Lesson 4
Fun with W and F

Overview

Introduction	This lesson introduces the first few PIC instructions.
In this section	Following is a list of topics in this section:

Writing Programs

Introduction

As we said way back in Lesson 1, we use an assembler to help translate mnemonics for the instructions and memory locations into the ones and zeroes that the processor needs to do its thing.

In this lesson, we will do a number of experiments using some of the more basic instructions in the PIC. These instructions manipulate the working register (W) and the file register (F).

Setting up the first project

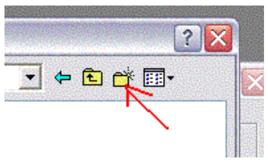
Before we can start to write, we need to have a project for the IDE.

Begin by starting the MPLab.

Select Project➔New… from the menu and a dialog box with 2 edit controls will appear. In the upper box, type "Lesson 4a" (without the quotes).

Click on the "Browse…" button on the lower right of the dialog.

Navigate to the "root of all projects" folder that you created in Lesson 3 and click on the "Create Folder" icon (a picture of a folder with a star in the upper right).



A new folder will appear named "New Folder" and the name will be highlighted, ready for editing. Type "Lesson 4" and then double-click on the folder icon.

Check that 'Lesson 4' appears in the top of the dialog then click on the 'Select' button.

Click on OK.

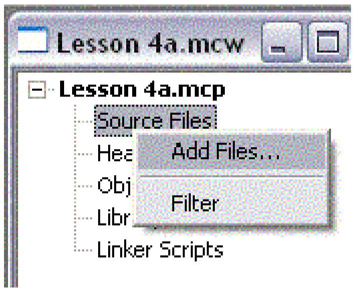
Writing Programs (continued)

Adding files to the project

OK, now we have a project, but it has nothing in it. We need to have at least one assembler source file to type in.

Select 'File➔New' from the menu. A new window will appear. Select File➔Save and type 'Lesson 4a.asm'. Click Save.

In the project window is a sub-window that lists the different types of files. Right-click 'Source Files' and select 'Add Files…':



A file open dialog will appear. Double-click Lesson 4a.asm. The name will be added to the Lesson 4a.mcw window and the title of the blank window will change from Untitled to the name of your file.

Also notice the asterisk in the title bar of the Lesson 4a.mcw window. This means that the project hasn't been saved. Select 'Project➔Save Project' from the main menu.

We now have an empty project, ready for us to go to work.

Writing a Program

Introduction

The project consists of a number of files. If you look in the Lesson 4 folder with Windows Explorer, you will see 3 files at this point. The Lesson 4a.asm file is the one we are currently interested in. The Lesson 4a.mcp file contains the actual project information, that is, what files make up this project. The Lesson 4a.mcw file is the 'Workspace' file. This file remembers what windows are open in our workspace. In the future, if you double-click on the mcw file, the MPLab will open with all the windows where you last left them.

Basic stuff

There are a few things you need in every program. Might as well get them in the file now.

When entering data into the MPLab assembler, there are 3 columns of interest. The columns are separated by whitespace (tabs and spaces). How much whitespace is entirely up to us. We can use a single space, or 10 tabs, really doesn't matter to the assembler. Personally, I like to use 2 tabs. This makes the columns line up without thinking much about it, and it allows a reasonable length for identifiers.

The first column is anything that starts in column 1. The assembler assumes that this is a ***label*** that we will reference somewhere in our program.

The second column contains the ***opcode***. This is the instruction that tells the PIC what we want it to do.

The third column is the ***operand***. This is the thing we want the PIC to do something to.

Besides instructions, there can be assembler directives. These don't end up as instructions in the PIC, instead, they tell the assembler things we want it to know.

We need 3 directives in any program:

```
    processor   16f84a
    include    <p16f83a.inc>
    end
```

It's also a good idea to include the configuration word. We will talk about this one in more detail, but for now, type in the following:

```
<tab><tab>processor<tab>16f84a<enter>
<tab><tab>include<tab><tab><p16f84a.inc><enter>
<tab><tab>__config<tab>_HS_OSC & _WDT_OFF & _PWRTE_ON<enter>
<tab><tab>end<enter>
```

The `processor` directive tells the assembler which type of PIC we are using. The `include` directive tells the assembler to include a file which contains definitions for a number of symbols relevant to that processor. The `__config` tells the processor that we will be using a crystal (`_HS_OSC`), we want the watchdog timer turned off (`_WDT_OFF`) and we want the power-up timer enabled (`_PWRTE_ON`).

