ADC samples
calcs    VAR all_data[16]  ' 16 bytes for calculated values
readings VAR all_data[32]  ' 16 bytes for port readings
```

The intent is to create arrays for samples, calcs, and readings, but to make them subsets of the all_data array. Even though samples, calcs, and readings are only declared as aliases to single elements of all_data, they can still be accessed as arrays by slapping on a bracketed offset value:

```
FOR x = 0 TO 15
  ADCIN 0, samples[x]      ' Store ADC sample
  calcs[x] = samples[x]/3  ' Store calculated value
  readings[x] = PORTC      ' Store port reading
NEXT x
```

Now we've stored data into three arrays. Let's say that the application requires that all three arrays must be sent to a data-logging device with an HSEROUT command. Since the all_data array contains all three sub-arrays, you can write:

```
HSEROUT [STR all_data\48]  ' Send all the data
```

The all_data array could be expanded to hold multiple scalar variables, also. In this example, though, all the variable types will end up as BYTEs.

7.6.4 Accessing Arrays as Multiple Variable-Types

It is possible for a single array to be declared with multiple names and for each name to be assigned a different variable type. Note that offsets for BITs are limited to a maximum value of 255.

In order to declare an array that can be accessed as both WORDs and BYTEs, the larger variable type must be declared first, then an alias to a modified element is declared.

```
my_words  VAR WORD[16]
my_bytes  VAR my_words.BYTE0   ' Enable BYTE access to the
                               my_words array.
```

The example above creates a single array in memory that can be accessed in two different ways. With the name "my_words" the array can be accessed as 16 WORD values. With the name "my_bytes", the array can be accessed as 32 BYTE values.

One reason to do this is that PBP doesn't allow the following syntax to access a BYTE portion of a WORD array element:

```
my_words[x].BYTE0 = 0       'COMPILE ERROR
```

The long work around for this is to move the value into a temp variable, manipulate it, then restore it to the array:

```
temp = my_words[x]
temp.BYTE0 = 0
my_words[x] = temp
```

If, however, the array can be accessed as both BYTEs and WORDs, you can write:

```
my_bytes[x*2] = 0           ' my_words[x].BYTE0
my_bytes[(x*2)+1] = 0       ' my_words[x].BYTE1
```

Modifiers like BYTE0 change the variable type that PBP perceives when an alias is declared. When we write "..VAR x.BYTE0", PBP will always typecast the alias as a BYTE, regardless of the variable type of "x".

The first element (element-0) of an array can be referenced without an index value. "my_words[0]" is the same as "my_words".

One last bit of information that is implied above: You can write aliases to other aliases. In the above example, you could create a name for a BYTE variable at the end of the array with:

```
last_byte  VAR  my_bytes[31]
```

This works even though "my_bytes" is, itself, an alias.

7.6.5 Applying Offsets to Bits within a Variable or Register

Another powerful result of the array-handling mechanism in PBP is that offsets may be applied to bits when accessing RAM entities. The application for this is most often associated with the need to choose a pin on a port using a variable value, but it also works for accessing bits within variables.

The individual bits within a port register are normally accessed with a period and number after the name of the register:

```
PORTB.0 = 1                 ' Set RB0 high
```

But, if you need to choose the pin with a variable value, it's illegal to write:

```
PORTB.x = 1                 ' COMPILE ERROR
```

The array mechanism in PBP offers a solution. An offset enclosed in brackets may be written after the bit number:

```
PORTB.0[x] = 1              ' Set RBx high
```

The actual effect of this is to add the value of x to the numeric bit number.

```
x = 2
PORTB.4[x] = 1              ' Set bit(4+x) high. In this
                            case, bit-6 is set.
```

NOTE THAT **PBP COMMANDS** WON'T ACCEPT THIS SYNTAX for command parameters. This method can only be used in expressions and with direct register access. You CANNOT write:

```
HIGH  PORTB.0[x]            ' COMPILE ERROR
COUNT PORTB.0[x], 100, y    ' COMPILE ERROR
```

When using this method, PBP will allow an offset value up to 255. As discussed before, there is no built-in protection against accessing bits that are beyond the scope of the parent entity. If you overflow the bits within the parent entity, PBP will access bits in the next higher location of memory.

Chapter 8: Appendixes

8.1 Debugging and Troubleshooting

There are several areas of programming for PIC MCUs that are commonly overlooked, especially by beginners. It is impossible to list all the details for all the hundreds of devices supported by PBP, but this section will try to give you some direction.

8.1.1 Configuration

See #CONFIG. Incorrect configuration of the target MCU can stop the MCU from running. It can also cause unexpected behavior.

Make sure the oscillator is configured correctly. External crystals with frequencies greater than 4MHz need a "High Speed" setting (HS). If you plan for the chip to run without an external oscillator source, make sure the oscillator configuration is set so that the internal oscillator is selected.

Low Voltage Programming should be disabled. If this is enabled and the LVP pin is left floating, the device may start and stop for no apparent reason.

Disable Extended Instruction Set. PBP doesn't use the extended instructions. Bizarre behavior has been observed when enabled.

Other configuration settings may need to be changed to match your intent and your hardware design.

8.1.2 Initializing values

Upon program startup, you should expect values in variables to be random. They will not be zeros or any other predictable value. If your program depends on a starting value for any variable, you must set that value at the beginning of your program.

The same is true for port output values. Don't assume that outputs will be in a low state upon startup. Initialize all PORT and GPIO values explicitly.

8.1.3 DEFINE OSC

DEFINE OSC tells PBP what system clock frequency to expect. Without it, PBP assumes that a 4MHz clock is in use. If the actual frequency is different than the frequency PBP expects, all timed commands in PBP will give incorrect results.

Play it safe and always use DEFINE OSC.

```
DEFINE  OSC  4              ' Compile for 4MHz clock
```

8.1.4 Analog Inputs

If there are analog inputs for converters and/or comparators on the target MCU, they will usually default to analog mode on the pins. This will interfere with digital operations performed on pins that also function as analog inputs. For digital use of pins with analog options, you must find and set a register to select digital mode for the pins.

Here are a few examples for a handful of MCUs, but remember that PBP supports more than 400 different devices. Don't assume that the settings are consistent from on device to the next.

