MichiganTech

Spring 2001

BE 3600 BioInstrumentation

Midterm Exam 2: 12 April 2001, Thursday

This exam:

- Consists of 7 questions,
- Score from this exam will determine 20% of your grade,
- You have 1 hour to complete the exam,
- Closed books, closed notes, and use of calculators is not allowed,
- Please mark your answers on the SCORE SHEET using pencils,
- Do not forget to mark your TEST FORM code,
- Mark your FAMILY NAME (no first name, no middle initials),
- No telephone numbers.

YOUR NAME: _____

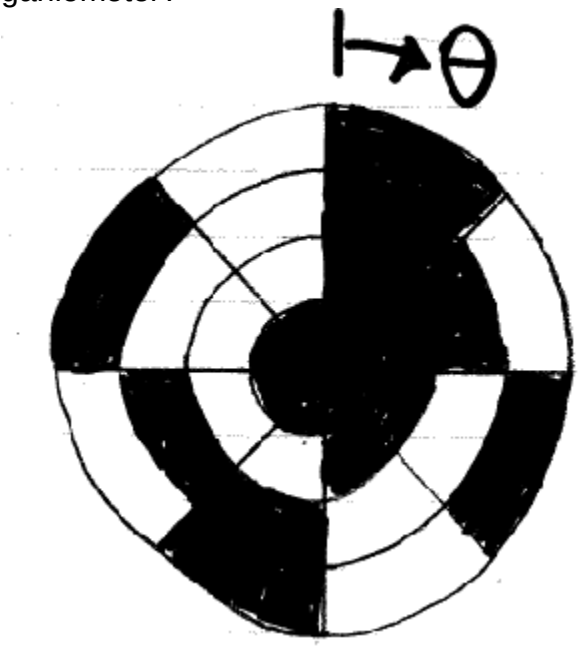
TEST FORM CODE:

GOOD LUCK!

QUESTION 1

[2 POINTS]

An optical encoder is being used as a ganiometer to measure the joint angle. As shown below, dark regions on the glass disk is painted black to prevent passage of light while the non-shaded regions are transparent to light. If the disk is turned counterclockwise by 250 degrees, what would be the output of this digital ganiometer?



ANSWERS:

A) $(100)_b$

B) $(001)_b$

C) $(101)_b$ CORRECT ANSWER

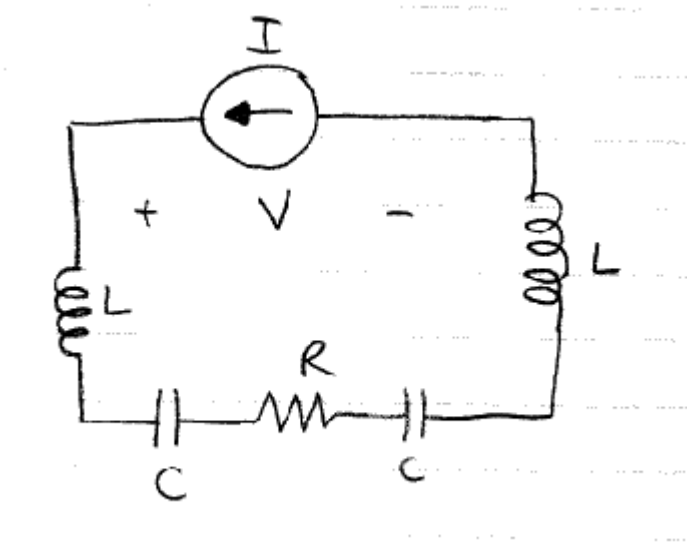
D) $(111)_b$

E) $(000)_b$

QUESTION 2

[3 POINTS]

A transthoracic impedance monitor consist of a sinusoidal current source (*I*), two leads modeled as *L,* two electrodes on the patient's skin modeled as *C*, and a resistance of the chest to be measured which is labeled as *R*. Determine the optimal frequency of operation where the voltage *V* measured by the monitor is primarily a function of the thoracic resistance *R*.



