ENGR-2300

Electronic Instrumentation

Quiz 1

Spring 2022

Soln.

Print Name ______________ **RIN** ______________

Section ___

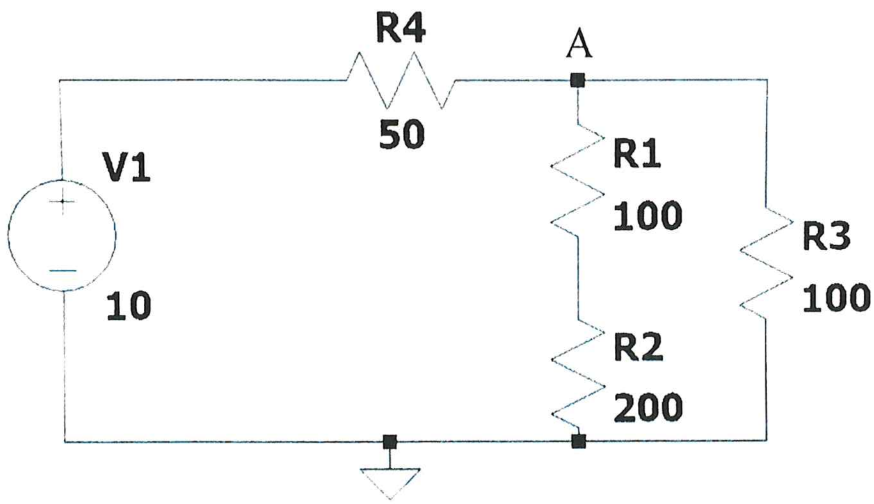
I have read, understood, and abided by the Collaboration and Academic Dishonesty statement in the course syllabus. The work presented here was solely performed by me.

Signature: Soln

Date: ________

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.

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.**



a. (6 pts) What is the voltage at point A in the circuit above?

$R12 = 100 + 200 = 300$

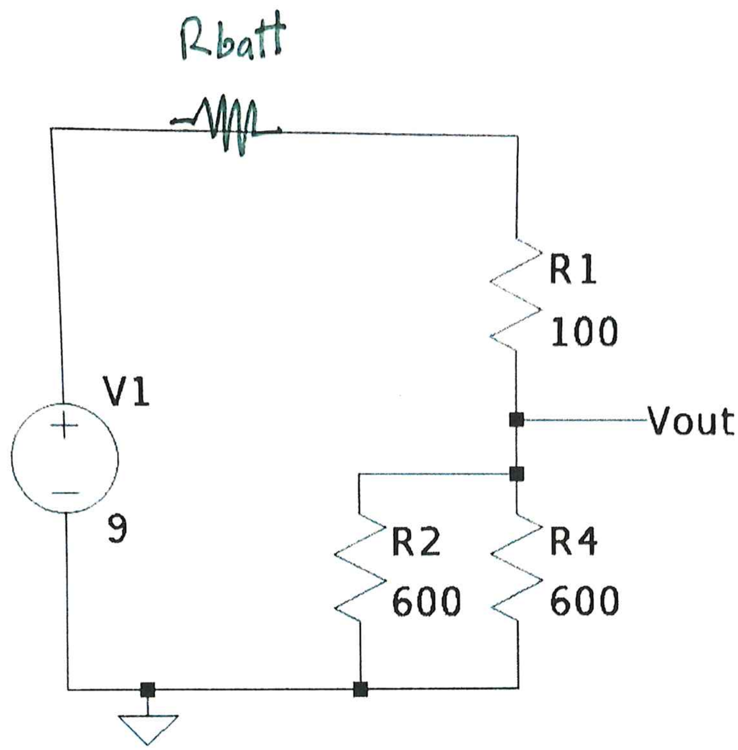
Let $R_{eq} = R_{12} \| R_3$. $R_{eq} = \frac{R_{12} \cdot R_3}{R_{12} + R_3} = \frac{300 \cdot 100}{300 + 100} = 75\Omega$

$V_A = V_1 \frac{R_{eq}}{R_4 + R_{eq}} = 10 \cdot \frac{75}{50 + 75} = 6V$

b. (4 pts) What is the current through R4?

Voltage across $R_4 = V_1 - V_A = 10V - 6V = 4V = V_{R4}$

$I_{R4} = \frac{V_{R4}}{R_4} = \frac{4}{50} = 80mA$



c. (2 pts) In the circuit above, the voltage source represents some 9-volt battery with battery resistance R_{batt}, which is not shown. Draw R_{batt} in the correct location in the circuit above. (This may require you to draw a resistor overtop of a wire.)

d. (4 pts) You use a voltage probe with a very high input resistance to measure V_{out} and you find it to be 6.4V. What is the value of R_{batt}?