```
ANSEL =  %00000000  ' 16F88, 16F688, 16F690, 16F88x
ANSELH = %00000000  ' 16F690, 16F88x
ADCON1 = %00000111  ' 16F87x, 16F87xA, 18F452
ADCON1 = %00001111  ' 18F4620
```

In the Microchip datasheet for the specific device you are using, the analog/digital selection will be located either in the I/O Ports section or the Analog/Digital Converter section. Common register names are ANSEL, ANSELH, ANSELA-ANSELG, ANCONx, ADCONx.

These settings are important. Save yourself some time and search the datasheet.

8.1.5 Internal Oscillator

A lot of devices are equipped with an internal oscillator, and these are widely used for convenience and to save component cost. In many cases, though, there are register settings that are needed to get the expected behavior from the internal osc.

Many parts have a register the selects the frequency of the internal osc. This is usually covered in the datasheet under Oscillator Configuration.

```
OSCCON = %70                ' Set internal to 8MHz for
                            PIC16F88
```

Older devices may need a calibration process in order for the internal oscillator to be accurate.

```
DEFINE  OSCCAL_1K  1        ' Calibrate internal osc for
                            PIC12F675
```

8.1.6 Read-Modify-Write

Changing the state of an output pin on a PIC MCU is not a simple one-way operation. Even though you're writing to a single bit on a port, the operation starts with a read of the entire port. Consider the simple example:

```
PORTB.0 = 1
```

The MCU makes this happen by reading all pins in PORTB, changing the Bit-0 value per your command, then writing all the bits back to the port. This is transparent as long as all of the pins on PORTB can be read correctly, but sometimes they can't.

Keep in mind that when the state of the pin is changed, the actual voltage will not change instantaneously. In a good situation, the voltage will change within one instruction cycle after commanded… perhaps with a 50nS delay. But, if the pin is affected somehow by its external connection, the voltage could be delayed much longer.

Problems can arise when the individual pins on a single port are changed in rapid succession:

```
PORTB.0 = 1
PORTB.1 = 0
PORTB.7 = 1
```

The microcontroller executes these commands VERY quickly. When the last line is executed to set the PORTB.7 pin, all the pins on PORTB are read and rewritten. If pins 0 and 1 haven't had time for the actual voltage to change, the states of these pins will be incorrectly read and then rewritten with the incorrect value.

The PIC18 family devices offer an alternative register that is immune to this phenomenon. In these parts you can write:

```
LATB.0 = 1
LATB.1 = 0
LATB.7 = 1
```

Another approach would be to write the register as a single value. The concern here is the PORTB pins we haven't mentioned (2 through 6). If these pins are inputs or if you don't care about their output states, simply set them to zeros when writing the port:

```
PORTB = %10000001          ' pin0=1, pin1=0, pin7=1
```

You may also be able to change the order of the settings so that slow-reacting pins are set last. Delays could be placed after settings to slow-reacting pins. You could also address this in the design stage, by placing pin connections on different ports.

8.1.7 Data Direction

All I/O pins on all PIC MCUs are configured as inputs by default. In order for a pin to be used as an output, a data-direction register must be changed.

PBP's HIGH, LOW, and TOGGLE commands change the data-direction to output automatically, but they do it every time they are executed. This can needlessly use instruction cycles.

It is a simple matter to change data-direction. This is usually done in an initialization section that is written near the top of the program. After the data-direction is set once, it won't change unless something in your program affects it.

```
init:
  TRISB = %11111011        ' All PORTB pins inputs except
                           PORTB.2
main:
  PORTB.2 = 1              ' Set PORTB.2 high
  PAUSE 500                ' Pause half second
  PORTB.2 = 0              ' Set PORTB.2 low
  PAUSE 500                ' Pause half second
GOTO main
```

If using aliases to name pins and you don't want to set the data-direction register by name, you can use PBP's INPUT and OUTPUT commands to automatically determine the data-direction register and set it.

```
led  VAR  PORTB.2          ' Alias name for pin

init:
  OUTPUT led               ' Make led an output pin

main:
  PORTB.2 = 1              ' Set PORTB.2 high
  ..
```

8.1.8 Analog Conversion

If your ADCIN command is misbehaving, there are probably some register settings that will help. All of the following can be found in the Analog/Digital Converter section of the datasheet for your specific part. Don't assume that one part works exactly like another.

The MCU always stores the result of an analog conversion in a 16-bit register pair. If "DEFINE ADC_BITS 8" is used, PBP takes a shortcut and only reads the most significant byte of the result. Microchip has accommodated this by LEFT-JUSTIFYING the result in the register pair by default.

However, when ADC_BITS is defined as greater than 8, PBP will read all 16-bits of the register pair. For the result to be correct without a subsequent shift operation, you can tell the chip to RIGHT-JUSTIFY the result. Here are a couple of examples that come with our standard warning… Don't assume that one part works exactly like another! Check the datasheet.

```
ADCON1.7 = 1               ' Right-justify ADC result for
                           PIC16F877
ADCON0.7 = 1               ' Right-justify ADC result for
                           PIC12F683
```

Another common issue that affects ADCIN is the ADC clock setting. You should use "DEFINE ADC_CLOCK" to set a number that corresponds to the desired setting from the datasheet, but some devices defy PBP's attempts to translate the define. It's always safe to use a register setting in addition to the define:

```
DEFINE  ADC_CLOCK  3       ' Inoperative on PIC16F887
ADCON0 = %11000000         ' Set ADC_CLOCK for PIC16F887
```

8.1.9 I/O pin parameters and limitations

On a PIC microcontroller, not all pins are created equal. Some pins have more current-capability than others. Some are built as open-drain drivers. Some can only be used as input.

The datasheet for the specific device you are using will have the details.

8.1.10 Piggybacked pin functions

Most pins on most PIC MCUs will have multiple functions available. In some cases, a "piggybacked" function of a pin will interfere with the pin's function as a normal, digital I/O (as in the previously discussed case of analog inputs).

If a pin is behaving unexpectedly, check the pin's description in the datasheet for the specific device that you are using. You may need to do some digging in the datasheet to find descriptions of each function assigned to the pin. Look to the default register settings (reset states) to determine how the pin is configured.

An example of this is encountered on some small MCUs of the 12-bit instruction set variety (PIC10 and some PIC12). On these devices, the pin GPIO.2 is forced to an input due to its function as a timer/counter clock input. To disable this function and allow the pin to work as a normal, digital I/O, you would set bit-5 in OPTION_REG to zero:

```
OPTION_REG.5 = 0
```

8.1.11 Pin Relocation and Defines

Some PIC MCUs offer options to move hardware peripheral I/O from one pin to another. For the PBP commands that depend on these hardware peripherals, PBP needs to be told where you've assigned the pin. If the hardware peripheral I/O on the MCU you've chosen cannot be relocated, PBP will automatically use the pin location that is available and no additional defines are required.

The most common example is related to PBP's HPWM command. On most PIC MCUs, the output for this command is limited to a few channels on dedicated pins that can't be relocated (CCP channels). On some devices, however, a single CCP channel can be relocated. This occurs on the PIC16F88, where CCP1 can be configured to output on PORTB.0 or PORTB.3. For this situation, PBP needs a DEFINE in order to know where the HPWM will be output. This DEFINE doesn't affect the actual configuration, it only tells PBP which configuration to expect.

