ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2019

Name SOLUTIONS

Section ___

Question I (20 points) ___________

Question II (20 points) ___________

Question III (20 points) ___________

Question IV (20 points) ___________

LMS Question (20 points) (graded on LMS)

Total (80 points) ______________

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Unless otherwise stated in a problem, provide 3 significant digits in answers. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

Analog Discovery 2 partial set of Specifications -
Analog Inputs

Channels: 2
Channel type: differential
Resolution: 14-bit
Input impedance: 1MΩ||24pF
Scope scales: 500uV to 5V/div
Analog bandwidth with included flywires: 9 MHz @ 3dB, 2.9 MHz @ 0.5dB, 0.8 MHz @ 0.1dB
Input range: ±25V (±50V diff)
Input protected to: ±50V
Cursors with advanced data measurements
Captured data files can be exported in standard formats
Scope configurations can be saved, exported, and imported

Arbitrary Waveform Generator

Channels: 2
Channel type: single ended
Resolution: 14-bit
AC amplitude (max): ±5 V
DC Offset (max): ±5 V
Analog bandwidth with included flywires: 9 MHz @ 3dB, 2.9 MHz @ 0.5dB, 0.8 MHz @ 0.1dB
Slew rate (10V step): 400V/μs
Standard waveforms: sine, triangle, sawtooth, etc.
Advanced waveforms: Sweeps, AM, FM.
User-defined arbitrary waveforms: defined within WaveForms software user interface or using standard tools (e.g. Excel)

Power Supplies

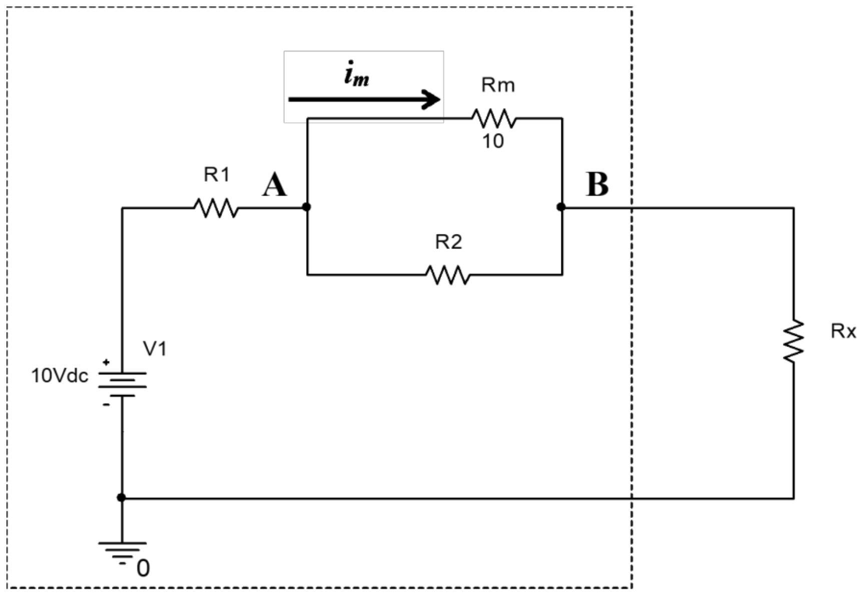
Voltage range: 0.5V…5V and -0.5V…-5V
Pmax (USB powered): 500mW total
Imax (USB powered): 700mA for each supply
Pmax (AUX powered): 2.1W for each supply
Imax (AUX powered): 700mA for each supply
Accuracy (no load): ±10mV
Output impedance: 50mΩ (typical)

Voltmeters

Channels (shared with scope): 2
Channel type: differential
Measurements: DC, AC, True RMS
Resolution: 14-bit
Accuracy (scale ≤0.5V/div): ±5mV
Accuracy (scale ≥1V/div): ±50mV
Input impedance: 1MΩ || 24pF
Input range: ±25V (±50V div)
Input protected to: ±50V

I. Voltage Dividers (20 points) As stated on the cover page: Round answers to 3 significant digits. Show formulas first and show your work. No credit will be given for numbers that appear without justification.

