United States Naval Academy

Electrical Engineering Department

EE361 Test 1 Solution

18 September 2008

1. Do a page check now. You should have one title page and seven pages of problems, totalling 8 pages in all. *Please do not remove staples from the examination booklet.*
2. *Do not discuss the test with anyone* until it has been graded and returned to you in class.
3. Show all work to receive maximum partial credit.
4. Work neatly and strive for clarity. Unclear answers earn little credit (if any).
5. You may use any calculator you have brought with you. You may not borrow a calculator from anyone during the exam. Although you may also use the computer at your seat and make use of the MPLAB program if it seems helpful, you may *not* make use of e-mail, chat, instant messenger, or any other program or device allowing one-way or two-way communications with other people, whether classmates or not.
6. If you make any assumptions necessary to proceeding, state them clearly.
7. Each problem is worth the following points:

Problem	Points	Score	Problem	Points	Score
1	4		4	16	
2	8		5	20	
3	8				
			Total:	**56**	

8. You have 1 hour 50 minutes to complete the test.
9. Upon the command of your instructor, you may commence work.
10. If you finish early, you may leave early. See point 2 above.

    Good Luck!

Name: _____

Section: _____

Date: 18 September 2008

1. (4 pts) Although the PIC16F884 has the instruction `comf` to complement the contents of a designated file register, there is no corresponding `comw` instruction to complement all the bits of register W. Write another instruction (not a macro), including any necessary operands, that accomplishes this.

   Solution

   `xorlw B'11111111'`

2. (8 pts) Consider the program fragment in Listing 1. Assume that all symbols defined in the file `p16f884.inc` file are already available and that the bank-selection bits have already been given suitable values. There is one very serious programming error in this program, as well as one syntax error. Explain what they are.

Listing 1: Listing for Problem 2

```
1  x        equ      0x20
2           ...
3  main
4          incfsz  x,F
5          goto    main
6  Zero
7          goto    ToggleBit
8           ...
9  ToggleBit
10         movlw   B'00010000'
11         xorwf   PORTA
12         return
```

Solution

Inevitably the **incfsz** instruction in line 4 will eventually cause the **goto** instruction in line 7 to execute. Soon, the **return** instruction in line 12 will execute, too. This is a serious error because there was no matching **call** instruction: the stack will 'underflow', resulting in unpredictable program behavior.

There also is a syntax error in line 9. The **xorwf** instruction requires a second parameter, either W or F, to direct the output. The assembler assumes that an F was intended, so this is not necessarily a significant error.

3. (8 pts) Consider a PIC16F884 instruction consisting of the hexadecimal code 344E.

   (a) (4 pts) What is the instruction and exactly what does it do? Answer thoroughly.

   SOLUTION

   This is a `retlw` instruction that places the hexadecimal value 4E in the W register and modifies the contents of the program counter (PC) to contain the address stored in the top of the stack.

   (b) (4 pts) How long does the instruction take to execute on a machine if the oscillator frequency is $f_{\text{OSC}} = 500\,\text{kHz}$?

   SOLUTION

   Paragraph 15.0 of the User's Guide states that one instruction cycle consists of four oscillator periods. According to Table 15-2 on page 232 of the Guide, the `retlw` instruction needs two instruction cycles to execute, which requires time

$$\begin{aligned} T_{\text{INST}} &= 2 \times 4 \times T_{\text{OSC}} \\ &= \frac{8}{f_{\text{OSC}}} \\ &= \frac{8}{500\,\text{kHz}} \\ &= 16\ \mu\text{s}. \end{aligned}$$

4. (16 pts) Consider the binary string 1101 0101 0111 0000.

   (a) (4 pts) What is its meaning in decimal when it is interpreted as an unsigned binary number?

   SOLUTION

$$\begin{aligned} 1101\,0101\,0111\,0000_2 &= \mathrm{D570}_{16} \\ &= 13 \times 16^3 + 5 \times 16^2 + 7 \times 16^1 \\ &= 54\,640_{10}. \end{aligned}$$

   (b) (4 pts) What is its meaning in decimal when it is interpreted as being a binary number in two's-complement format?

   SOLUTION

$$\begin{aligned} 1101\,0101\,0111\,0000_2 &= -0010\,1010\,1001\,0000 \\ &= -\mathrm{2A90}_{16} \\ &= -(2 \times 16^3 + 10 \times 16^2 + 9 \times 16^1) \\ &= -10\,896_{10}. \end{aligned}$$

(c) (4 pts) What is its meaning in decimal when it is interpreted as a signed binary number (not a two's-complement binary number)?