```
DEFINE  CCP1_REG  PORTB    ' Locate CCP1 port and bit
DEFINE  CCP1_BIT  3
```

These defines will be listed in the associated command pages. More information for the example above can be found in the HPWM section.

8.1.12 Omitting parentheses

While most users realize the importance of parentheses in mathematical expressions, a common mistake is to omit parentheses in logical expressions. It's important to realize that, without parentheses, the logic can be interpreted differently: Consider this example:

```
IF x = 0 AND y = 0 OR z = 0 THEN label
```

The conditional here is ambiguous, at best. It should be written with parentheses to make clear the intent. Here are two ways to write it that give entirely different results. To illustrate the point, try to decide which one will give the same result as the above example:

```
IF ((x = 0) AND (y = 0)) OR (z = 0) THEN label
IF (x = 0) AND ((y = 0) OR (z = 0)) THEN label
```

Parentheses are strongly encouraged in all expressions, be they mathematical, comparison, bitwise, logical, or any combination.

8.1.13 Channel numbers vs. pins

Some commands, like ADCIN and HPWM, use channel numbers instead of port.pin descriptions. A common mistake is to write the port.pin instead of the channel. .

```
ADCIN  PORTA.0, adc_result ' DON'T DO THIS
```

The above example will read the digital state of PORTA.0, then perform an analog conversion on either channel-0 or channel-1, depending on what it received for state data. If the intent is to perform ADCIN on channel-0, the correct syntax is:

```
ADCIN  0, adc_result
```

8.1.14 Hardware Stack

Too many nested GOSUBs, or entering and exiting subroutines incorrectly may corrupt the hardware call stack on the PIC MCU. This can cause unexpected resets and some intermittent bizarre behavior.

See section 7.5 Hardware Stack for more information.

8.1.15 Overrunning Array Variables

When you declare an array variable with 16 elements, those elements are numbered 0-15. Writing to element-16 will write to a memory location beyond the end of the memory reserved for the array.

Because of the open-ended nature of the array variable handling in PBP, an error will not be reported if you write data past the end location of an array variable that you have declared.

```
my_array  VAR  BYTE[16]
my_array[24]  =  0          'No error, but results in
                            corrupted memory
```

It is good practice to write in limits when accessing arrays with variable indexes.

```
my_array  VAR  BYTE[16]

my_array[x MIN 15]          ' Limit index expression to
                            maximum value of 15
my_array[x & $0F]           ' Use a bitwise mask to limit
```

See section 7.6 Array Handling Mechanism for more information.

8.2 12-Bit Instruction Set Considerations

Because of the architecture of the 12-bit instruction-set PIC MCUs, programs compiled for them by PBP will, in general, be larger and slower than programs compiled for the other PIC MCU families. In many cases, choosing a device from one of these other families will be more appropriate. However, many useful programs can be written and compiled for the 12-bit instruction set.

The two main programming limitations that will most likely occur are running out of RAM memory for variables and running past the first 256 word limit for the library routines. These limitations have made it necessary to eliminate some compiler commands and modify the operation of some others.

The compiler for 12-bit instruction set uses between 20 and 22 bytes of RAM for its internal variables, with additional RAM used for any necessary temporary variables. This RAM allocation includes a 4 level software stack so that the BASIC program can still nest **GOSUB**s up to 4 levels deep. Some PIC MCU devices only have 24 or 25 bytes of RAM so there is very little space for user variables on those devices. If the Unable to Fit Variable error message occurs during compilation, choose another PIC MCU with more general purpose RAM.

PIC MCUs with the 12-bit instruction set can call only into the first half (256 words) of a code page. Since the compiler's library routines are all accessed by calls, they must reside entirely in the first 256 words of the PIC MCU code space. Many library routines, such as **I2CREAD**, are fairly large. It may only take a few routines to overrun the first 256 words of code space. If it is necessary to use more library routines that will fit into the first half of the first code page, it will be necessary to move to a 14- or 16-bit instruction set instead of the 12-bit.

8.3 PBPX Command Line Operation