Select 'File➔Save' to save your work.

Assembling the program

OK, so far, the program doesn't do anything … there are no instructions. But we can check for typos by assembling the program. From the main menu, select 'Project➔Build All'.

We will get a new window with a bunch of junk, but the last line should say:

BUILD SUCCEEDED

Adding some instructions

Introduction

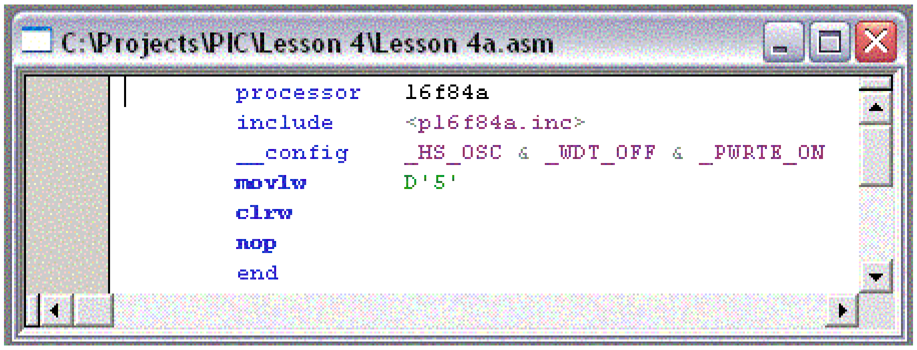
Now that we have the basic skeleton for all programs, we can go ahead and work over the actual instructions for our program. In this lesson, we aren't going to do a lot useful. Out point here is to get to understand how some of the basic instructions work.

At this point, you may find it useful to find the file for the quick reference card, and print out the page titled '14-Bit Core Instruction Set'. Throughout this course we will be referring to this page. There are other parts of the card that are interesting, but this particular page is the one that will get dog-eared.

Our first instructions

We are going to begin with the simplest of instructions. When we enter instructions, we place them after the `__config` directive and before the `end` directive. For our experiments right now, we need a `nop` instruction right before end. This is the simplest of instructions, it does nothing!

Let's add 2 more instructions before our `nop`, a `movlw D'5'` and a `CLRW` instruction. These instructions move the number 5 into the W register, then clear it. Our program should now look like this:


C:\Projects\PIC\Lesson 4\Lesson 4a.asm

```
        processor   16f84a
        include     <p16f84a.inc>
        __config    _HS_OSC & _WDT_OFF & _PWRTE_ON
        movlw       D'5'
        clrw
        nop
        end
```

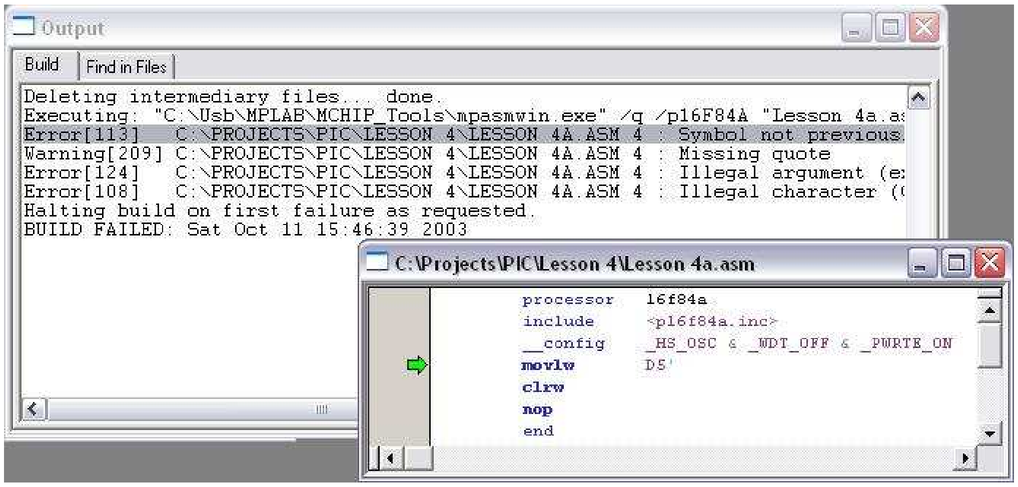
Assembling the program

As before, select 'Project➔Build All'. With a little luck, you should get the friendly 'BUILD SUCCEEDED'. You can also select the Build All toolbar button:

or simply hold down the Ctrl key and press F10.