ANSWERS:

A) $\omega = \frac{1}{\sqrt{RLC}}$

B) $\omega = \frac{R}{\sqrt{LC}}$

C) $\omega = \frac{1}{\sqrt{2LC}}$

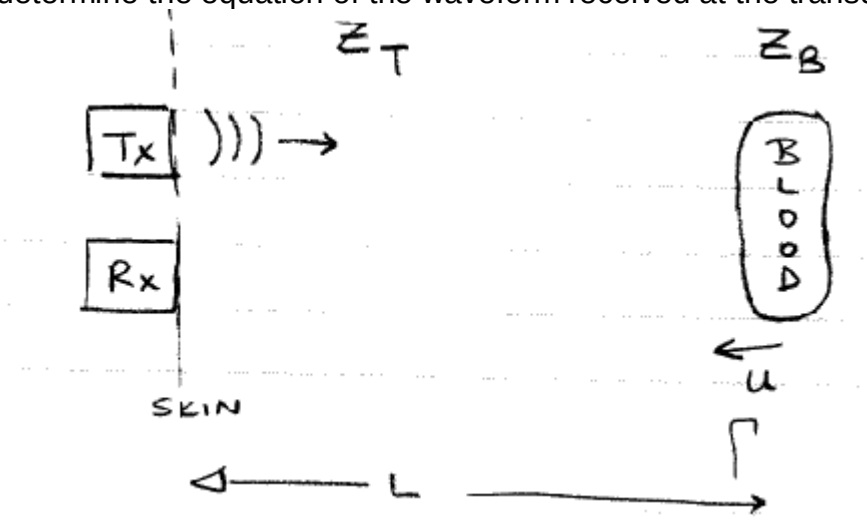
D) $\omega = \frac{1}{\sqrt{\frac{LC}{2}}}$

E) $\omega = \frac{1}{\sqrt{LC}}$ **CORRECT ANSWER**

QUESTION 3

[3 POINTS]

A Doppler Ultrasound based measurement system is used to detect the velocity of blood. Transmitter and the receiver are placed on the skin of the patient, and the blood vessel is at a distance L from the transducer. Transmitter is producing a pressure waveform $P_{Tx}(t)=\cos(2\pi f_{Tx}t)$. It can be assumed that the amplitude of the pressure wave is degraded by the equation $P(x)=P_0e^{-\alpha x}$, where x is the distance traveled by the pressure waveform, and α is the attenuation constant. Speed of sound in the tissue is given as c, and the blood velocity is u. If the reflection coefficient of the blood is assumed to be Γ, then determine the equation of the waveform received at the transducer.



ANSWERS:

A) $P_R(t)=\Gamma\frac{1}{e^{2\alpha x}}\cos\left[2\pi f_{Tx}\left(1+\frac{u}{c}\right)\left(t-\frac{L}{c}\right)\right]$

B) $P_R(t)=\Gamma\frac{1}{e^{2\alpha x}}\cos\left[2\pi f_{Tx}\left(1+\frac{u}{c}\right)\left(t-2\frac{L}{c}\right)\right]$ **CORRECT ANSWER**

C) $P_R(t)=\Gamma\frac{1}{e^{\alpha x}}\cos\left[2\pi f_{Tx}\left(1+\frac{u}{c}\right)\left(t-\frac{L}{c}\right)\right]$

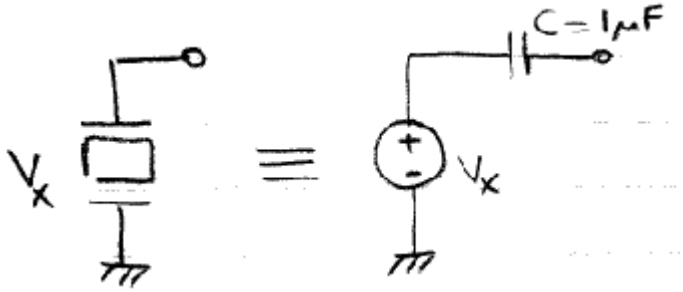
D) $P_R(t)=\Gamma\frac{1}{e^{\alpha x}}\cos\left[2\pi f_{Tx}\left(1+\frac{u}{c}\right)\left(t-2\frac{L}{c}\right)\right]$

E) $P_R(t)=\Gamma\frac{1}{2e^{\alpha x}}\cos\left[2\pi f_{Tx}\left(1+\frac{u}{c}\right)\left(t-\frac{L}{c}\right)\right]$