```
PBPX <Options> <Filename>
```

Options:

-h or -?	Display command line help on the screen.
-n	Enable LONG variables for PIC18. (PBPL)
-p<pic>	Specify target MCU. [-p18F4620]
-a<assembler>	Specify assembler executable. [-aMPASMWIN]
-o<asm param>	Pass command line parameter to assembler. [-os]
-k+ or -k#	Add source-level debugging information (COFF).
-k-	Add assembler-level debugging information (COFF).
-c	Insert source comments into compiled output.
-s	Suppress assembler (compile only).
-v	Verbose mode.
-i	Set include paths.
-l<library>	Use alternate library. [-lPBPPIC18.LIB]
-d<user #DEFINE>	User-created #DEFINE [-dFOO]

Although most users will depend upon an integrated development environment (IDE) to control PBP, under the hood it remains an application that is operated by the use of command-line parameters (aka switches).

This section is intended to guide those who need to operate PBP from the command line and those who wish to install PBP as a language tool within their favorite, generic IDE or program editor.

This information is only applicable to PBP3 and later versions. Older versions of PBP use different executable filenames and may use different parameters.

The name of the PBP executable is PBPX.EXE.

Before launching PBPX, the location of the assembler executable should be placed in an environment variable named PBP_MPASM.

Before launching PBPX, the working directory should be set to the location of the source program files.

The slash (/) character may be used instead of the dash. Multiple command-line options may be separated by a space. However, no space should intervene between an option and its argument. Multiple options of the same type may be used.

PBPX Command Line Operation

With the working directory set to the source folder location, PBPX must be invoked with the full path to its install location. For other install locations, substitute the real path in the examples that follow.

Usage: <path>\PBPX <Options> <Filename>

Options:

-h or -? **-h**

When used, will override all other parameters and will cause PBPX to return a brief description of command-line options

-n -n

Causes "PBP In LONG Mode" (PBPL) to be invoked. This should only be used for PIC18 target devices.

-p<pic> -p18F4620 -p18F46K22

Used to specify the target PIC MCU for the compile. The device number should be given without the "PIC" prefix.

-a<assembler> -aMPASMWIN -aMPASMX

Used to specify the filename of the assembler executable. Should not be used with full path information (e.g. c:\program files\microchip\mpasm suite\mpasmwin). Instead, prepend the location of the assembler executable to the system's PATH environment variable.

-o<asm param> -0q- -os

May be used multiple times on the command-line. The parameter that follows –o is ignored by PBPX, except that it is passed to the assembler command line preceded by a slash character. If you write:

-aMPASMWIN –oq –os

The resulting command line that invokes the assembler will include:

MPASMWIN /q /s

-k+ or -k# -k+ -k#

Causes PBPX to rewrite the assembler-created .COF file with source-level debugging data. The switch is required for source-level debugging in MPLAB.

-k-	-k-

Instructs PBPX to rewrite the assembler-created .COF file with assembly-level debugging data. Source-level debugging will be disabled in MPLAB, allowing debugging in Assembly Language.

-c	-s

Instructs PBPX to insert BASIC program lines as comments in the generated .ASM file.

-s	-s

Causes PBPX to create the .ASM file, but the assembler will not be invoked. Cannot be used with –k options.

-v	-v

Cause PBPX to return a more detailed report of its actions during compilation.

-i<path>	-iC:\PBP\MY_INCLUDES

Instructs PBPX to search the specified path for include files during compilation. Since spaces are not allowed in the path, this option is of limited use on modern Windows systems.

-l<library>	PBPPIC18.LIB

Instructs PBPX to override the LIBRARY directive found in the .PBPINC file and, instead, use the library file specified here.

-d<user_#DEFINE>	-dFOO

May be used multiple times on the command line. This parameter allows the user to create the equivalent of a #DEFINE directive from the command line instead of from the source program. This option may be used multiple times on a single command line. Spaces are not allowed in the –d text.

Here are some examples of –d usage and their equivalent program code:

-dFOO	#DEFINE FOO
-dFOO=1	#DEFINE FOO 1

String constants may not be defined with –d.

Examples of command lines:

PBPX Command Line Operation

```
C:\PBP\PBPX -n -p18F4620 -aMPASMWIN -os -k# blink.pbp
```

Compiles blink.pbp for the PIC18F4620 using PBPL. The MPASMWIN assembler is invoked with its /s parameter, causing its progress dialog to close automatically. The COFF file is rewritten after assembly to accommodate source-level debugging.

```
C:\PBP\PBPX -p16F88 -aMPASMWIN -k# blink.pbp -dver2
```

Compiles blink.pbp for the PIC16F88 using the MPASMWIN assembler.

8.4 Specifying Assembler Location with PBP_MPASM

As discussed earlier in this manual, PBP must invoke an assembler application to finish the compile/assembly process. The assembler executable name is set with the –a command line option. This is usually handled by the IDE in the form of a compiler option setting.

The location of the assembler folder on the system is held in an environment variable named PBP_MPASM. This variable holds path location in the form of a string value. An example is: "C:\Program Files\Microchip\MPASM Suite\"

When launching the assembler, PBP will look first in the location that it finds in the PBP_MPASM variable. If the assembler executable is not found there, PBP will continue its search using all locations available in the system's PATH environment variable.

The PBP_MPASM variable is set automatically after installation of PBP, when the system is next restarted. The installer will search for the most recent installation of MPLAB and set the value to the assembler folder within that installation.

If you install a new version of MPLAB in a different path, the PBP_MPASM variable will need to be updated with the new assembler location. A utility for this may be found in the Start Menu Program Group for PBP.

8.5 defs Include Files

Your PBP installation includes some special-purpose files that may be included in your program code. These files are mostly made up of constant and variable declaration statements that make PBP more compatible with other (simplified and limited) languages. Details are most easily found by reading the contents of the files.

8.5.1 modedefs.bas

```
INCLUDE "modedefs.bas"
```

The file modedefs.bas gives names to modes used in commands like SERIN/SEROUT and SHIFTIN/SHIFTOUT. An example would be the name "T9600" in the SERIN command. "T9600" is a constant which is defined in modedefs.bas.

modedefs.bas is not needed for every PBP program. It is only needed for programs where mode names are used instead of the actual mode numbers. Even when mode names are used, you have the option of creating the names in your program instead of including modedefes.bas, which will create many names that you may not use.

8.5.2 bs1defs.bas

```
INCLUDE "bs1defs.bas"
```

The file bs1defs.bas creates a set of variables and aliases with names that are identical to those pre-defined by the BASIC Stamp (first version, BS1) by Parallax. These names are also identical to those pre-defined by PICBASIC Compiler (aka PBC) by melabs.

8.5.3 bs2defs.bas