Suppose there was an error

If we had a typo, this can cause the assembler to get confused and give us a lot of error messages. Don't be concerned if you see a long list of messages. If we left off one of the quotes around the 5 we might see something like this:


Output

```
Deleting intermediary files... done.
Executing: "C:\Usb\MPLAB\MCHIP_Tools\mpasmwin.exe" /q /p16F84A "Lesson 4a.a
Error[113]   C:\PROJECTS\PIC\LESSON 4\LESSON 4A.ASM 4 : Symbol not previous
Warning[209] C:\PROJECTS\PIC\LESSON 4\LESSON 4A.ASM 4 : Missing quote
Error[124]   C:\PROJECTS\PIC\LESSON 4\LESSON 4A.ASM 4 : Illegal argument (e
Error[108]   C:\PROJECTS\PIC\LESSON 4\LESSON 4A.ASM 4 : Illegal character (
Halting build on first failure as requested.
BUILD FAILED: Sat Oct 11 15:46:39 2003
```

C:\Projects\PIC\Lesson 4\Lesson 4a.asm

```
        processor   16f84a
        include     <p16f84a.inc>
        __config    _HS_OSC & _WDT_OFF & _PWRTE_ON
        movlw       D5'
        clrw
        nop
        end
```

Double-clicking the error message will cause MPLab to put a green arrow left of the offending line. It's always good to look at the first error first. The remaining messages could be a result of the first. In this case, they are all on the same line, but sometimes an error on one line causes another line to be in error, so correct the first error first.

Let's see what happens

Once we get the program to assemble correctly, we want to see whether it does what we expect.

From the main menu, select 'Debugger➔Select Tool➔MPLAB SIM'. Now select 'Debugger➔Reset➔Processor Reset F6'

Notice at the bottom of the window is says 'pc:0' and 'W:0'. This says that the program counter is pointing at the first address in program memory, zero, and that the working register, W, contains a zero.

Select 'Debugger➔Step Into F7'. Several things happen. First, the green arrow moves down one line in our program. At the bottom of the window, it now says, pc:0x1 and W:0x5. The 0x business is a way of warning us that the numbers we are looking at are in hexadecimal. The program counter has incremented by one, as we would expect, and the W register contains a 5, which is what we told it to do with the `movlw D'5'` instruction.

Now press F7 (or select 'Debugger➔Step Into F7' again). The green arrow moves yet again, the bottom of the screen changes telling us that we have incremented the program counter one more time, and have cleared the W register, just like we told it to do.

Some more playing with the simulator

Now add a few more lines so our program looks like this:

```
             processor     16f84a
             include       <p16f84a.inc>
             __config      _HS_OSC & _WDT_OFF & _PWRTE_ON
Spot1        equ           H'30'
             movlw         D'5'
             movwf         Spot1
             clrw
             clrf          Spot1
             nop
             end
```

Assemble the program, and select View➔File Registers. Arrange the windows so you can see both the program source and the file register window.

Select 'Debugger➔Clear Memory➔File Registers' and reset the processor (F6). Now as we press F7, there are several things to watch. On the first F7, besides the pc and w changing at the bottom of the screen as before, notice that location 0x02 in the file register also changed to a 0x01. This is because the low 8 bits of the program counter are mapped into location 0x02 of the file register.

The next time we press F7, besides 0x02 of the file register, 0x30 also changes. This is because we used that location to store our value `Spot1`. If we don't want to remember where we put things when we are debugging, we can click on the 'Symbolic' tab of the file register display. When we scroll down to 0x30 we can see the name, Spot1, on the right.

Press F7 again and our W register again goes to zero, and yet again and that zero gets stored in Spot1.

Let's do some

OK, so we've loaded a number into both the working register and the file registers.

Arithmetic

Now let’s do a little something with those values.

