Name Solution

Real Time Computing Systems

EE 4770

Final Examination

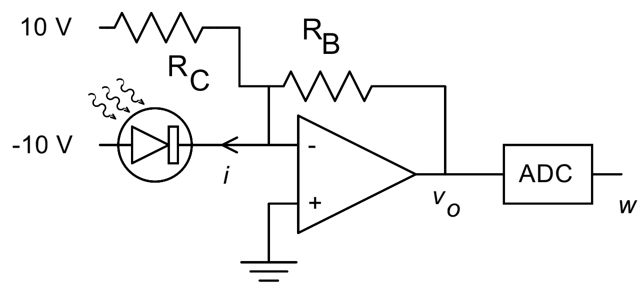
7 May 1997, 7:30-9:30 CDT

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 circuit to convert process variable $x \in [10\,\frac{\mathrm{W}}{\mathrm{sr}}, 20\,\frac{\mathrm{W}}{\mathrm{sr}}]$, the radiant intensity of a light source, to $H(x) = x/\,\frac{\mathrm{W}}{\mathrm{sr}}$, a floating-point number to be written into variable `rad_int`. The precision should be $\pm 1\,\frac{\mathrm{mW}}{\mathrm{sr}}$. Use a photodiode with response $H_{\mathrm{t}}(E) = 2.12E\,\frac{\mu\mathrm{A\,cm}^2}{\mathrm{mW}}$ mounted 718 mm from the light source. Make full use of the ADC dynamic range. The light source radiates uniformly in all directions. Draw a schematic of the circuit, indicating all component and source values. Show the interface routine. (25 pts)



To make full use of the ADC's dynamic range, a summing amplifier is used. The photodiode is connected as in a current-to-voltage converter, a second resistor, R_{C}, "subtracts" the photodiode current at the minimum irradiance.

Minimum irradiance: $E_{\min} = H_{\mathrm{p}}(x_{\min}) = \frac{x_{\min}}{r^2} = 1.940\,\frac{\mathrm{mW}}{\mathrm{cm}^2}$, where $r = 718\,\mathrm{mm}$, $x_{\min} = 10\frac{\mathrm{W}}{\mathrm{sr}}$, and $H_{\mathrm{p}}(x)$ converts radiant intenstity x to irradiance at distance r.

Photodiode current at minimum irradiance: $i_{\min} = H_{\mathrm{t}}(E_{\min}) = 4.112\,\mu\mathrm{A}$.

$E_{\max} = \frac{x_{\max}}{r^2} = 3.880\,\frac{\mathrm{mW}}{\mathrm{cm}^2}$ and $i_{\max} = H_{\mathrm{t}}(E_{\max}) = 8.225\,\mu\mathrm{A}$.

At $x = 10\frac{\mathrm{W}}{\mathrm{sr}}$ want $v_o = 0\,\mathrm{V}$, so find R_{C} that satisfies:

$$\frac{10\,\mathrm{V}}{R_{\mathrm{C}}} = i_{\min} \Rightarrow R_{\mathrm{C}} = \frac{10\,\mathrm{V}}{i_{\min}} = 2.432\,\mathrm{M}\Omega$$

.

At $x = 20\frac{\mathrm{W}}{\mathrm{sr}}$ want $v_o = 5\,\mathrm{V}$, so find R_{C} that satisfies:

$$5\,\mathrm{V} = -R_{\mathrm{B}}\left(\frac{10\,\mathrm{V}}{R_{\mathrm{C}}} - i_{\max}\right) = -R_{\mathrm{B}}\left(i_{\min} - i_{\max}\right) \quad \Rightarrow R_{\mathrm{B}} = 1.216\,\mathrm{M}\Omega$$

ADC precision easily computed because of linearity:

$$2^b \geq \frac{x_{\max} - x_{\min}}{0.1\,\mathrm{mW}/\,\mathrm{sr}} = 10,000 \qquad \Rightarrow b \geq 14, \quad \text{choose } b = 14.$$