Solution

$$\begin{aligned}
1101\,0101\,0111\,0000_2 &= -101\,0101\,0111\,0000_2 \\
-5570_{16} & \\
&= -(5 \times 16^1 + 5 \times 16^0 + 7 \times 16^{-1}) \\
&= -21\,872_{10}.
\end{aligned}$$

(d) (4 pts) What is its meaning in decimal when it is interpreted as an unsigned binary number with 6 fractional bits, that is, 11 0101 0101.1100 00?

Solution

$$\begin{aligned}
11\,0101\,0101.1100\,00_2 &= 355.\mathrm{C}0_{16} \\
&= 3 \times 16^2 + 5 \times 16^1 + 5 \times 16^0 + 12 \times 16^{-1} \\
&= 853.75_{10}.
\end{aligned}$$

Listing 2: Listing for Problem 20

```
1  xinit   equ     D'365'
2  x       equ     D'320'  ; A memory location for x
3  yinit   equ     D'147'
4  y       equ     D'487'  ; A memory location for y
5  zz      equ     D'488'  ; A memory location for z
6  STATUS_Init     equ     B'01000000'
7  STATUS_Mask     equ     B'11100000'
8          movlw   ~STATUS_Mask
9          andwf   STATUS,F
10         movlw   STATUS_Init
11         iorwf   STATUS,F
12         movlw   x
13         movwf   FSR
14         movlw   xinit
15         movwf   INDF
16         incf    FSR,F
17         addlw   yinit
18         movwf   zz
```

5. (20 pts) Consider the PIC16F884 program fragment in Listing 2, which contains errors and also lacks enough comments to make it easy to understand. Assume that all symbols defined in the file `p16f884.inc` file are already available.

   (a) (8 pts) Use hexadecimal to express

      i. (4 pts) the address to which the contents of the W register are actually written by the instruction in line 15 and

      Solution

      Lines 8 and 9 zero the IRP and the RP1 and RP0 bits of the STATUS register. Lines 10 and 11 set IRP to 0 and RP1 and RP0 to 1 and 0, respectively. This means that indirect addressing will be in Banks 0 and 1 and direct addressing will be in Bank 2. Line 12 moves the least significant eight bits of $320_{10} = 140_{16}$, that is, 40_{16}, into the W register and from there to the FSR register. Line 14 moves the least significant eight bits of $365_{10} = 16D_{16}$, that is $6D_{16}$, into the W register. A reference to INDF means that indirect addressing is being used. The actual address calculated in line 15 is found by combining `STATUS`$\langle$`IRP`$\rangle$ with the contents of `FSR`. Now `STATUS`$\langle$`IRP`$\rangle = 0$. `FSR` contains 40_{16}, so the complete target address is $0\,0100\,0000 = 040_{16}$.

ii. (4 pts) the address to which the result in line 18 is actually written.

SOLUTION

The destination address is calculated using direct addressing. The two most significant bits are `STATUS`⟨`RP1:RP0`⟩ $= 10_2$ and the seven least significant bits are the seven least significant bits of $488_{10} = 1E8_{16}$, or 68_{16}. The resultant address is $1\,0110\,1000_2 = 168_{16}$.

(b) (4 pts) What are the values of the Z, DC, and C bits after line 17 has completed executing? Explain.

SOLUTION

Line 14 leaves the eight least significant bits of $365_{10} = 16D_{16}$ in the `W` register. This is the string $6D_{16}$. Line 17 adds to this the eight least significant bits of $147_{10} = 93_{16}$, giving the sum 100_{16}. The most significant bit is the carry `C`= 1. The `DC` bit also is 1 because of the carry from bit position 3 into bit position 4. The `Z` bit is 1 because the eight least significant bits of the sum all are 0. `Z,DC,C`= 111.

(c) (8 pts) In a processor with an oscillator frequency $f_{\text{OSC}} = 10\,\text{MHz}$, how long does it take to execute this program fragment? Give your answer in microseconds with precision to the nearest 0.010 µs.

SOLUTION

The `equ` directives do not correspond to microprocessor instructions, so they do not consume any time at all on the microprocessor. The rest of the instructions take 400 ns apiece because the instruction period is

$$\begin{aligned} T_{\text{INST}} &= 4T_{\text{OSC}} \\ &= \frac{4}{f_{\text{OSC}}} \\ &= \frac{4}{10\,\text{MHz}} \\ &= 400\,\text{ns}. \end{aligned}$$

Because there are 11 instructions, the program will take 4.40 µs to execute.

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