Consider the circuit diagram shown below. Rm represents the resistance of an ammeter (a current measuring device). The circuit with the dashed line is the model of an ohmmeter, which can be used to measure the value of an unknown resistance Rx.



Case 1: Given that when Rx = 0 Ω, the current through resistor Rm is 2 mA, i.e. i_m = 2 mA.
Case 2: Given that when Rx = 2000 Ω, the current through resistor Rm is 1 mA, i.e. i_m = 1 mA.

a. (2 pts) Find voltage between points A and B for each of the cases described above.

Case 1: $V_{AB} = i_m R_m = 20\ mV$

Case 2: $V_{AB} = i_m R_m = 10\ mV$

b. (1 pt) What is the equivalent resistance between points A and B, R_{AB}? (Express in terms of R2)

$$R_{AB} = R_2 \parallel R_m = \frac{10 R_2}{10 + R_2}$$

c. (5 pts) Using voltage divider and your answer to parts a and b, develop a relationship between R1 and R2 for <u>case 1</u>.

$$V_{AB} = 20mV = V_1 \left(\frac{R_{AB}}{R_1 + R_{AB} + R_x} \right)$$

($V_1 \to 10V$, $R_x \to 0\Omega$)

$$\Rightarrow (R_1 + R_{AB})\,2mV = R_{AB}$$

$$\Rightarrow R_1 + \frac{10R_2}{10+R_2} = \frac{5000\,R_2}{10+R_2} \Rightarrow \boxed{10R_1 - 4990R_2 + R_1R_2 = 0}$$

equation 1

d. (8 pts) Using voltage divider and your answer to parts a and b, develop a relationship between R1 and R2 for <u>case 2</u>.

$$V_{AB} = 10mV = V_1 \left(\frac{R_{AB}}{R_1 + R_{AB} + R_x} \right)$$

($V_1 \to 10V$, $R_x \to 2000\Omega$)

$$\Rightarrow \left(R_1 + \frac{10R_2}{10+R_2} + 2000\right) 1mV = \frac{10\,R_2}{10+R_2}$$

$$\Rightarrow \boxed{10R_1 - 7990R_2 + R_1R_2 = -20000}$$

equation 2

e. (4 pts) Solve the linear relationships derived in the previous parts, to determine the values of resistors R1 and R2 such that both case 1 and 2 are satisfied.

equation 1 − equation 2

$\Rightarrow \quad 3000 R_2 = 20000 \quad \Rightarrow$ $R_2 = 6.667\ \Omega$

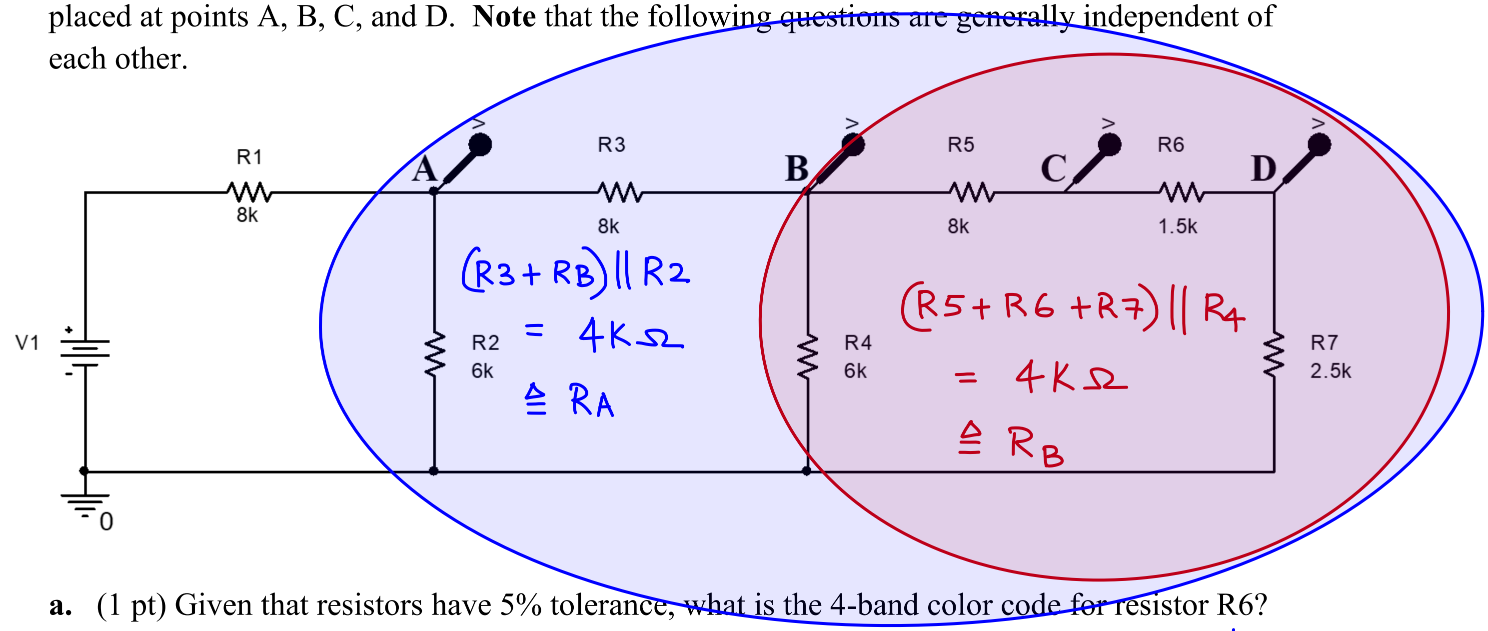
Substitute in equation 1.

