Final Exam – Spring 2023
CS 4380: Embedded Systems
CS 5331: Sp Problems in CS: Cyber Physical Systems

Department of Computer Science, Texas Tech University

Date: May 08, 2023. Time: 7:30 PM – 10:00 PM. Room: Elec 101

Instructor: Dr. Morshed, Assoc. Prof. **Number of pages: 13**

Exam duration: 150 minutes **Marks: 35**

Name:	**R number:**
Signature:	**Date:**

EXAM RULES

1. **Before you begin the exam, complete the information section above.**
2. **Use this question paper to answer all your work (including rough work). Use of additional paper is not allowed. If needed, use the blank backside of this exam paper with appropriate indicators.**
3. **Show all your work in details. Partial marks will be awarded for proper procedure even if the result is incorrect. Correct results without the procedure will not receive full marks.**
4. **In case of excess number of attempts in each section, the EXTRA ATTEMPT AT THE END OF THAT SECTION WILL BE DISCARDED.**
5. **No clarification of questions will be provided during the exam. If a question requires you to make an assumption, state the assumption clearly with proper rationale.**
6. **This is a CLOSED BOOK exam. A NON-PROGRAMMABLE CALCULATOR is allowed.**
7. **ALL PHONES MUST BE COMPLETELY TURNED OFF. A clock display will be available during the exam.**

Section A:	Answer any **5 (five)** out of 6 (six) questions:	5 X 3	=	15
Section B:	Answer any **5 (five)** out of 6 (six) questions:	5 X 4	=	20
		Total Marks	**=**	**35**

Section A: Answer any FIVE (5) questions in this section. (5x3 = 15 marks)

A1. Using a space heater as an example of an embedded system, draw a hardware block diagram of this system. Other than essential components, the system contains a manual keypad entry, a forced air heater, option for oscillating 120˚ range, and a display to show the set temperature and the sensed ambient temperature.

A2. **a)** For an embedded system product with 3 years life cycle, a delayed product was launched after 6 months compared to on-time products. Compute the percentage potential revenue loss for the delayed product using a triangular revenue model approximation.

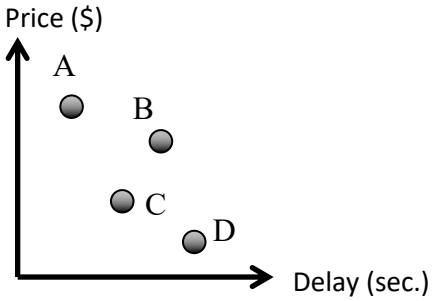
b) If a product unit cost is $20, and NRE cost is $5,000, determine the minimum quantity of units to be produced to keep per-unit cost below $30.

A3. **a)** Write 4 differences between a microprocessor and a microcontroller.
b) Define: (i) Embedded Systems. (ii) Cyber-physical systems (CPS).

A4. **a)** Draw a diagram of a ring buffer with detailed labeling, and briefly describe how it operates.
b) Explain the differences between polling and interrupt mechanism for an input port. What are the advantages and disadvantages of each?

A5. **a)** Define: "**Failure**", "**Fault**", and "**Error**". Provide an example of each within the context of embedded system for a room temperature controller.
b) Calculate ***Availability*** for a system for road traffic light controller, if the corresponding MTTF = 1,000 hours, and MTTR = 40 hours.

A6. **a)** What are the various wireless technologies for data communication available in Embedded Systems and Cyber-Physical systems? Write one advantage and one disadvantage of each.
b) For Pareto Point analysis, compare designs A, B, C, and D below to determine mutual **dominance or indifference**, based on the following plot. Also determine Pareto Set.



Section B: Answer any FIVE (5) questions in this section. (5x4 = 20 marks)

B1. **a)** What are the 3 common features of Embedded Systems?

b) Write 10 future-trend technology-areas of embedded systems, and briefly discuss each of them.