ADC Output:

$$\begin{aligned} w =& H_{\mathrm{ADC}}(H_{\mathrm{c}}(H_{\mathrm{t}}(H_{\mathrm{p}}(x)))) \\ =& \frac{v_{\mathrm{ADC}}}{2^b - 1}\left(-R_{\mathrm{B}}\left(-K_{\mathrm{s}}\frac{x}{r^2} + \frac{10\,\mathrm{V}}{R_{\mathrm{C}}}\right)\right) \\ =& \frac{x - x_{\min}}{x_{\max} - x_{\min}}(2^b - 1) \\ \Rightarrow x =& \frac{w}{2^b - 1}(x_{\max} - x_{\min}) + x_{\min} \end{aligned}$$

Interface routine:

```
w = readInterface(); rad_int = w * 0.0006104 + 10.0;
```

Problem 2: Events and their interrupts and handlers in a real time system are described in the partially filled table below. Item "1 Time" in the table indicates that the respective event will occur just once, "3 Times" indicates that the event will occur three times. Complete the table. To be eligible for partial credit show the event sequences used. (25 pts)

The table below includes solution, under "Latency" and "Response Time."

Event Name	Str. Pri.	Weak Pri.	Run Time	Period or Num. Occur.	Worst Case Latency	Worst Case Response Time
A	3	1	$1\,\mu$s	$10\,\mu$s	0	$1\,\mu$s
B	2	4	$2\,\mu$s	1 Time	$12\,\mu$s	$14\,\mu$s
C	2	3	$3\,\mu$s	$200\,\mu$s	$14\,\mu$s	$17\,\mu$s
D	2	2	$10\,\mu$s	1 s	$12\,\mu$s	$23\,\mu$s
E	2	1	$5\,\mu$s	1 Time	$17\,\mu$s	$23\,\mu$s
F	1	1	$7\,\mu$s	3 Times	$38\,\mu$s	$46\,\mu$s

Notes: Event A occurs twice during B's latency period.

Event A interrupts D, E, and F while they are running, adding to their response times.

The latency and response time for F are based on the last of three occurrences; the third occurring an insignificant amount of time after the first.

Event A is the only periodic event to occur more than once during the periods analyzed.

Problem 3: Flow is to be measured using a turbine flow meter. The turbine consists of twelve blades; as described in class, a sensor detects the passing of each blade. When functioning properly, its k factor is 200/l (200 pulses per liter). However, these turbine blades can break off. If they do, the turbine will continue to rotate and its rotation rate will be the same as it would with all blades attached.

Each time a turbine blade passes the sensor the routine below is called with insignificant latency. Complete the routine so that variable `flow_rate` is assigned the flow rate in liters per minute. The variable need not be updated on every call. State any reasonable assumptions made. Solve the problem in *one* of the following ways:

- For full credit, complete the routine so that it determines the correct flow rate with any five or fewer blades missing. (The number and position of missing blades is *not* available.) (25 pts)
- For partial credit, complete the routine using variable `blades`, which gives the number of blades currently on the turbine. (That is, `blades` is provided for your use.) ($<$ 25 pts)
- For reduced partial credit, complete the routine assuming that all twelve blades are attached. ($<$ 20 pts)

```
void blade_handler()
{
 /* Seconds since midnight 1 January 1970, microsecond precision. */
 double now = precision_time();

 /* Static variables hold values from call to call. */
 /* On first call, -1; thereafter, time of previous call. (See below.)  */
 static double previous = -1;
 static int count=0;  /* Number of times this routine has been called. */
 count++;
```

Solution: with five or fewer blades missing there will be at least two consecutive positions with attached blades. The time between such a pair will be the minimum time over 12 (actually fewer) blades. Assumptions: blades are equally spaced, change in flow rate during a single turbine rotation is insignificant.

```
 /* Solution code starts. */
 static double delta_t_min = 0x7fffffff;  /* Minimum time between blades. */
 double delta_t = now - previous;
 if ( delta_t < delta_t_min ) delta_t_min = delta_t;
 if( count > 12 ) {
  flow_rate = 60.0 / ( 200.0 * delta_t_min );
  count = 0;
  delta_t_min = 0x7fffffff; /* Unix programmers won't be so smug in 2038. */
 }
 /* Solution code ends. */



 flow_rate = ???;
 previous = now;
}
```

Problem 4: Answer each question below and on the next page. Be brief.

