Department of Electrical and Computer Engineering
University of Alabama in Huntsville

CPE 323 – Introduction to Embedded Computer Systems
Final Exam

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Date: April 30, 2014

Place: SC 109

Time: 3:00 PM – 5:30 PM

Note: Work should be performed systematically and neatly. This exam is closed books and closed neighbor(s). Allowable items include exam, pencils, straight edge, calculator, and materials distributed by the instructor. Best wishes.

Question	Points	Score
1	20	
2	20	
3	20	
4	20	
5	20+2	
Sum	100+2	

Please print in capitals:

Last name:______________________________

First name: ______________________________

1. (20 points) MSP430 System Architecture/Miscellaneous

Answer the questions or circle the correct answers when appropriate.

A. (6 points) The MSP430FG4617 is a microcontroller with address space divided between code memory (flash), RAM memory, and input/output peripherals. It has 8 KBytes of RAM memory starting at the address 0x01100, and 256 Bytes of address space reserved for special purpose registers and 8-bit input/output peripherals (starting at the address 0x0000), followed by 256 Bytes reserved for 16-bit input/output peripherals. The flash memory of 92 KB placed at the address that follows the RAM memory.
Determine the address map by filling in the following table.

Address	Address [hexadecimal]	What?
Last Flash address		Flash Memory
First Flash address		
Last RAM address		RAM Memory
First RAM address		
Last I/O address (16-bit per.)		I/O address space
First I/O address (16-bit per.)		
Last I/O address (8-bit per.)		I/O address space
First I/O address (8-bit per.)		

B. (2 points) The interrupt vector table includes 32 entries and contains 16-bit addresses (i.e., interrupt service routines can reside in the first 64 KByte of address space). What is the address range of the interrupt vector table?

Interrupt Vector Table	First address	Last address
--		

C. (2 points) What is the maximum size of the program stack in the MSP430FG4617 from A?
________________WORDS

D. (2 points) (True | False) The content of the RAM memory remains intact if the power is turned off?

E. (2 points) (True | False) The content of the RAM memory is lost when the processor goes into a low-power mode (clocks are turned off).

F. (2 points) (True | False) The RETI instruction that returns from the interrupt service routine retrieves only the program counter from the top of the stack as follows: PC <= M[SP]; SP <= SP + 2;

G. (2 points) (True | False) The content of the FLASH memory remains intact when the MSP430 goes into a low-power mode.

H. (2 point) (True | False) Instruction MOV.B 0x01100, R7 reads a byte from RAM memory from address 0x01100 and stores it into register R7.

2. (20 points) Interrupts

Answer the questions or circle the correct answers when appropriate.

A. (2 points) (True | False) During exception processing in hardware, the R0 (PC, program counter) and R1 (SP, stack pointer) registers are pushed on the stack.

B. (2 points) (True | False) The GIE bit in the status register retains its original value during exception processing in hardware.

C. (2 points) (True | False) *An interrupt enable bit* associated with a peripheral is always automatically cleared upon accepting the corresponding interrupt request.

D. (2 points) (True | False) An interrupt flag bit remains set as long as the corresponding interrupt request is pending (waiting to be serviced) and can be cleared automatically in hardware upon accepting the interrupt request or explicitly in software.

E. (2 points) (True | False) If multiple interrupt requests are pending at the time of exception processing, the fixed priority is used to select the one that is processed first.

An MSP430-based system interfaces switches SW1 and SW2 connected to P1.0 and P1.1, respectively. When a switch is pressed, the ground is connected to the corresponding input pin (a logic '0'). When SW1 is pressed LED1 (connected to P2.1) should be turned on (a logic '1' on the port). When SW2 is pressed LED2 (connected on P2.2) should be turned on. When switches are released the leds should be turned off.

F. (3 points) Specify registers that need to be initialized in the main program to configure the system. Fill in the table below. Note: to specify interrupts active on the falling edge the edge-selection bits should be set to 1.

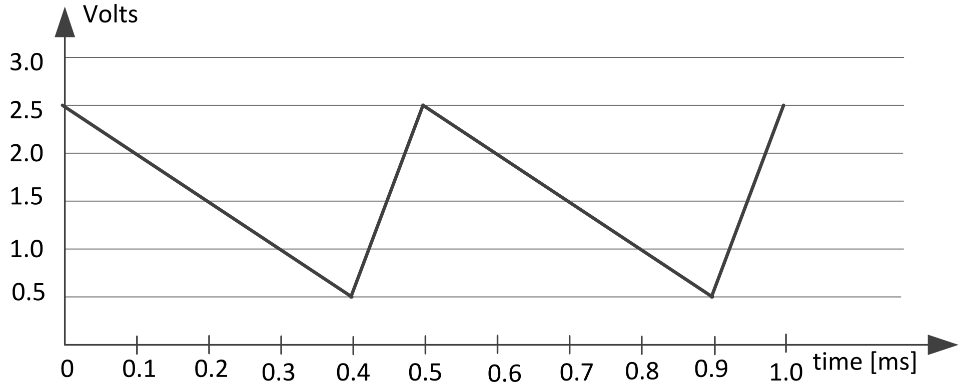
Register	Full Name	Content after initialization (in binary)

G. (2 points) How many interrupt service routines is needed to handle SW1 and SW2?

H. (5 points) Outline the interrupt service routine(s) and the main loop for handling requests from SW1 and SW2 as described above.