$10R_1 - 33268.33 + 6.667 R_1 = 0$

$\Rightarrow$ $R_1 = 1996\ \Omega$

II. Resistor Combinations, concepts and miscellaneous (20 points) *Note: Page 2 of this quiz has background information.*

The following circuit consists of 7 resistors, 1 DC voltage source and has 4 voltage markers placed at points A, B, C, and D. **Note** that the following questions are generally independent of each other.



a. (1 pt) Given that resistors have 5% tolerance, what is the 4-band color code for resistor R6?

↳ 1.5KΩ

Brown – Green – Red Gold

b. (6 pts) Given that voltage at point A, VA = 9V, find the voltages at point B and the source voltage V1.

$$V_A = V_1 \left(\frac{R_A}{R_A + R_1} \right) \Rightarrow 9 = V_1 \left(\frac{4K}{4K + 8K} \right)$$

$$\Rightarrow \boxed{V_1 = 27\ V}$$

$$\text{Voltage @ point B} = V_B = V_A \left(\frac{4K}{8K + 4K} \right)$$

$$= 9 \left(\frac{4K}{12K} \right) = 3V$$

$$\boxed{V_B = 3V}$$

c. (2 pts) Given that voltage at point B, VB = 4V, find the current through resistor R6?

$$I_{R6} = \frac{V_B}{R_5+R_6+R_7} = \frac{4}{12\,K} = \boxed{0.333\ mA}$$

d. (2 pts) Given that the current through R6 is 0.25 mA, find the power dissipated through resistor R7?

$$I_{R6} = I_{R7} \quad \text{Resistors in series}$$

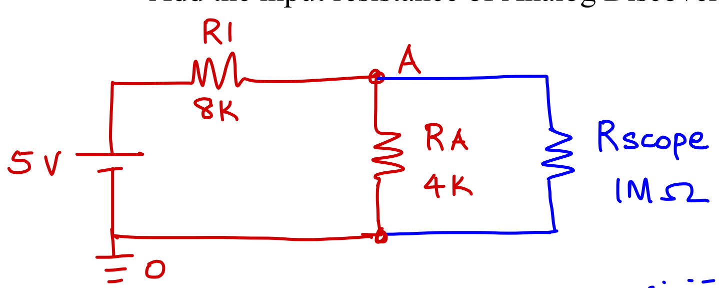
$$P_{R7} = I_{R7}^2 \cdot R7 = (0.25\,mA)^2 \times 2.5\,K = \boxed{0.15625\ mW}$$

e. (1 pts) A ceramic capacitor has a code "1 0 3" written on it. What is its capacitance?

$$\boxed{0.01\,\mu F} \qquad 10 \times 10^3\ pF = 10^4\ pF$$

Now consider that the same resistive circuit is built on a protoboard, V1 is set to 5V DC supplied by Analog discovery 2 board, and voltage at point A is being measured using scope channel 2.