QUESTION 4

[3 POINTS]

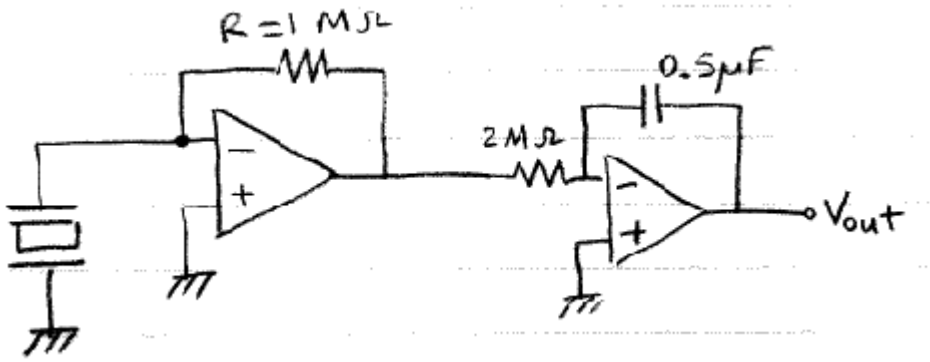
A piezoelectric crystal is being used as a pressure transducer, where the equivalent circuit for the crystal is given as a combination of a voltage source and a capacitor (shown below)



where $V_x = gP$, and $g = 1.0$.

If the transducer is connected to a circuitry as shown below, then find the step response of the system, i.e. what is $V_{out}(t)$, when the applied pressure, $P(t)$ is

$$P(t) = \begin{cases} 0, t < 0 \\ 1, t \geq 0 \end{cases}$$



ANSWERS:

A) $V_{out}(t) = \begin{cases} 0, t < 0 \\ t, t \geq 0 \end{cases}$

B) $V_{out}(t) = \begin{cases} 0, t < 0 \\ 1, t \geq 0 \end{cases}$ **(CORRECT ANSWER)**

C) $V_{out}(t) = \delta(t)$ $(impulse)$

D) $V_{out}(t) = \begin{cases} 0, t < 0 \\ 1, t^2 \geq 0 \end{cases}$

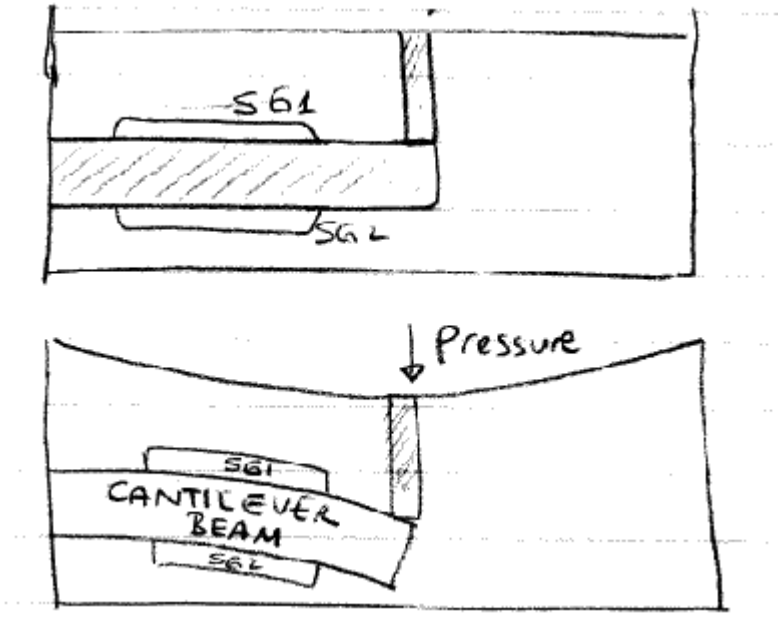
E) $V_{out}(t) = \begin{cases} 0, t < 0 \\ 1, t = 0 \\ 0, t > 0 \end{cases}$

QUESTION 5

[3 POINTS]

A diaphragm based pressure transducer was constructed using a cantilever beam and two strain gauges, SG_1 and SG_2 mounted on either side of the beam, as shown in the figure below. Resistance of the strain gauges with no strain is given as R_0. Application of the pressure P_1 onto the diaphragm causes it to bend, resulting a strain value of 1/3, i.e.