$R_2 \| R_4 = \frac{R_2 \cdot R_4}{R_2 + R_4} = 300\,\Omega$ $V_{out} = 6.4 = 9 \cdot \frac{300}{300 + 100 + R_{batt}}$

$6.4 \cdot 400 + 6.4 \cdot R_{batt} = 9 \cdot 300$ $R_{batt} = 21.875\,\Omega$

e. (2 pts) Suppose that you instead measured V_{out} using a voltage probe with much lower input resistance. How would this affect the voltage measured at V_{out}?

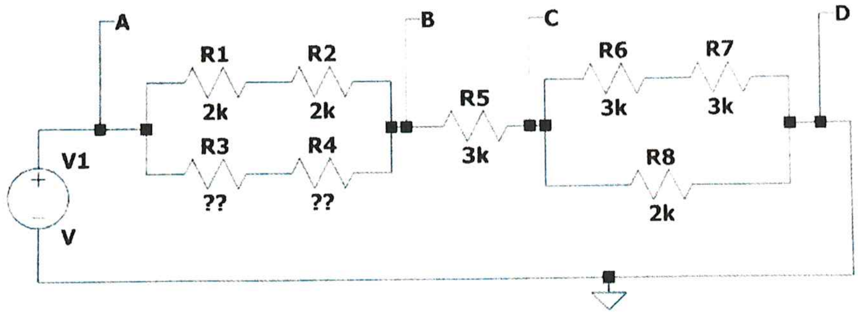
This would cause the measured voltage to drop.

f. (2 pts) Name one reason that two 9-volt batteries might have different resistances.

One battery may be more depleted than another.

II. Resistor Combinations, concepts and miscellaneous (20 points) *Note: Page 2 of this quiz has background information. The crib sheet may also be useful.*

The following circuit consists of 8 resistors and there are 4 voltage markers at points A, B, C, and D. V1 is a DC voltage source which can be created using W1 of the instrumentation board. **Note:** several of the following questions are independent of each other, but not all.



a. (4 pt) It is desired to have the effective **resistance of R3 combined with R4 to be 4.8kΩ.** Using the table on page 2 of this quiz, standard 5% resistor values, **pick resistors for R3 and R4**. State the resistance of each. If these resistors have 5% tolerance, what is the 4-band color code for each resistor? You should note that 4.8k isn't a standard value.

One option:

R3 value: 3.0 K Color bands: orange black red gold

R4 value: 1.8k Color bands: brown gray red gold

b. (3 pts) If the voltage is measured to be 2.5V at point B, what is the current through R7, R8, and R5? Be sure to include units on all answers.

answer on next page

I(R7) 0.139 mA

I(R8) 0.417 mA

I(R5) 0.556 mA

c. (2 pts) What is the equivalent resistance between points A and B? Call this R_{AB}. Use part a. for the values of R3 and R4,

$$R_{AB} = \frac{(R_1+R_2)(R_3+R_4)}{R_1+R_2+R_3+R_4} = \frac{(4k)(4.8k)}{4+4.8k}$$

R_{AB} 2182 Ω

R_{total} between B and D is: $R_5 + \frac{(R_6 + R_7) R_8}{R_6 + R_7 + R_8} = 4500\,\Omega$

$$\frac{2.5V}{4500\,\Omega} = 0.556 \text{ mA} = I_5$$

$0.556\text{mA} \cdot R_5 = 1.667\text{ V}$ Voltage at C is $2.5V - 1.667V = 0.8$

$$I_8 = \frac{0.833V}{R_8} = 0.417 \text{ mA}$$

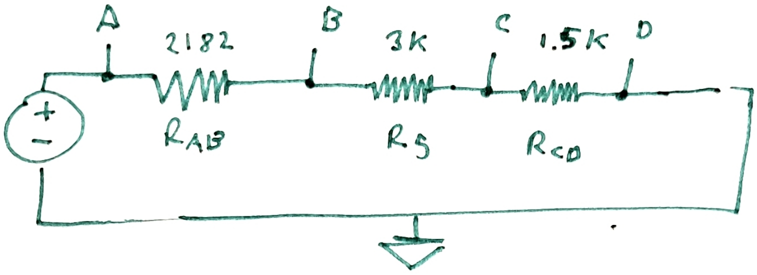
$$I_7 = \frac{0.833V}{R_6 + R_7} = 0.139 \text{ mA}$$

d. (2 pts) What is the equivalent resistance between points C and D, Call this R_{CD}.

$$R_{CD} = \frac{(R_6 + R_7) R_8}{R_6 + R_7 + R_8} = \frac{6k \cdot 2k}{6k + 2k} = 1500$$

R_{CD} 1500 Ω

e. (2 pts) Redraw the circuit with 3 resistors, R_{AB}, R5, R_{CD}. Label the resistor values and mark points A, B, C, and D.



