16.317: Microprocessor-Based Systems I

Summer 2012

Exam 3
August 13, 2012

Name: _____ ID #: _____ Section: _____

For this exam, you may use a calculator and one 8.5" x 11" double-sided page of notes. All other electronic devices (e.g., cellular phones, laptops, PDAs) are prohibited. If you have a cellular phone, please turn it off prior to the start of the exam to avoid distracting other students.

The exam contains 3 questions for a total of 100 points. Please answer the questions in the spaces provided. If you need additional space, use the back of the page on which the question is written and clearly indicate that you have done so.

Please note that Question 3 has three parts, but you are only required to complete two of the three parts. You may complete all three parts for up to 10 points of extra credit. If you do so, **please clearly indicate which part is the extra one—I will assume it is part (c) if you mark none of them.**

The last three pages of the exam (beginning with page 8) contain reference material for the exam: the PIC 16F684 instruction set, memory map, and block diagram. You may detach these pages and do not have to submit them when you turn in your exam.

You will have three hours to complete this exam.

Q1: Multiple choice	/ 20
Q2: Reading PIC assembly language	/ 40
Q3: Writing PIC assembly language	/ 40
TOTAL SCORE	/ 100
EXTRA CREDIT	/ 10

1. (20 points, 5 points per part) ***Multiple choice***

For each of the multiple choice questions below, clearly indicate your response by circling or underlining the single choice you think best answers the question.

a. Which of the following statements about microcontrollers are true?

A. A microcontroller typically contains a processor, on-chip storage, and additional peripheral devices.

B. Microcontrollers are ideal for workloads that require significant processing power.

C. Microcontrollers are always used by very small people to control very small remote-controlled cars.

D. Microcontrollers are typically low-power devices, allowing them to be widely used in battery-powered embedded systems.

i. A and C

ii. B and C

iii. A and D

iv. B and D

b. Which of the following statements about the PIC16F684 microcontroller are true?

A. The PIC16F684 system stack is used to store function return addresses, function arguments, and registers that need to be saved before being overwritten by the function

B. The PIC16F684 uses a Harvard memory architecture, which merges program and data memory into a single module.

C. The RP0 bit in the PIC16F684 STATUS register determines which data memory bank is currently being accessed.

D. The only true data register in the PIC16F684 is the working register (W). All other "registers" are technically stored in data memory, which is divided into special function registers (SFRs) and general purpose registers (GPRs).

i. A and B

ii. C and D

iii. B and D

iv. A and C

1 (cont.)

c. You are given the PIC function shown below:

```
F:      movf   PORTA, W
        andlw  0x03
        addwf  PCL, F
        retlw  0xAA
        retlw  0xBB
        retlw  0xCC
        retlw  0xDD
```

What is the return value of this function if the current value of PORTA is 0x3F?

i. 0xAA

ii. 0xBB

iii. 0xCC

iv. 0xDD

d. Choose your favorite statement(s) from the list below. Circle all that apply (but don't waste too much time!):

i. "I'm so glad I spent the last six weeks taking this course—that's how I've always wanted to spend July and August!"

(You may be more likely to agree with this statement if you imagine saying it with just a hint of sarcasm.)

ii. "The exam ends here, right? Everything after this is just reference material … isn't it? Please?"

iii. "I would have been perfectly happy not doing Lab 5. Really. Sure you don't want to reconsider that 'extra credit' idea?"

iv. "I'd actually like to take this opportunity to leave some constructive feedback in the space below" *(Note: don't do this unless you have time left at the end of the exam.)*

2. (40 points) ***Reading PIC assembly language***

Show the result of each PIC 16F684 instruction in the sequences below.

a. (22 points)

```
    cblock 0x20
        x, y
    endc
    movlw   0x34

    addlw   0x33

    movwf   x

    comf    x, F

    subwf   x, F

    btfsc   x, 7

    goto    L1

    swapf   x, W

    goto    L2

L1: addlw   0x11

L2: movwf   y
```

2 (cont.)

b. (18 points)

```
    cblock 0x20
        q
    endc
    movlw   0xF1

    movwf   q

    andlw   0xC3

    iorlw   0x18

    xorwf   q, F

    bcf     STATUS, C

    rrf     q, W

    addlw   0xFF
```