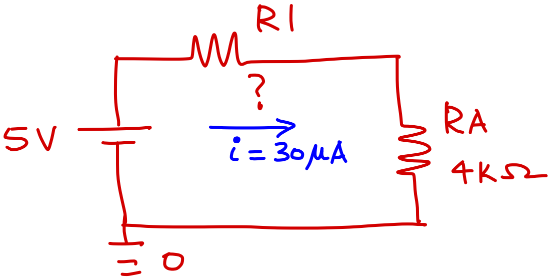
f. (2 pts) What voltage would the analog discovery scope channel 2 measure at point A? Hint: Add the input resistance of Analog Discovery channel.



$$V_{A,meas} = 5\left(\frac{4K \,||\, 1M}{8K + 4K \,||\, 1M}\right) = \boxed{1.662\ V}$$

$4K \,||\, 1M = 3.984\ K\Omega$

g. (4 pts) You are now asked to change R1 from 8kΩ to a new value such that the current through resistor R1 is close to 30 ~~m~~ μA. Voltage source V1 is set to 5V. What is your new choice of R1?



$$5V = i\,(R1 + RA)$$

$$\Rightarrow R1 + 4k = \frac{5}{30\mu}$$

$$\Rightarrow \boxed{R1 = 162.67\ k\Omega}$$

h. (2pts) When defining the VSIN component (sinusoidal voltage source), indicate any two (of the four) parameters that are available when you place the part.

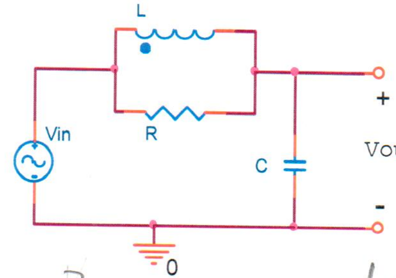
Amplitude Frequency

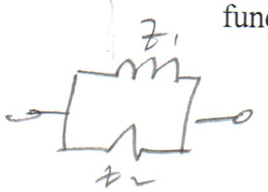
Offset AC

III. Filters & Transfer Functions (20 points) For this problem assume AC Steady State.

a) Use the circuit shown for this part.

1. Find the transfer function of the circuit shown. Simplify such that there are no fractions in the numerator or denominator of the transfer function. H(jω) = Vout(jω)/Vin(jω) (6pts)





$\Rightarrow \frac{1}{Z_{eq}} = \frac{1}{Z_1} + \frac{1}{Z_L} = \frac{1}{j\omega L} + \frac{1}{R}$

$Z_{eq} = \frac{1}{\frac{1}{j\omega L} + \frac{1}{R}} = \frac{j\omega LR}{R + j\omega L}$

$H(j\omega) = \frac{V_{out}}{V_{in}} = \frac{Z_C}{Z_C + Z_{eq}} = \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + \frac{j\omega LR}{R + j\omega L}}$

$H(j\omega) = \frac{R + j\omega L}{R + j\omega L + j^2\omega^2 LRC}$

$H(j\omega) = \frac{R + j\omega L}{R + j\omega L - \omega^2 LRC}$

2. Determine the amplitude and phase of the transfer function for the circuit for very small frequency and for very high frequency. Do not take this to 0 or infinite Hz. (4pts)

w small

$H(j\omega) \simeq \frac{R}{R} = 1\angle 0^0$

amp = 1 angle = 0°

w large

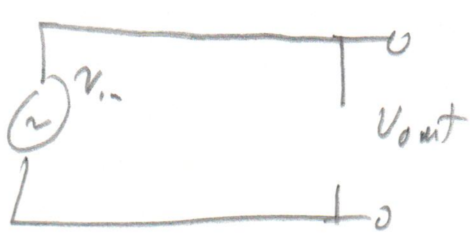
$H(j\omega) \simeq \frac{j\omega L}{-\omega^2 LRC} = \frac{-j}{\omega RC}$