3. (20 points) Embedded Software Design (Digital to Analog Conversion).

We are using a 10-bit analog-to-digital converter to sample a periodic input signal shown below. Answer the following questions.



A. (2 points) What is the maximum and the minimum voltage at the analog input? Fill in the table below by specifying min/max values and times when those values are achieved.

Min/Max	Value [Volts]	Time [milliseconds]
Min		
Max		

B. (2 points) What is the duration of one period of the signal in milliseconds?

C. (2 points) What is a minimum change of the input signal that can be detected by the ADC10, if we use reference voltages Vref- = 0 V and Vref+ = 3 V?

D. (6 points) What values would you read from the 10-bit ADC if your sampling rate is 10,000 Hz. Fill in the following table with the values for the first 5 samples (assume the first sample is taken at t = 0 s). Assume Vref- = 0 V and Vref+ = 3 V.

Sample	*t=? [ms]*	*Signal*	*Samples from ADC [unsigned value in decimal]*
1			
2			
3			
4			
5			

E. (2 points) Describe steps taken during program initialization to configure the analog-to-digital conversion as described above.

F. (2 points) If we use a TimerB to trigger an ADC conversion, how would you configure TimerB assuming its input clock, SMCLK, is set to 2,000,000 Hz?

G. (2 points) Is it possible to improve resolution (V_{LSB}) of the analog-to-digital conversion described in this problem? If yes, explain what changes would you make?

H. (2 points) Assume you want to generate a signal described above using a DAC12 and a lookup table with predefined samples for 50,000 Hz sampling frequency. What is the size of the lookup table in bytes you will need to prepare?

4. (20 points) Time, Timers, Operating time

Answer the questions or circle the correct answers when appropriate.

A. (2 points) (True | False) The MSP430 FLL+ module can be configured in active mode as follows: ACLK = 32,767 Hz, MCLK = 4,194,304 Hz, and SMCLK = 1,048,576 Hz.

B. (2 points) (True | False) The MSP430 clocks can be sourced from an internal digital control oscillator or external crystal oscillators or resonators.

C. (2 points) (True | False) The MSP430's TimerA and TimerB are 16-bit peripherals that can be used to generate multiple pulse-width modulated signals.

D. (2 points) (True | False) A single capture and compare block of TimerA/TimerB can be configured in both capture and compare modes.

E. (2 points) How do we exit a low-power mode in the MSP430-based systems to continue processing in the main program?

Consider the following code segment that utilizes the watchdog timer in in the interval mode with period set to 1 s (line 4 of the code).

```
1.  #include <msp430xG46x.h>
2.  void main(void) {
3.    int p = 0;
4.    WDTCTL = WDT_ADLY_1000; // 1 s interval timer
5.    P2DIR |= BIT2; // Set P2.2 to output direction
6.    for (;;) {
7.      if ((IFG1 & WDTIFG) == 1) {
8.        p++;
9.        if (p == 4) {P2OUT ^= BIT2; p=0;}
10.       IFG1 &= ~WDTIFG;
11.     }
12.    }
13. }
```

F. (5 points) What does the code segment do?

G. (5 points) How would you implement the given functionality using an interrupt service routine? Sketch the code.

5. (20 points + 3 points) Misc. peripherals

A. (4 points) Consider two experimenter's boards, A and B. You need to create a half-duplex parallel link between A and B, so they can exchange 8-bits as follows: A sends one byte to B, and then B responds by sending two bytes to A. You have ports 4 and 5 (P4, P5) pins available on both boards for this purpose. Give a block diagram that specifies all the wires needed to carry out this communication. Fill in the table below with wire names and their purpose.

Wire Name	Direction (A2B or B2A)	Description

B. (2 points) What is the minimum number of wires (do not include the common ground) needed between A and B to carry out the communication from above?

C. (4 points) Sketch a code that carries out the exchange on device A.

Consider the following C source code.

```
1.  char gm1[] = "MSP430";

2.  void UART0_putdchar(char c) {
3.    while (!(IFG2 & UCA0TXIFG));
4.    UCA0TXBUF = c;
5.    while (!(IFG2 & UCA0TXIFG));
6.    UCA0TXBUF = ‘_‘;
7.  }
8.  …
9.  for(int i = 0; i < 6; i++) {
10.   ch = gm1[i];
11.   UART0_putdchar(ch);
12. }
```

D. (4 points) What does the code segment from lines 9 – 12 do? USCIA0 is configured in the UART mode.

E. (3 points) USCI0 is configured in the UART mode to transfer 19,200 bits/second, 8-bit characters, no parity, and one stop bits. Estimate the time needed to execute the code segment from lines 9 to 12. You can ignore time needed to execute the non-waiting instructions.

F. (3 points) Could you do the transfer described above using a DMA channel? If yes, explain what changes would you make and how you would initialize the DMA? Specify the content of relevant registers.

G. (2 points, BONUS) You need to interface an LCD with <u>four</u> 8-segment digits from your platform that includes the LCD controller. If you are using 2-mux mode, how many port signals you need to run between your microcontroller and display?