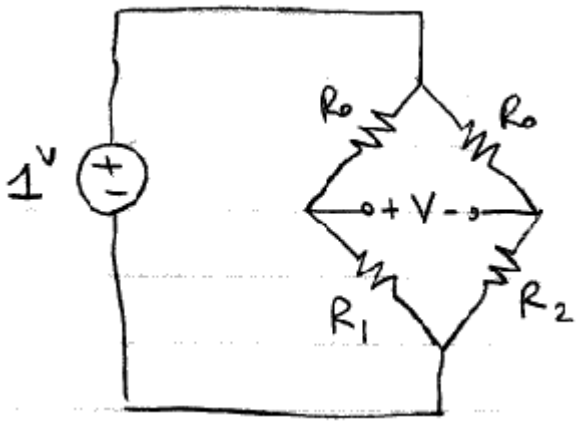
$$\frac{\Delta L_1}{L_1} = -\frac{\Delta L_2}{L_2} = \frac{1}{3}$$



Gauge factor for both strain-gauges are given as:

$$G = \frac{\frac{\Delta R}{R}}{\frac{\Delta L}{L}} = 1.0$$

Find the resulting bridge voltage, V, when the pressure P_1 is applied to the diaphragm (Please note that the strain gauges SG_1 and SG_2 are shown as R_1 and R_2 respectively).



CORRECT ANSWER:

A) 1/35

B) 3/35

C) 4/35

D) 6/35 CORRECT ANSWER

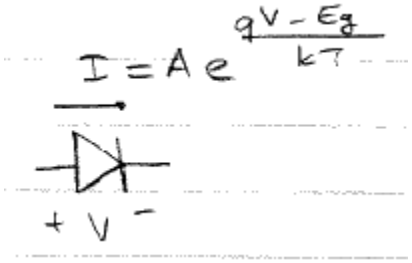
E) 8/35

QUESTION 6

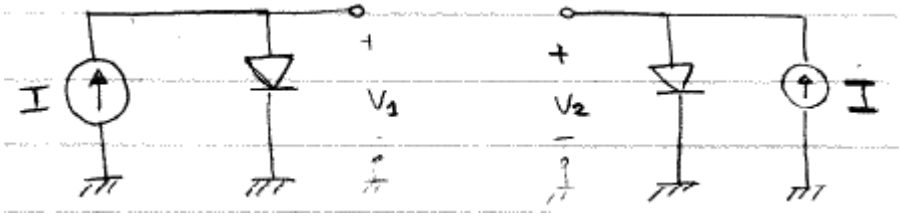
[3 POINTS]

A temperature sensor was constructed using two P-N junction diodes, where the current over the diode is given as:

$$I = Ae^{\frac{qV-E_g}{kT}}$$ where V is the voltage drop across the diode,
q, E_g, k and A are constants,
T is the absolute temperature.



If the two diodes are connected as shown in the circuit below, determine the relationship between the output voltage and the temperature (you can assume that both diodes are at the same temperature, T, and $I_1 \neq I_2$.



ANSWERS:

A) $V = V_1 - V_2 = c_1 T + c_0$, where c_0 and c_1 are constants.

B) $V = V_1 - V_2 = T$

C) $V = V_1 - V_2 = cT$ **, where c is a constant. (CORRECT ANSWER)**

D) $V = V_1 - V_2 = c_1 \ln(T) + c_0$, where c_0 and c_1 are constants.

E) $V = V_1 - V_2 = c_1 \ln(c_2 T) + c_0$, where c_0, c_1 and c_2 are constants.