$mag = \frac{1}{\omega RC}$, $Phase = -90^0$

3. Redraw the circuit and simplify the circuit for operation at low and high frequency. For this part you take it to extremes, low frequency is dc operation. High is approaching infinity. (2pts)

Low Frequency

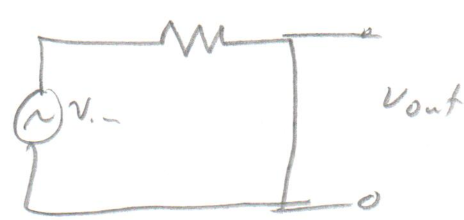
L = short C = open



Note: mag = 1, phase = 0

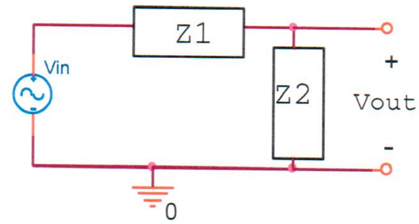
High Frequency

L = open C = short



can't get magnitude Note 0 - phase

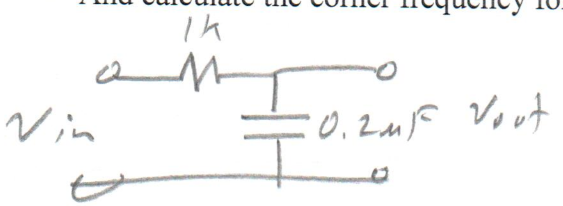
b) In the circuit shown, Z1 and Z2 represent a single component, either a resistor, capacitor or inductor. Complete the table below by entering a Y for yes is that configuration of Z1 and Z2 would be a low pass or a high pass filter. (5pts)



Z1	Z2	Low Pass (Y or N)	High Pass (Y or N)
R	C	Y	N
C	R	N	Y
R	R	N	N
R	L	N	Y
L	R	Y	N

all freq. the same

c) Draw a low pass filter using just a 1kΩ resistor and a 0.2uF capacitor. Label the input and output.
And calculate the corner frequency for this circuit. (3pts)



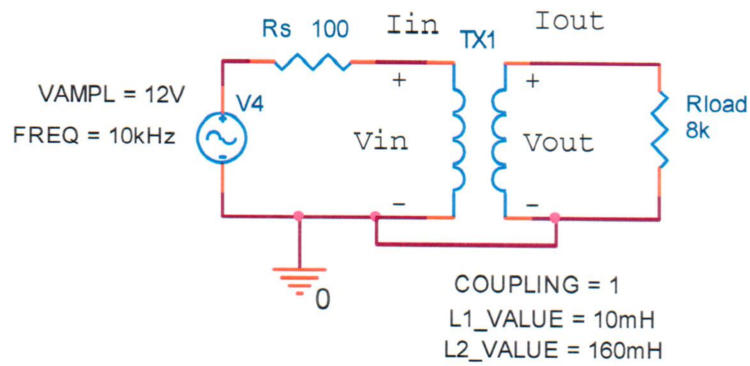
Corner freq $\left|\frac{1}{j\omega C}\right| = R$

or $\omega = \frac{1}{RC} = \frac{1}{(10^3)(2\times10^{-7})}$

$\omega = 5\times10^3$

$f = \frac{\omega}{2\pi} = 796\text{ Hz}$

IV – Phasors and Transformers (20 points)



1) Assume an ideal transformer with full coupling.

a. For the given information, determine the turns ratio, a. And determine the ratios Vout/Vin, Iout/Iin and the transformer input impedance Rin. (Rin is Vin/Iin) (6 pts)

$a = \sqrt{\frac{L2}{L1}} = \sqrt{\frac{160}{10}} = 4$ $\qquad Z_{in} = \frac{Z}{a^2}$

$V_2 = aV_1 \quad \frac{V_{out}}{V_{in}} = 4 \qquad R_{in} = \frac{8000}{16} =$

$I_{out} = \frac{1}{a} I_{in} \quad , \frac{I_{out}}{I_{in}} = \frac{1}{4} = 0.25$

a= 4 (2pt)