```
INCLUDE "bs2defs.bas"
```

The file bs2defs.bas creates a set of variables and aliases with names that are identical to those pre-defined by the BASIC Stamp (second version, BS2) by Parallax.

8.6 SERIN2/SEROUT2 Mode List

Common modes for commands SERIN2 and SEROUT2:

Baud Rate	Bit 15 (Output)	Bit 14 (Conversion)	Bit 13 (Parity)	Mode Number
300	Driven	True	None	3313
300	Driven	True	Even*	11505
300	Driven	Inverted	None	19697
300	Driven	Inverted	Even*	27889
300	Open	True	None	36081
300	Open	True	Even*	44273
300	Open	Inverted	None	52465
300	Open	Inverted	Even*	60657
600	Driven	True	None	1646
600	Driven	True	Even*	9838
600	Driven	Inverted	None	18030
600	Driven	Inverted	Even*	26222
600	Open	True	None	34414
600	Open	True	Even*	42606
600	Open	Inverted	None	50798
600	Open	Inverted	Even*	58990
1200	Driven	True	None	813
1200	Driven	True	Even*	9005
1200	Driven	Inverted	None	17197
1200	Driven	Inverted	Even*	25389
1200	Open	True	None	33581
1200	Open	True	Even*	41773
1200	Open	Inverted	None	49965
1200	Open	Inverted	Even*	58157
2400	Driven	True	None	396
2400	Driven	True	Even*	8588
2400	Driven	Inverted	None	16780
2400	Driven	Inverted	Even*	24972
2400	Open	True	None	33164
2400	Open	True	Even*	41356
2400	Open	Inverted	None	49548
2400	Open	Inverted	Even*	57740
4800	Driven	True	None	188
4800	Driven	True	Even*	8380
4800	Driven	Inverted	None	16572
4800	Driven	Inverted	Even*	24764
4800	Open	True	None	32956
4800	Open	True	Even*	41148
4800	Open	Inverted	None	49340
4800	Open	Inverted	Even*	57532

*Parity is odd when DEFINE SER2_ODD 1 is used.

Continued…

SERIN2/SEROUT2 Mode List

Baud Rate	Bit 15 (Output)	Bit 14 (Conversion)	Bit 13 (Parity)	Mode Number
9600 baud may be unreliable with 4MHz clock				
9600	Driven	True	None	84
9600	Driven	True	Even*	8276
9600	Driven	Inverted	None	16468
9600	Driven	Inverted	Even*	24660
9600	Open	True	None	32852
9600	Open	True	Even*	41044
9600	Open	Inverted	None	49236
9600	Open	Inverted	Even*	57428
baud rates below require 8MHz clock or faster				
14400	Driven	True	None	49
14400	Driven	True	Even*	8241
14400	Driven	Inverted	None	16433
14400	Driven	Inverted	Even*	24625
14400	Open	True	None	32817
14400	Open	True	Even*	41009
14400	Open	Inverted	None	49201
14400	Open	Inverted	Even*	57393
baud rates below require 10MHz clock or faster				
19200	Driven	True	None	32
19200	Driven	True	Even*	8224
19200	Driven	Inverted	None	16416
19200	Driven	Inverted	Even*	24608
19200	Open	True	None	32800
19200	Open	True	Even*	40992
19200	Open	Inverted	None	49184
19200	Open	Inverted	Even*	57376
baud rates below require 16MHz clock or faster				
28800	Driven	True	None	15
28800	Driven	True	Even*	8207
28800	Driven	Inverted	None	16399
28800	Driven	Inverted	Even*	24591
28800	Open	True	None	32783
28800	Open	True	Even*	40975
28800	Open	Inverted	None	49167
28800	Open	Inverted	Even	57359
baud rates below require 20MHz clock or faster				
38400	Driven	True	None	6
38400	Driven	True	Even*	8198
38400	Driven	Inverted	None	16390
38400	Driven	Inverted	Even*	24582
38400	Open	True	None	32774
38400	Open	True	Even*	40966
38400	Open	Inverted	None	49158
38400	Open	Inverted	Even	57350

*Parity is odd when DEFINE SER2_ODD 1 is used.

8.7 Defines

```
DEFINE ADC_BITS 8           'Number of bits in ADCIN result
DEFINE ADC_CLOCK 3          'ADCIN clock source (rc = 3)
DEFINE ADC_SAMPLEUS 50      'ADCIN sampling time in
                            microseconds (pause after
                            channel is selected)
DEFINE BUTTON_PAUSE 10      'BUTTON debounce delay in ms
DEFINE CCP1_REG PORTC       'HPWM channel 1 pin port
DEFINE CCP1_BIT 2           'HPWM channel 1 pin bit
DEFINE CCP2_REG PORTC       'HPWM channel 2 pin port
DEFINE CCP2_BIT 1           'HPWM channel 2 pin bit
DEFINE CCP3_REG PORTG       'HPWM channel 3 pin port
DEFINE CCP3_BIT 0           'HPWM channel 3 pin bit
DEFINE CCP4_REG PORTG       'HPWM channel 4 pin port
DEFINE CCP4_BIT 3           'HPWM channel 4 pin bit
DEFINE CCP5_REG PORTG       'HPWM channel 5 pin port
DEFINE CCP5_BIT 4           'HPWM channel 5 pin bit
DEFINE CHAR_PACING 1000     'SEROUT character pacing in us
DEFINE DEBUG_REG PORTB      'DEBUG pin port
DEFINE DEBUG_BIT 0          'DEBUG pin bit
DEFINE DEBUG_BAUD 2400      'DEBUG baud rate
DEFINE DEBUG_MODE 1         'DEBUG mode: 0 = True, 1 =
                            Inverted
DEFINE DEBUG_PACING 1000    'DEBUG character pacing in us
DEFINE DEBUGIN_REG PORTB    'DEBUGIN pin port
DEFINE DEBUGIN_BIT 0        'DEBUGIN pin bit
DEFINE DEBUGIN_MODE 1       'DEBUGIN mode: 0 = True, 1 =
                            Inverted
DEFINE HPWM2_TIMER 1        'HPWM channel 2 timer select
DEFINE HPWM3_TIMER 1        'HPWM channel 3 timer select
DEFINE HSER_BAUD 2400       'HSER baud rate
DEFINE HSER_SPBRG 25        'HSER SPBRG init
DEFINE HSER_SPBRGH 0        'HSER SPBRGH init
DEFINE HSER_RCSTA 90h       'HSER receive status init
DEFINE HSER_TXSTA 20h       'HSER transmit status init
DEFINE HSER_EVEN 1          'HSER If even parity desired
DEFINE HSER_ODD 1           'HSER If odd parity desired
DEFINE HSER_BITS 9          'HSER Use for 8 bits + parity
DEFINE HSER_CLROERR 1       'Automatically clear HSERIN
                            overflow errors
DEFINE HSER_PORT 1          'HSER port to use on devices
                            with more than one
DEFINE HSER2_BAUD 2400      'HSER2 baud rate
DEFINE HSER2_SPBRG 25       'HSER2 SPBRG2 init
DEFINE HSER2_SPBRGH 0       'HSER2 SPBRGH2 init
DEFINE HSER2_RCSTA 90h      'HSER2 receive status init
DEFINE HSER2_TXSTA 20h      'HSER2 transmit status init
DEFINE HSER2_EVEN 1         'HSER2 If even parity desired
```

DEFINEs

