Name ______________________________

Real Time Computing Systems

EE 4770

Final Examination

7 May 1999, 10:00-12:00 CDT

Problem 1	______	(25 pts)
Problem 2	______	(25 pts)
Problem 3	______	(25 pts)
Problem 4	______	(25 pts)
Exam Total	______	(100 pts)

Alias ______________________________

Good Luck!

Problem 1: Design a system to convert process variable $x \in [0, 2000\,\mathrm{N}]$, force, to a floating point number $H(x) = x/\,\mathrm{N}$, to be written to variable `force`. Force is to be measured using a load cell with four strain gauges mounted. Force is converted to strain so that $\epsilon = H_{\mathrm{tfs}}(x) = \pm(xk_1 + x^2k_2)$, where $k_1 = \frac{1.100\times10^{-7}}{\mathrm{N}}$ and $k_2 = \frac{2.420\times10^{-11}}{\mathrm{N}^2}$. The sign is based on where the strain gauge is mounted, two are positive and two are negative. The strain gauges are ideal; their model function is $H_{\mathrm{t}}(\epsilon) = 1000\,\Omega(1 + 2\epsilon)$. (25 pts)

- Use a 10-volt, 16-bit ADC.
- Choose a conditioning circuit appropriate to the strain gauge responses.
- Show all component and supply values.
- Write the interface routine. Do not expect a symbolic equation solver to be linked in with the real-time program.
- Indicate the minimum precision of `force`. The answer can be given as a formula, be sure to indicate which values to substitute. Justify your answer.

Problem 2: Events and their handlers are described in the first table below. The period for event C can vary from $32\,\mu$s to $64\,\mu$s. The run time of C's handler depends on the time between the current occurrence of C and the last, denoted Δt. (For example, if C_0 occurs at $20\,\mu$s and C_1 occurs at $60\,\mu$s then $\Delta t = 40\,\mu$s and the handler for C_1 will use $1\,\mu\text{s} + \frac{40\,\mu\text{s}}{4} = 11\,\mu$s.) Fill in the blank table using worst-case values. Also indicate total system load. (25 pts) To be eligible for partial credit, show the event sequences used, particularly for the latency of D.

Event Name	Strong Priority	Weak Priority	Handler Run Time	Occurrence
A	3	3	$1\,\mu$s	Periodic, $7\,\mu$s period.
B	3	2	$11\,\mu$s	Periodic, $47\,\mu$s period.
C	3	1	$1\,\mu\text{s} + \frac{\Delta t}{4}$	From $32\,\mu$s to $64\,\mu$s between occurrences.
D	2	1	5 ms	At init., then 10 ms after each response.
E	1	1	9 ms	Periodic, 1 s period.

Event	Latency	Actual Run Time	Response Time
A			
B			
C			
D			
E			

Event	Load	Load Set	Loading Factor	Loaded Duration
A				
B				
C				
D				
E				

Total Load: ☐

Problem 3: The table below describes tasks that run on a system with task-preemptive scheduling. R1 to R4 are resource names. The numbers in the activity column indicate CPU time, R1→indicates that R1 is locked, and ←R1 indicates that R1 is unlocked. For example, task D computes for 1 unit, locks R2, computes for 3, unlocks R2, computes for 2, and finishes.

Task	Priority	Arrival	Activity
A	5	19	4 R1→R2→7←R2←R1 3 R3→8 ←R3 1.
B	4	16	5
C	3	12	3 R4→9 ←R4 10 R3→11 ←R3 1.
D	2	10	1 R2→3 ←R2 2.
E	1	0	5 R4→8 ←R4 8 R1→20 ←R1 2.

(*a*) Show CPU activity from 0 **to 40** for the tasks above on a system without a locking protocol of any kind. (For **reduced** credit solve the problem above but interpreting, for example, R1→3 ←R1 as meaning I/O that takes 3 cycles to complete.) (10 pts)

(*b*) Assign ceilings to the resources for a priority ceiling protocol. The ceilings should be chosen to allow maximum flexibility. What is the worst-case blocking time for *A* using the immediate priority ceiling protocol? Ignore the arrival times in the table. (To be eligible for partial credit show what happens.) (5 pts)

Problem 3, continued.

Use the table below for the following problems. The table is **not** the same as the table on the previous page.

Task	Priority	Activity
A	5	4 R1→R2→7←R2←R1 3 R3→8 ←R3 1.
B	4	5
C	3	3 R2→17 ←R2 10 R3→11 ←R3 1.
D	2	1 R2→3 ←R2 2 R3→11 ←R3 5.
E	1	5 R1→20 ←R1 2.

(*c*) What is the worst-case total blocking time for A without a locking protocol? (To be eligible for partial credit show what happens.) (5 pts)

(*d*) What is the worst-case blocking time for A with priority inheritance? (To be eligible for partial credit show what happens.) (5 pts)

Problem 4: Answer each question below.

(a) Find a linear model for a thermistor with model function $H_{\mathrm{t2}}(x) = R_0 e^{\beta/x}$ suitable for the temperature range $[20\,^\circ\mathrm{C}, 40\,^\circ\mathrm{C}]$ matching the slope at the center of the temperature range. $R_0 = 0.059\,\Omega$ and $\beta = 3000\,\mathrm{K}$. The answer can be a formula but show which values to substitute. (5 pts)

(b) Describe how the thermodynamic temperature scale is defined using a fixed-volume ideal-gas thermometer. Does one need a thermometer or any other *calibrated* measuring device to construct the fixed-volume thermometer? *(Hint: $PS = n\Re T$.)* (5 pts) (*c*) Describe the steps in creating a new task in Unix. (5 pts)

(*d*) Describe the differences between strong and weak priority levels in terms of the interrupt hardware and software mechanisms. (5 pts)

(*e*) How do an RTD and a thermistor measure temperature? How do their responses to temperature differ? (5 pts)