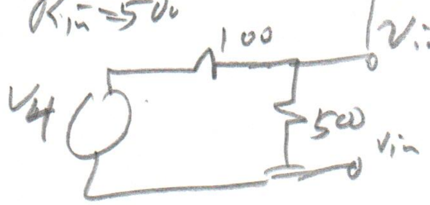
Vout/Vin= 4 (1pt)

Iout/Iin= 0.25 (1pt)

Rin= 500 (2pt)

b. ***Solve for Vin*** (voltage across the input terminals of the ideal transformer) ***and Vout,*** the voltage across the output terminals and the of the ideal transformer. **Assume the phase of V4 is zero degrees and give the answer in the form of v(t)=V₁Cos(ωt+θ₁)** (2 pts)

$R_{in} = 500$



$|V_{in}| = \frac{500}{500+100} \cdot 12 = 10V$

$\angle V_{in} = \angle V_4 = 0$

$\omega = (2\pi)(10^4)$

Vin(t)= $10\cos(2\pi 10^4 t + 0^\circ)$

Vout(t)= $4 \cdot V_{in} = 40\cos(2\pi \cdot 10^4 t)$

OR $= 10\cos(2\pi 10^4 t)$ OR $10\cos(6.3 \times 10^4 t)$

c. Above you were told to assume that the transformer is ideal. For that to be valid, the impedance of the primary inductor should be much larger than the source resistance. Is that valid in this case? Explain or justify. Would it be valid at if the signal source was at 60Hz? (3pts) At 10kHz $|j\omega L| = (2\pi)(10^4)(10^{-2}) = 628\Omega$

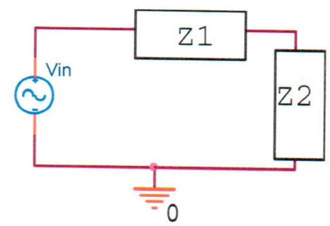
(2pt)

$628\Omega \gg 100\Omega$ – reasonably true so Yes Valid

$|j\omega L|\,/_{60Hz} = 3.8\Omega$ this is much less than 100Ω NO

1pt

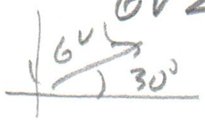
2) Phasors: This circuit shown has 2 complex impedances, Z1 and Z2, connected as shown.
Given: $Vin = 10V\angle 0^o$ and the voltage across Z2 is measured to be $Vz2 = 6V\angle 30^o$



a. Write Vin and Vz2 in Cartesian form. (2pts)

$10V\angle 0^\circ \Rightarrow 10 + j0V = 10V$

$6V\angle 30^\circ \Rightarrow 6\cos\theta + j\,6\sin\theta = (5.2 + j3)V$



b. Determine Vz1, the voltage across Z1 in Cartesian and polar form (3pts)

$\vec{V}_{in} = \vec{V}_{Z1} + \vec{V}_{Z2}$ use Cartesian $\vec{V}_{Z1} = \vec{V}_{in} - \vec{V}_{Z2}$

$= 10 - (5.2 + j3) = (4.8 - j3)V$

$4.8 - j3 \Rightarrow (4.8^2 + 3^2)^{1/2} \angle \tan^{-1}\frac{-3}{4.8} = 5.66\angle -32^0$

c. If Z2 is a 1kΩ resistor, and only a resistor, what is the current through Z2 in both polar and Cartesian form? (3pts)

$\vec{I} = \frac{\vec{V}}{R} = \frac{6\angle 30^0}{1k} = 6\angle 30^\circ (mA)$ (1pt)

$\vec{I} = \frac{5.2 + j3}{1000} = (5.2 + j3)(mA)$ (2pt)

3) Give the names of 2 of the people teaching this course. This can be first names or last names and can be the professors and/or the teaching assistants. (1pt)

see bottom of page – or

Zhizhuo	weston
Liang	Fong
Ruixuan	Melissa
Yan	Shuey
James	Jenn
Cassidy	Krentoffio

spelling doesn't matter