```
DEFINE HSER2_ODD 1          'HSER2 If odd parity desired
DEFINE HSER2_BITS 9         'HSER2 Use for 8 bits + parity
DEFINE HSER2_CLROERR 1      'Automatically clear HSERIN2
                            overflow errors
DEFINE I2C_HOLD 1           'I2CREAD/WRITE Pause I2C
                            transmission while clock held
                            low
DEFINE I2C_INTERNAL 1       'I2CREAD/WRITE Use for internal
                            EEPROM on PIC16CE and PIC12CE
DEFINE I2C_SCLOUT 1         'I2CREAD/WRITE Set serial clock
                            bipolar instead of open-
                            collector
DEFINE I2C_SLOW 1           'I2CREAD/WRITE Use for >8MHz OSC
                            with standard speed devices
DEFINE I2C_SCL PORTA,1      'I2CREAD/WRITE For 12-bit core
                            only
DEFINE I2C_SDA PORTA,0      'I2CREAD/WRITE For 12-bit core
                            only
DEFINE ICD_USED  1          'Place a nop in location-0 of
                            code space
DEFINE INTHAND Label        'Assign assembler interrupt
                            handler label
DEFINE INTLHAND Label       'Assign assembler low priority
                            interrupt handler label for
                            PIC18
DEFINE LCD_DREG PORTA       'LCDOUT/IN data port
DEFINE LCD_DBIT 0           'LCDOUT/IN data starting bit 0
                            or 4
DEFINE LCD_RSREG PORTA      'LCDOUT/IN register select port
DEFINE LCD_RSBIT 4          'LCDOUT/IN register select bit
DEFINE LCD_EREG PORTB       'LCDOUT/IN enable port
DEFINE LCD_EBIT 3           'LCDOUT/IN enable bit
DEFINE LCD_RWREG PORTE      'LCDOUT/IN read/write port
DEFINE LCD_RWBIT 2          'LCDOUT/IN read/write bit
DEFINE LCD_BITS 4           'LCDOUT/IN bus size 4 or 8
DEFINE LCD_LINES 2          'LCDOUT/IN Number lines on LCD
DEFINE LCD_COMMANDUS 2000   'LCDOUT/IN Command delay time in
                            us
DEFINE LCD_DATAUS 50        'LCDOUT/IN Data delay time in us
DEFINE LOADER_USED 1        'Bootloader is being used
DEFINE NO_CLEAR_STKPTR 1    'See RESUME Label
DEFINE NO_CLRWDT 1          'Don't insert CLRWDTs
DEFINE OSC 4                'Oscillator speed in MHz:
                            3(3.58) 4 8 10 12 16 20 24 25 32
                            33 40 48 64
DEFINE OSCCAL_1K 1          'Set OSCCAL for 1K PIC12
DEFINE OSCCAL_2K 1          'Set OSCCAL for 2K PIC12
DEFINE PULSIN_MAX 65535     'Maximum PULSIN/RCTIME count
DEFINE RESET_ORG 0h         'Change reset address for PIC18
```