Change our program yet again to look like this:

```
              processor     16f84a
              include              <p16f84a.inc>
              __config      _HS_OSC & _WDT_OFF & _PWRTE_ON
Spot1         equu          H'30'
Spot2         equ           H'31'
              movlw         D'5'
              movwf         Spot1
              movlw         D'2'
              addwf         Spot1,W
              movwf         Spot2
              movlw         D'3'
              subwf         Spot2,W
              movwf         Spot1
              clrw
              clrf          Spot1
              nop
              end
```

Now as we step through the program, we will see us storing the 5 in Spot1 like before, but then we will load a 2 into the W register, and add it to Spot1, then store the result in Spot2. Next, we will move a 3 into the W register, subtract that from Spot2, and store the result in Spot1.

Notice the ‘`,W`’ on the add and subtract instructions. These instructions can store the result either into the W register, or the original memory location. If we had wanted the result to go back into the file register, we would have used ‘,F’ instead of ‘,W’.

Helping to understand our program

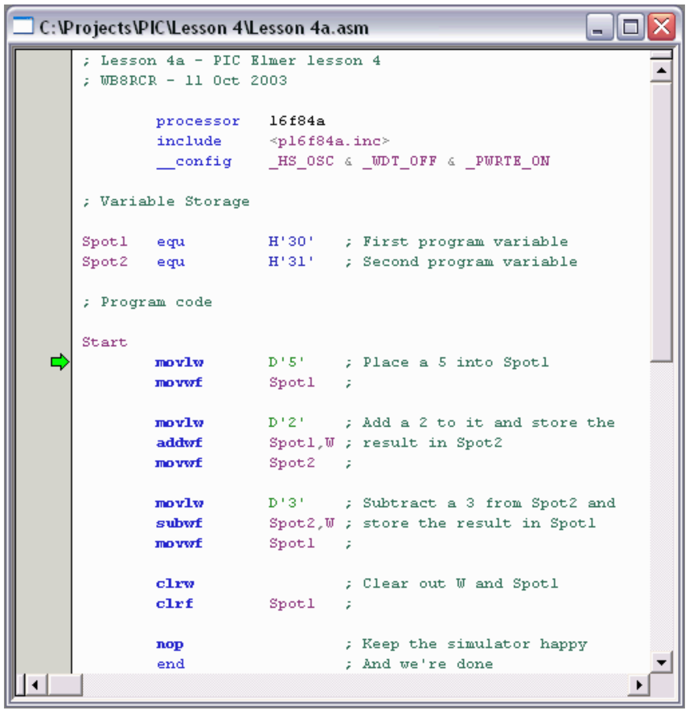
Introduction

So far, we've worried only about the specific instructions that make up the program. As we develop programs, they can get to be a little long. We need some aid in understanding the program, especially when we come back to it after being away a few days, or weeks.

Comments

The assembler allows us to put comments in our code. Whenever the assembler encounters a semicolon, everything after that is ignored. The assembler also allows us to have lines that are entirely blank, which can help us with readability.

The following assembly is exactly equivalent to what we had before:



```
; Lesson 4a - PIC Elmer lesson 4
; WB8RCR - 11 Oct 2003

        processor   16f84a
        include     <p16f84a.inc>
        __config    _HS_OSC & _WDT_OFF & _PWRTE_ON

; Variable Storage

Spot1   equu        H'30'   ; First program variable
Spot2   equ         H'31'   ; Second program variable

; Program code

Start
        movlw       D'5'    ; Place a 5 into Spot1
        movwf       Spot1   ;

        movlw       D'2'    ; Add a 2 to it and store the
        addwf       Spot1,W ; result in Spot2
        movwf       Spot2   ;

        movlw       D'3'    ; Subtract a 3 from Spot2 and
        subwf       Spot2,W ; store the result in Spot1
        movwf       Spot1   ;

        clrw                ; Clear out W and Spot1
        clrf        Spot1   ;

        nop                 ; Keep the simulator happy
        end                 ; And we're done
```

EEPROM

Introduction

The final type of memory in the PIC is Electrically Erasable PROM. This is data memory that the PIC itself can alter, and which retains its value even when the power is removed.

EEPROM takes multiple steps to access, so we won't deal with it until later in the course. It is useful, though, to remember things like code speed or the last frequency set.

OK, what does this mean?

Introduction

So far, we've talked about a lot of dull stuff that may not mean very much. Let's take a minute to pull some of this together.

Power Up

When power is first applied to a computer, any computer, there is a lot of unknown stuff. In the case of the PIC, the contents of the data memory and registers are random. Fortunately, the program memory remembers what we put in it.