3. (40 points, 20 per part) ***Writing PIC assembly code***

For each of the following 80386 instructions, write a sequence of PIC 16F684 instructions that performs an equivalent operation. The operation is described in italics. **CHOOSE ANY TWO OF THE THREE PARTS** and fill in the space provided with appropriate code. **You may complete all three parts for up to 10 points of extra credit, but must clearly indicate which part is the extra one—I will assume it is part (c) if you mark none of them.**

Assume that variables with the same names are defined for all 8-bit 80386 registers (for example, "AL" and "BL"). If an operation uses a 16-bit register (e.g., AX), you can address each byte within that register (e.g. AH and AL). Also assume "TEMP" has been defined for cases where you may need an extra variable.

Finally, note that shift or rotate operations should not be done by simply writing copies of the PIC rotate instructions. Use the shift amount provided as a literal value that will help determine the number of times you shift or rotate.

a. RCR AX, 6 *(Rotate 16-bit value AX right, through the carry, by 6 bits)*

3 (cont.)

b. SETC AL *(AL = 0xFF if carry bit is 1; AL = 0x00 otherwise)*

c. NEG AX *(Perform two's complement negation of 16-bit value AX)*

The following pages contain references for use during the exam: tables containing the PIC 16F684 instruction set and memory map, as well as a block diagram of the microcontroller. You may detach these sheets from the exam and do not need to submit them when you finish.

Remember that, in the table below:

- f = a register file address
- W = the working register
- d = destination select: “F” for a file register, “W” for the working register
- b = bit position within an 8-bit file register
- k = literal field, constant data or label
- PC = the program counter
- C = the carry bit in the status register
- Z = the zero bit in the status register

TABLE 13-2: PIC16F684 INSTRUCTION SET

Mnemonic, Operands		Description	Cycles	14-Bit Opcode MSb			LSb	Status Affected	Notes
BYTE-ORIENTED FILE REGISTER OPERATIONS									
ADDWF	f, d	Add W and f	1	00	0111	dfff	ffff	C, DC, Z	1, 2
ANDWF	f, d	AND W with f	1	00	0101	dfff	ffff	Z	1, 2
CLRF	f	Clear f	1	00	0001	lfff	ffff	Z	2
CLRW	–	Clear W	1	00	0001	0xxx	xxxx	Z	
COMF	f, d	Complement f	1	00	1001	dfff	ffff	Z	1, 2
DECF	f, d	Decrement f	1	00	0011	dfff	ffff	Z	1, 2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00	1011	dfff	ffff		1, 2, 3
INCF	f, d	Increment f	1	00	1010	dfff	ffff	Z	1, 2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00	1111	dfff	ffff		1, 2, 3
IORWF	f, d	Inclusive OR W with f	1	00	0100	dfff	ffff	Z	1, 2
MOVF	f, d	Move f	1	00	1000	dfff	ffff	Z	1, 2
MOVWF	f	Move W to f	1	00	0000	lfff	ffff		
NOP	–	No Operation	1	00	0000	0xx0	0000		
RLF	f, d	Rotate Left f through Carry	1	00	1101	dfff	ffff	C	1, 2
RRF	f, d	Rotate Right f through Carry	1	00	1100	dfff	ffff	C	1, 2
SUBWF	f, d	Subtract W from f	1	00	0010	dfff	ffff	C, DC, Z	1, 2
SWAPF	f, d	Swap nibbles in f	1	00	1110	dfff	ffff		1, 2
XORWF	f, d	Exclusive OR W with f	1	00	0110	dfff	ffff	Z	1, 2
BIT-ORIENTED FILE REGISTER OPERATIONS									
BCF	f, b	Bit Clear f	1	01	00bb	bfff	ffff		1, 2
BSF	f, b	Bit Set f	1	01	01bb	bfff	ffff		1, 2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01	10bb	bfff	ffff		3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01	11bb	bfff	ffff		3
LITERAL AND CONTROL OPERATIONS									
ADDLW	k	Add literal and W	1	11	111x	kkkk	kkkk	C, DC, Z	
ANDLW	k	AND literal with W	1	11	1001	kkkk	kkkk	Z	
CALL	k	Call Subroutine	2	10	0kkk	kkkk	kkkk		
CLRWDT	–	Clear Watchdog Timer	1	00	0000	0110	0100	$\overline{TO}$, $\overline{PD}$	
GOTO	k	Go to address	2	10	1kkk	kkkk	kkkk		
IORLW	k	Inclusive OR literal with W	1	11	1000	kkkk	kkkk	Z	
MOVLW	k	Move literal to W	1	11	00xx	kkkk	kkkk		
RETFIE	–	Return from interrupt	2	00	0000	0000	1001		
RETLW	k	Return with literal in W	2	11	01xx	kkkk	kkkk		
RETURN	–	Return from Subroutine	2	00	0000	0000	1000		
SLEEP	–	Go into Standby mode	1	00	0000	0110	0011	$\overline{TO}$, $\overline{PD}$	
SUBLW	k	Subtract W from literal	1	11	110x	kkkk	kkkk	C, DC, Z	
XORLW	k	Exclusive OR literal with W	1	11	1010	kkkk	kkkk	Z	