(a) Show a situation where round robin runs tasks differently than first-come, first-served would. In both cases a fixed quantum should be used. *(Hint: consider three tasks, one performs I/O, the other two don't.)* (5 pts)

Consider three tasks A, B, and C, each with an infinite run time. Let their round-robin classes be 1, 2, and 3, and let the system be non task preemptive with a quantum of $10\,\mathrm{ms}$. Let task A perform I/O after $9\,\mathrm{ms}$ of computation and let the I/O take $15\,\mathrm{ms}$ to complete. Let tasks A, B, and C arrive at times 0, 1, and $2\,\mathrm{ms}$, respectively.

Under round robin scheduling the first four tasks run would be A, B, C, and A, whereas under FCFS the first four tasks run would be A, B, C, and B. Task A is not the last of four under FCFS because it entered the ready list while C was running, and so B, which was in the ready list, was chosen.

(b) Consider the following displacement transducers: a potentiometer, a capacitive displacement transducer, and a linear variable differential transformer (LVDT). For each, describe (and justify) a measurement situation where it is the obvious choice over the other two. (5 pts)

Potentiometer measuring the position of a CD tray in a home CD player. A LVDT would be too expensive, a capacitive sensor might have difficulty with the range of displacement.

Capacitive transducer measuring position of a fast-vibrating diaphragm. A potentiometer would have difficulty measuring such small displacements and an LVDT would have trouble with high frequencies.

LVDT measuring the position of arm in robot used for precision assembly. A potentiometer would have lower accuracy and would be subject to wear. A capacitive sensor might have difficulty with the range of displacement.

(c) Design (or remember a design used previously) a circuit to measure clockwise rotation using a two-way coded displacement transducer. The amount of clockwise rotation should be converted to an integer. (Do not be concerned with units or overflow.) Counterclockwise rotation should have no effect, that is, the counter *should not* count up or down. (5 pts)

See the solution to 1997 homework 4 problem 2.

(d) How does a photodiode work? Why are photodiodes reverse-biased? (5 pts)

A photon strikes the depletion region, exciting an electron from the valence to the conduction band, creating a electron/hole carrier pair. Propelled by the electric field in the depletion region, the electron and hole move in opposite directions, forming a current.

When reverse biased, the only current carriers the depletion region are those excited from the valence band, in a photodiode exposed to light these are mostly due to photons. When forward biased, the change in current due to optically excited photons is very small.

(e) What property of thermocouple junctions makes the type of metal in the conditioning circuit leads connecting to an isothermal block irrelevant? Illustrate mathematically. (5 pts)

If a single thermocouple junction is replaced by two junctions by inserting a third metal, the potential will be unchanged if all junctions are at the same temperature: $v_{\mathrm{AB}}(T) = v_{\mathrm{AX}}(T) + v_{\mathrm{XB}}(T)$. Suppose the thermocouple uses metals A and B and the conditioning circuit leads use metal C. Let v denote the voltage across the conditioning circuit leads and T_{R} denote the temperature of the conditioning circuit to thermocouple connections. Then $v = v_{\mathrm{CA}}(T_{\mathrm{R}}) + v_{\mathrm{AB}}(T) + v_{\mathrm{BC}}(T_{\mathrm{R}})$. Using the above identity, $v = v_{\mathrm{AB}}(T) + v_{\mathrm{BA}}(T_{\mathrm{R}})$.