```
DEFINE SER2_BITS 8          'Set number of data bits for
                            SERIN2 and SEROUT2
DEFINE SER2_ODD 1           'Set odd parity for SERIN2 and
                            SEROUT2
DEFINE SHIFT_PAUSEUS 50     'Slow down the SHIFTIN and
                            SHIFTOUT clock
DEFINE USE_LFSR 1           'Use PIC18 LFSR instruction
DEFINE WRITE_INT 1          'Disable/enable global
                            interrupts during WRITE
DEFINE XINXLAT_OFF 1        'Don't translate XIN commands to
                            BS2 format
DEFINE XOUTXLAT_OFF 1       'Don't translate XOUT commands
                            to BS2 format
```

8.8 Reserved Words

#DEFINE
#ELSE
#ENDIF
#ERROR
#IF
#IFDEF
#IFNDEF
#MSG
#WARNING
ABS
ADCIN
AND
ANDNOT
ARRAYREAD
ARRAYWRITE
ASM
ATN
BANK0
BANK1
BANK2
BANK3
BANK4
BANK5
BANK6
BANK7
BANK8
BANK9
BANK10
BANK11
BANK12
BANK13
BANK14
BANK15
BANKA
BIN
BIN1
BIN2
BIN3
BIN4
BIN5
BIN6
BIN7
BIN8
BIN9
BIN10
BIN11
BIN12
BIN13
BIN14
BIN15
BIN16
BIN17
BIN18
BIN19
BIN20
BIN21
BIN22
BIN23
BIN24
BIN25
BIN26
BIN27
BIN28
BIN29
BIN30
BIN31
BIN32
BIT
BIT0
BIT1
BIT2
BIT3
BIT4
BIT5
BIT6
BIT7
BIT8
BIT9
BIT10
BIT11
BIT12
BIT13
BIT14
BIT15
BIT16
BIT17
BIT18
BIT19
BIT20
BIT21
BIT22
BIT23
BIT24
BIT25
BIT26
BIT27
BIT28
BIT29
BIT30
BIT31
BRANCH
BRANCHL
BUTTON
BYTE
BYTE0
BYTE1
BYTE2
BYTE3
CALL
CASE
CLEAR
CLEARWDT
CON
COS
COUNT
DATA
DCD
DEBUG
DEBUGIN
DEC
DEC1
DEC2
DEC3
DEC4
DEC5
DEC6
DEC7
DEC8
DEC9
DEC10
DEFINE
DIG
DISABLE
DIV32
DO
DTMFOUT
EEPROM
ELSE
ELSEIF
ENABLE

END
ENDASM
ENDIF
ERASECODE EXIT
EXT
FLAGS
FOR
FREQOUT
GOP
GOSUB
GOTO
HEX
HEX1
HEX2
HEX3
HEX4
HEX5
HEX6
HEX7
HEX8
HIGH
HIGHBYTE
HIGHWORD
HPWM
HSERIN
HSERIN2
HSEROUT
HSEROUT2
HYP
I2CREAD
I2CWRITE
IBIN
IBIN1
IBIN2
IBIN3
IBIN4
IBIN5
IBIN6
IBIN7
IBIN8
IBIN9
IBIN10
IBIN11
IBIN12
IBIN13
IBIN14
IBIN15
IBIN16
IBIN17
IBIN18
IBIN19
IBIN20
IBIN21
IBIN22
IBIN23
IBIN24
IBIN25
IBIN26
IBIN27
IBIN28
IBIN29
IBIN30
IBIN31
IBIN32
IDEC
IDEC1
IDEC2
IDEC3
IDEC4
IDEC5
IDEC6
IDEC7
IDEC8
IDEC9
IDEC10
IF
IHEX
IHEX1
IHEX2
IHEX3
IHEX4
IHEX5
IHEX6
IHEX7
IHEX8
INCLUDE
INPUT
INTERRUPT
IS
ISBIN
ISBIN1
ISBIN2
ISBIN3
ISBIN4 ISBIN5
ISBIN6
ISBIN7
ISBIN8
ISBIN9
ISBIN10
ISBIN11
ISBIN12
ISBIN13
ISBIN14
ISBIN15
ISBIN16
ISBIN17
ISBIN18
ISBIN19
ISBIN20
ISBIN21
ISBIN22
ISBIN23
ISBIN24
ISBIN25
ISBIN26
ISBIN27
ISBIN28
ISBIN29
ISBIN30
ISBIN31
ISBIN32
ISDEC
ISDEC1
ISDEC2
ISDEC3
ISDEC4
ISDEC5
ISDEC6
ISDEC7
ISDEC8
ISDEC9
ISDEC10
ISHEX
ISHEX1
ISHEX2
ISHEX3
ISHEX4
ISHEX5
ISHEX6
ISHEX7
ISHEX8

Reserved Words

LCDIN
LCDOUT
LET
LIBRARY
LONG
LOOKDOWN
LOOKDOWN2
LOOKUP
LOOKUP2
LOOP
LOW
LOWBYTE
LOWWORD
MAX
MIN
NAP
NCD
NEXT
NOT
OR
ORNOT
OUTPUT
OWIN
OWOUT
PAUSE
PAUSEUS
PEEK
PEEKCODE
PIN
POKE
POKECODE
POT
PULSIN
PULSOUT
PWM
R0
R1
R2
R3
R4
R5
R6
R7
R8
RANDOM
RB1**
RB2**
RCTIME
READ
READCODE REM
REP
REPEAT
RESUME
RETURN
REV
REVERSE
RM1
RM2
RR1
RR2
RS1***
RS2***
SBIN
SBIN1
SBIN2
SBIN3
SBIN4
SBIN5
SBIN6
SBIN7
SBIN8
SBIN9
SBIN10
SBIN11
SBIN12
SBIN13
SBIN14
SBIN15
SBIN16
SBIN17
SBIN18
SBIN19
SBIN20
SBIN21
SBIN22
SBIN23
SBIN24
SBIN25
SBIN26
SBIN27
SBIN28
SBIN29
SBIN30
SBIN31
SBIN32
SDEC
SDEC1
SDEC2
SDEC3
SDEC4
SDEC5
SDEC6
SDEC7
SDEC8
SDEC9
SDEC10
SELECT
SERIN
SERIN2
SEROUT
SEROUT2
SHEX
SHEX1
SHEX2
SHEX3
SHEX4
SHEX5
SHEX6
SHEX7
SHEX8
SHIFTIN
SHIFTOUT
SIN
SKIP
SLEEP
SOFT_STACK*
SOFT_STACK
_PTR*
SOUND
SQR
STEP
STOP
STR
SWAP
SYMBOL
SYSTEM
THEN
TO
TOGGLE
UNTIL
USBIN

USBINIT
USBOUT
USBSERVICE
USER
VAR
WAIT
WAITSTR
WEND
WHILE
WORD
WORD0
WORD1
WRITE
WRITECODE
XIN
XOR
XORNOT

8.9 ASCII Conversion Chart

Non-printing ASCII codes:

Dec	Hex	Abbr	Description
0	$0	NUL	Null character
1	$1	SOH	Start of Header
2	$2	STX	Start of Text
3	$3	ETX	End of Text
4	$4	EOT	End of Transmission
5	$5	ENQ	Enquiry
6	$6	ACK	Acknowledgment
7	$7	BEL	Bell
8	$8	BS	Backspace
9	$9	HT	Horizontal Tab
10	$0A	LF	Line feed
11	$0B	VT	Vertical Tab
12	$0C	FF	Form feed
13	$0D	CR	Carriage return[g]
14	$0E	SO	Shift Out
15	$0F	SI	Shift In
16	$10	DLE	Data Link Escape
17	$11	DC1	Device Control 1 (oft. XON)
18	$12	DC2	Device Control 2
19	$13	DC3	Device Control 3 (oft. XOFF)
20	$14	DC4	Device Control 4
21	$15	NAK	Negative Acknowledgement
22	$16	SYN	Synchronous idle
23	$17	ETB	End of Transmission Block
24	$18	CAN	Cancel
25	$19	EM	End of Medium
26	$1A	SUB	Substitute
27	$1B	ESC	Escape[i]
28	$1C	FS	File Separator
29	$1D	GS	Group Separator
30	$1E	RS	Record Separator
31	$1F	US	Unit Separator
127	$7F	DEL	Delete

Continued…

Printable ASCII codes:

Dec	Hex	Glyph	Dec	Hex	Glyph	Dec	Hex	Glyph
32	$20	?	64	$40	@	96	$60	`
33	$21	!	65	$41	A	97	$61	a
34	$22	"	66	$42	B	98	$62	b
35	$23	#	67	$43	C	99	$63	c
36	$24	$	68	$44	D	100	$64	d
37	$25	%	69	$45	E	101	$65	e
38	$26	&	70	$46	F	102	$66	f
39	$27	'	71	$47	G	103	$67	g
40	$28	(	72	$48	H	104	$68	h
41	$29	)	73	$49	I	105	$69	i
42	$2A	*	74	$4A	J	106	$6A	j
43	$2B	+	75	$4B	K	107	$6B	k
44	$2C	,	76	$4C	L	108	$6C	l
45	$2D	-	77	$4D	M	109	$6D	m
46	$2E	.	78	$4E	N	110	$6E	n
47	$2F	/	79	$4F	O	111	$6F	o
48	$30	0	80	$50	P	112	$70	p
49	$31	1	81	$51	Q	113	$71	q
50	$32	2	82	$52	R	114	$72	r
51	$33	3	83	$53	S	115	$73	s
52	$34	4	84	$54	T	116	$74	t
53	$35	5	85	$55	U	117	$75	u
54	$36	6	86	$56	V	118	$76	v
55	$37	7	87	$57	W	119	$77	w
56	$38	8	88	$58	X	120	$78	x
57	$39	9	89	$59	Y	121	$79	y
58	$3A	:	90	$5A	Z	122	$7A	z
59	$3B	;	91	$5B	[	123	$7B	{
60	$3C	<	92	$5C	\	124	$7C	|
61	$3D	=	93	$5D	]	125	$7D	}
62	$3E	>	94	$5E	^	126	$7E	~
63	$3F	?	95	$5F	_			

8.10 Glossary

alias	An alternate name assigned to a previously existing entity.
ASCII	Acronym for the American Standard Code for Information Interchange. Pronounced ask-ee, ASCII is a code for representing English characters as numbers.
assembler	A PC software application that converts Assembly Language to machine language. In this manual, "assembler" usually refers to the MPASM software from Microchip.
Assembly Language	The programming language that corresponds most closely with machine language codes. Also referred to as "Assembly". This language is specific to a microcontroller and its instructions are detailed in the microcontroller datasheet.
assembly	1. Assembly Language (when capitalized) 2. The process of converting an Assembly Language program to machine language.
binary	Base-2 number system in which there are only two possible values for each digit: 0 and 1.
BIT	The smallest element of computer storage. It is a single digit in a binary number (0 or 1). BIT is also a variable type in PBP.
bitwise	Dealing with bits and binary states instead of numbers or logic.