FIGURE 2-2: DATA MEMORY MAP OF THE PIC16F684

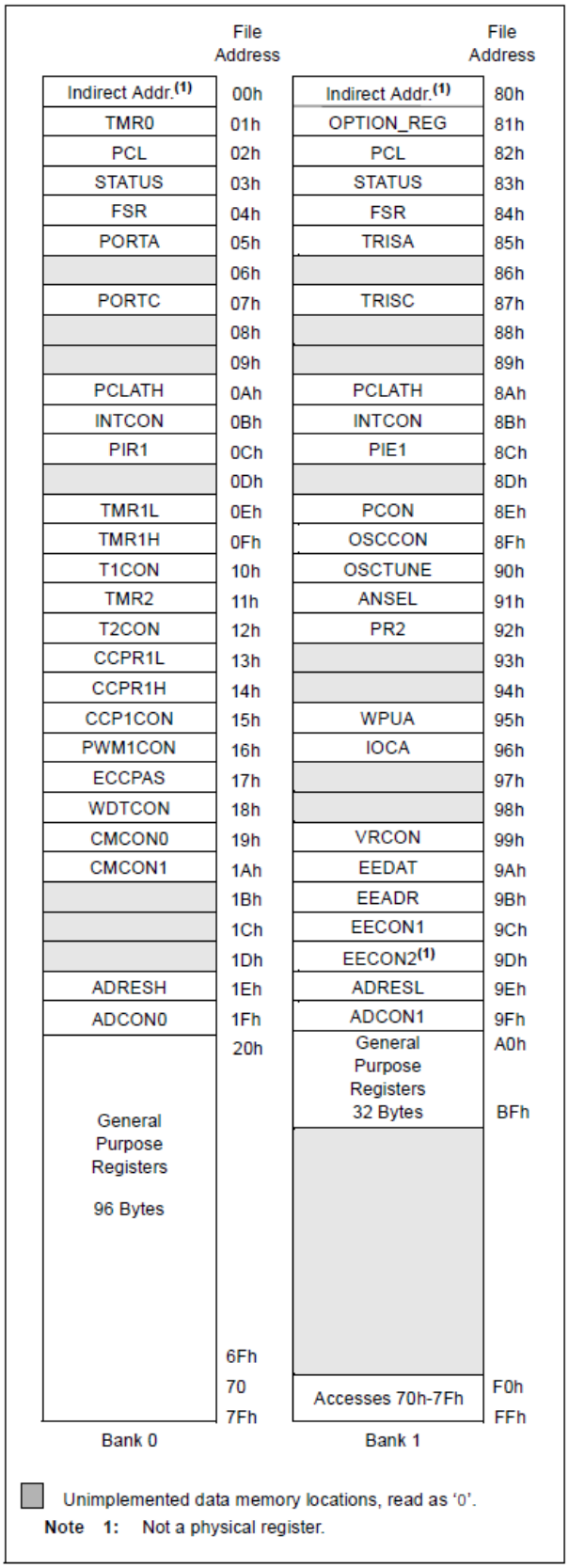
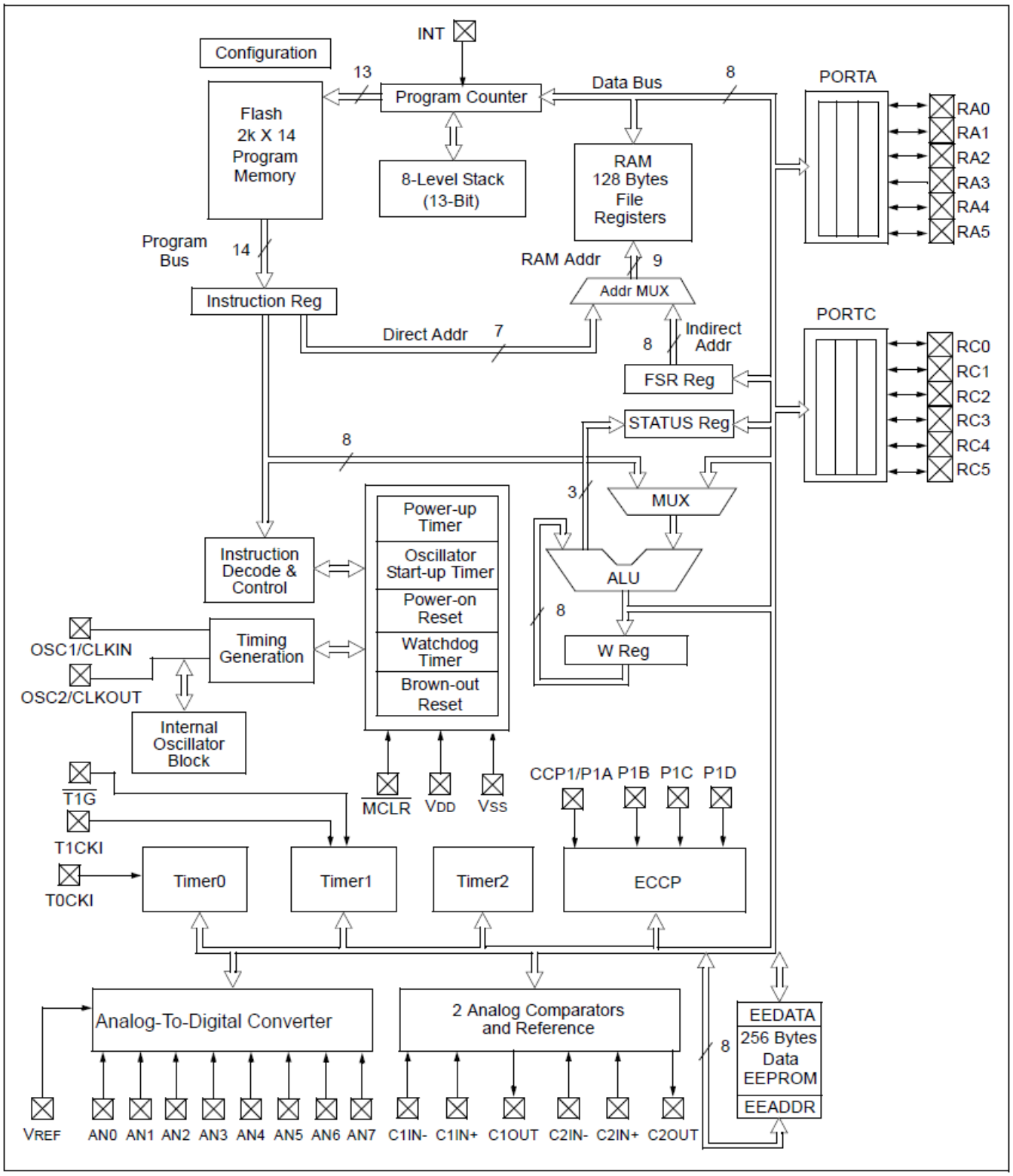


FIGURE 1-1: PIC16F684 BLOCK DIAGRAM



Source for all figures: *"PIC 16F684 Data Sheet", Microchip Technology, Inc. http://ww1.microchip.com/downloads/en/DeviceDoc/41202F-print.pdf*