One thing that is constant among all computers, though, on power up, the state of the program counter is known. In the case of the PIC, the program counter contains a zero on power up.

There are lots of things that have to happen on power up with any computer. Fortunately, on the PIC, most of these are handled very smoothly and we can ignore them for most purposes.

Clock Ticks

The PIC has a clock, whose frequency can be set with a crystal, a resonator, or an RC circuit. Some PICs even have a clock on board, so you don't need to add any frequency controlling circuitry.

As the clock relentlessly ticks along, the PIC uses it to do its thing. On the PIC, every instruction takes 4 cycles of the clock. That means that with a 20 MHz crystal, the PIC is going to execute 5 million instructions a second.

Five million times a second the PIC will:

- Examine the program counter
- Fetch the contents of program memory pointed to by the program counter
- Interpret the instruction
- Do what it says
- Increment the program counter

That's basically all any computer does. It just relentlessly picks one instruction after another to execute. Instructions may tell it to load the working register with something, do some math, or store the result somewhere. Those I/O pins allow that "somewhere" to affect the outside world, that is, the circuit we want it to control.

Assembler

Introduction

The PIC, or any computer for that matter, simply stores combinations of bits. It gets tough looking at long strings of ones and zeroes, so we need some sort of help. An assembler is a program that takes representations of these numbers that are more readable to a human, and translates them into a form that the computer can understand.

You may also have heard of a compiler. The main difference between an assembler and a compiler is that everything you do in the assembler translates one to one into something in the computer. One thing you do in a compiler may translate into hundreds of things in the computer.

The advantage of a compiler is that, if you are doing something the compiler knows how to do, it is a lot simpler than an assembler.

The advantage of an assembler is that you control precisely what the computer will do. When we are using the computer for an embedded controller, we are often very concerned about timing, and this is a huge advantage.

Number Representation

As we said, to the computer, any computer, the world is a series of ones and zeroes. To us humans, though, it's a real pain looking at these strings. In the assembler, we can, if we choose, represent a ten as B'00001010', but that's kind of tough to look at. In the assembler, we can represent a ten as a decimal number by putting D in front of it. So the value D'10' means exactly the same thing as B'00001010'.

More often, we use hexadecimal representation for numbers, because decimal numbers don't map nicely into the bits. Hexadecimal numbers are like decimal numbers, except there are 16 values for each digit instead of 10. They run from 0 to F. Thus, 6 decimal would be represented as 006h in hexadecimal. But 10 decimal would be represented as 00ah in hex.

Continued on next page

Assembler, Continued

Machine Instructions

Within the PIC, or any computer for that matter, any number that is pointed to by the program counter is interpreted as an instruction. Generally, these instructions include an operator and an operand. Also, in general, different operators use different numbers of bits, thus leaving a different number of bits for the operand.

We could manually translate the operation we want into a number and store it in the machine's program memory, but this is a big pain. The assembler deals with all this stuff for us.

Let's assume that we want to place the number 4 into the working register. We could refer to the programming card and recognize that we need to put:

```
        11000000000100
```

Into the program memory to cause this to happen. It's a lot easier, though, to say:

```
        MOVLW 004h
```

The `MOVLW` tells the assembler that we want to move a literal constant into the W register. The `004h` tells it that the literal constant we want to move is a 4. The assembler figures out that the left 6 bits being `110000` tells the chip to load the right 8 bits into the W register.

Symbols

OK, so the assembler helps us with the instructions, and it allows us to represent numbers in a variety of ways. Perhaps the most important feature, though, is that it allows us to associate symbols with values.

Suppose, for example, that we were doing a keyer. We decide to store the current code speed in location 03Bh in the file register. Now, if we wanted to load the current code speed into the working register, we could tell the assembler:

```
        MOVF 03Bh,0
```

The zero tells the assembler that the target of the move is the W register. However, we could define the symbol CodeSpd to mean 03Bh. Now we can write:

```
        MOVF CodeSpd,W
```

We not only don't need to be constantly remembering where we put things, but later on, when we come back to look at this program, it will make a lot more sense.

CLRW

CLRF

MOVF

MOVWF

ADDWF

SUBWF

DECF

INCF

ANDWF

IORWF

XORWF

COMF

BSF

BCF