Boolean	Of or relating to a combinatorial system devised by George Boole that combines propositions with the logical operators AND and OR and IF THEN and EXCEPT and NOT
BYTE	A numeric entity composed of 8 binary bits. An 8-bit, unsigned variable type in PBP
Code Space	The area of memory in a PIC MCU that holds the program code.
comment	Notes placed in a program for the benefit of humans that view the program. Comments are not passed to the microcontroller.

compiler	A PC software application that converts a high-level language like BASIC to Assembly Language. In this manual, "compiler" usually refers to the PICBASIC PRO Compiler from microEngineering Labs.
compile-time	Acting during compile, and not executed as a command when the program is running on the microcontroller.
constant	A name that stands for a value that is defined in the program. The value is substituted in place of the name when the program is compiled and assembled. It is not stored in RAM and cannot be changed during program execution.
Data Space	An area of memory in a PIC MCU that is intended for powered-down storage or values. Data Space is accessed in PBP using EEPROM, DATA, READ and WRITE commands.
debug	To gather the information necessary to solve problems encountered when a program executes. (Not to be confused with PBP's DEBUG command, which simply outputs serial data. The DEBUG command used to be the primary means of debugging, but this is no longer the case.)
debugger	A tool with which the execution of the program is slowed, controlled, or simulated in order to test the program and gather information.
decimal	1. Base-10 number system that humans use in everyday life. 2. The "dot" in a base-10 number that separates the integer portion from the fractional portion.
device programmer	A tool that "burns" the machine language code into the PIC microcontroller.
directive	An instruction intended for the compiler or assembler. Affects the resulting compiled or assembled code, but does not correspond to a command that is executed when the microcontroller runs.

Glossary

EEPROM	A type of memory that holds data without power and can be erased and written at will. Stands for Electrically Erasable/Programmable Read Only Memory. There is a PBP command called EEPROM, and EEPROM may be used synonymously for "Data Space".
expression	A variable, constant, or combination thereof that represents a stored or calculated value.
hex	see hexadecimal
hexadecimal	Base-16 number system in which each digit may represent a value of 0-15, represented by 0-9 with A-F standing in for values 10-15. Each hexadecimal digit can represent a 4-bit binary value.
IDE	Integrated Development Environment – The software environment that serves as code editor and controls the various programming tools to accomplish software development.
interrupt	The use of a predefined signal or condition that halts normal execution in favor of a special purpose routine that is assigned high priority.
keyword	Any word that has special meaning to PBP.
label	A word that marks a location in a program.
least-significant	In reference to binary numbers, the bit or group of bits that include the "ones" bit. The rightmost bit or group of bits when a binary number is written.
LONG	A numeric entity composed of 32 binary bits. A 32-bit, signed variable type in PBP
Microchip	The company that manufactures PIC microcontrollers. They also provide the MPLAB and MPASM software.
modifier	A keyword that in some manner changes the interpretation or behavior associated with a command or variable that is written either before or after the modifier.
most-significant	in reference to binary numbers, the bit or group of bits that include the bit that signifies the highest power of two. The leftmost bit or group of bits when a binary number is written.
MPASM	The assembler provided free of charge by Microchip.

MPASMWIN	see MPASM
MPASMX	see MPASM
MPLAB	Software application provided free of charge by Microchip for PIC MCU development. MPLAB includes MPASM, which allows Assembly Language development. High-level languages such as PBP can be installed in MPLAB. MPLAB also serves as the control interface for Microchip's device programmers and debuggers.
nibble	A 4-bit binary quantity, most often used to refer to the most-significant or least-significant 4-bits of an 8-bit BYTE. A single hexadecimal digit represents one nibble of binary. Not a variable type in PBP.
overflow	The event taking place when a value in a variable is increased beyond the capacity of the variable type, resulting in an incorrect result.
PBPL	PBP in LONG mode. Only available for devices with prefix PIC18. When used, LONG variables are available and some commands and operators may work differently than in PBPW.
PBPW	PBP in WORD mode. When used, LONG variables are not available and some commands and operators may work differently than in PBPL.
PBPX	The name of the executable file that invokes PBP.
PM	The assembler created by microEngineering Labs and included with PBP. This assembler should be considered obsolete and MPASM should be used instead.
programmer	YOU. The person who writes the program.
RAM	The area of memory in a PIC MCU that is used to hold variables. Accessing RAM is faster than accessing other memory areas, and values in RAM are lost when power is removed.
register	An 8-bit memory location that performs a special function in a microcontroller. Registers (Microchip calls them SFRs) are built into the microcontrollers and their functions are detailed in the datasheet published for the specific device.

Glossary

run-time	Executed by the microcontroller when the program runs.
SFR	Special Function Register – see register
signed	Capable of representing or processing negative numbers as well as positive.
twos-complement	A system that allows negative numbers to be represented in binary.
typecasting	Specifying the variable type to the compiler.
underflow	The event taking when a value in an unsigned variable is decreased below zero (negative number), or when a signed variable is decreased below its limit value in the negative, resulting in an incorrect result.
unsigned	Only capable of representing or processing positive numbers. Negative numbers are invalid in unsigned variables or processes.
variable	A name that stands for a value that is stored in RAM and can be read and changed during program execution
WORD	A numeric entity composed of 16 binary bits. A 16-bit, unsigned variable type in PBP

8.11 Index

Index

C

D

E

Index

F

G

H

I

J

L

M

N

O

Index

T

U

V

W

Index

X