B2. Using bitmath technique, write an Arduino Uno code to light up 5 LEDs one by one when an analog light sensor senses lesser lights progressively (arbitrary thresholds). The 5 LEDs are connected to digital pins 3 to 7. Ambient light sensor is connected to Analog Pin 0 (i.e., A0). Note: All 5 LEDs must be on when the ambient light is at lowest (i.e., below the lowest threshold) and none of the LEDs must be on when the ambient light is at highest (i.e., higher than the highest threshold).

B3. Write an Arduino program for a night light, where an analog temperature sensor is connected to analog input pin A0, and 2 LEDs are connected to a digital output pins 10 and 11. The analog sensor values are polled in every 5 seconds and saved in a mutex buffer A or B, both of size 12 Bytes. If mutex buffer A is full, next data will start to be stored in mutex buffer B, and vice versa. Also, if any of the mutex buffer is full, the corresponding data is averaged. If the average value is above Threshold1, then the heater is ON, otherwise the heater is OFF (represented by the LED connected to pin 10). If the average value is below Threshold2, then the cooler is ON, otherwise the cooler is OFF (represented by the LED connected to pin 11). Also, for debugging purpose, use the serial port (monitor) to send each data (Baud rate = 9600) to a computer.

B4. Write an Arduino program with bitmath style of coding that uses interrupt PCINT0 (*corresponding to PCIE0*) to toggle an LED connected to pin 13 (*Port B*) when a push switch connected to pin 8 (*Port B*) is pressed (normally low). Set the microcontroller in deep sleep Power Save mode. (*Required datasheet snapshots are given below.*)

Bit	7	6	5	4	3	2	1	0	
(0x68)	–	–	–	–	–	PCIE2	PCIE1	PCIE0	PCICR
Read/Write	R	R	R	R	R	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Bit	7	6	5	4	3	2	1	0	
	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0	
Access	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	
Reset	0	0	0	0	0	0	0	0	PCMSK0

B5. Write an Arduino program with bitmath style of coding that uses Timer 0 overflow (*TIMER0_OVF_vect*) to generate a 100 Hz output signal at PIN 4. *(Clock frequency = 16 MHz. For Normal Mode: WGMA = 000. Counter value must be initialized to TCNT0. Set TOIE0 to enable timer overflow interrupt. Required datasheet snapshots are given below).*

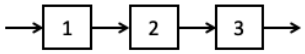
Bit	7	6	5	4	3	2	1	0	
0x24 (0x44)	COM0A1	COM0A0	COM0B1	COM0B0	–	–	WGM01	WGM00	TCCR0A
Read/Write	R/W	R/W	R/W	R/W	R	R	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Bit	7	6	5	4	3	2	1	0	
0x25 (0x45)	FOC0A	FOC0B	–	–	WGM02	CS02	CS01	CS00	TCCR0B
Read/Write	W	W	R	R	R/W	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

Bit	7	6	5	4	3	2	1	0	
(0x6E)	–	–	–	–	–	OCIE0B	OCIE0A	TOIE0	TIMSK0
Read/Write	R	R	R	R	R	R/W	R/W	R/W	
Initial Value	0	0	0	0	0	0	0	0	

CS02	CS01	CS00	Description
0	0	0	No clock source (Timer/Counter stopped)
0	0	1	$clk_{I/O}$/(No prescaling)
0	1	0	$clk_{I/O}$/8 (From prescaler)
0	1	1	$clk_{I/O}$/64 (From prescaler)
1	0	0	$clk_{I/O}$/256 (From prescaler)
1	0	1	$clk_{I/O}$/1024 (From prescaler)
1	1	0	External clock source on T0 pin. Clock on falling edge.
1	1	1	External clock source on T0 pin. Clock on rising edge.

B6. **a)** How can you improve reliability of an ES system? Give two examples.
b) Determine the reliability of the ES with network of sub-systems shown below with reliabilities of $R_1 = 0.8$, $R_2 = 0.9$, $R_3 = 0.4$.



c) To increase overall reliability, you added a redundant block of 3 in the network in parallel as follows. Determine the new overall reliability. What is the improvement in reliability?