QUESTION

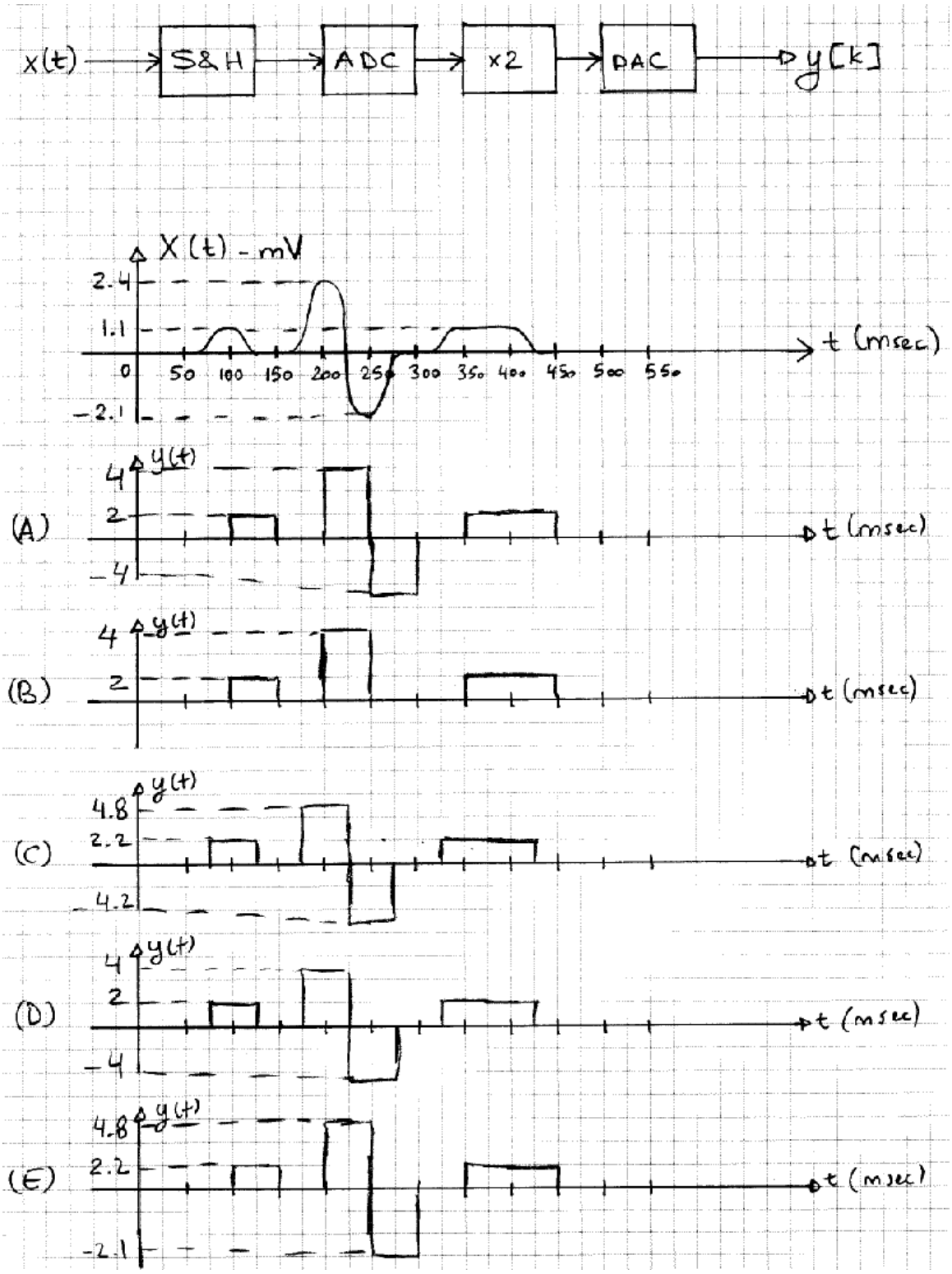
[3 POINTS]

A digital ECG amplifier system was constructed as shown below.

Sampling is done at 20 Hz (ΔT=50 milli-seconds), ADC (analog to digital converter) and the DAC (digital to analog converter) both have a 3 bits resolution and 0 to 7 milli-Volts range.

Given the input signal $x(t)$, determine the correct output signal of $y(t)$.

CORRECT ANSWER: B


x(t)
S&H
ADC
x2
DAC
y[k]
X(t) - mV
2.4
1.1
0
50
100
150
200
250
300
350
400
450
500
550
-2.1
t (msec)
(A)
y(t)
4
2
-4
t (msec)
(B)
y(t)
4
2
t (msec)
(C)
y(t)
4.8
2.2
-4.2
t (msec)
(D)
y(t)
4
2
-4
t (msec)
(E)
y(t)
4.8
2.2
-2.1
t (msec)