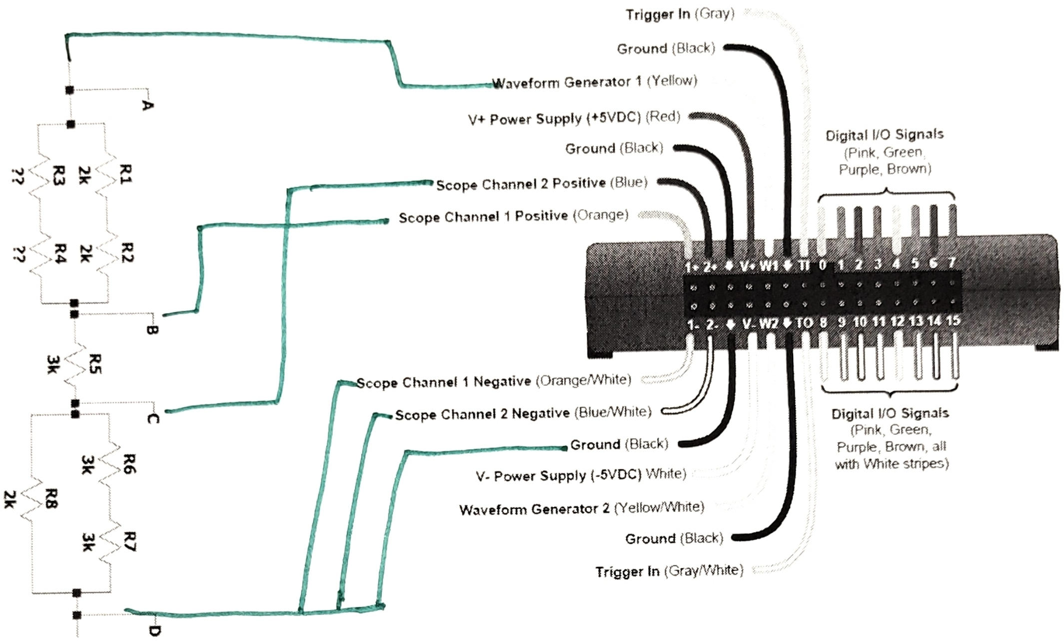
f. (2 pts) Using the figure you drew for part e., if V1=4V what is the voltage at point B?

$$I_B = \frac{V_1}{R_{AB} + R_5 + R_{CD}} = \frac{4}{2182 + 3k + 1.5k} = 0.599\,mA$$

$V_B =$ 2.69 V

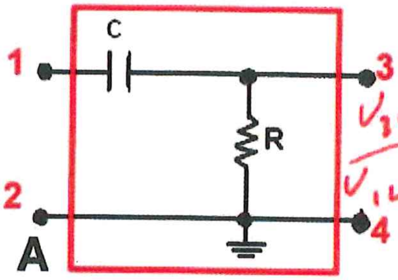
$$V_B = 4V - R_{AB} \cdot I_B = 4 - (2182)(0.599 \times 10^{-3}) = 2.69\ V$$

g. (5 pts) Wire this circuit shown for part a. by drawing lines on the figure below. Use the wave gen/signal gen to provide a signal for V1, which is point A. Use channel 1 to measure the signal at point B and use channel 2 to measure the signal at point C.

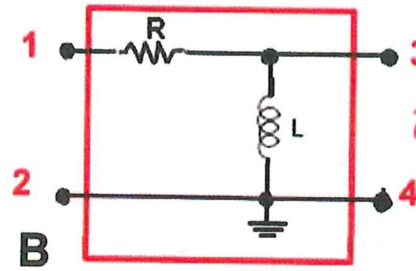


Draw lines between the 2 figures to indicate wires. Both the M2K and the AD2 have the same wiring and colors. W1 is called Signal Generator on the M2K and Waveform Generator on the AD2.

III. Filters & Transfer Functions (20 points) For this problem, assume AC steady state.



$\frac{V_{34}}{V_{12}} = \frac{R}{R+\frac{1}{j\omega C}} = \frac{j\omega RC}{1+j\omega RC}$



$\frac{V_{34}}{V_{12}} = \frac{j\omega L}{R+j\omega L}$

1) Filters: Use figures A and B above to answer the following questions:

a) (2pts) Shown above are basic, two-element, passive filter configurations made with CR and RL combinations. Determine the general complex transfer function for each circuit in terms of R, L, C and frequency ω, by modeling each as a voltage divider. This is an AC steady state problem.

A) CR: $\frac{V_{OUT}}{V_{IN}} = \frac{V_{34}}{V_{12}} = \frac{j\omega RC}{1+j\omega RC}$

B) RL: $\frac{V_{OUT}}{V_{IN}} = \frac{V_{34}}{V_{12}} = \frac{j\omega L}{R+j\omega L}$

b) (2pts) For both circuits, what are the magnitude and phase for low but not zero phase? (frequency)

Circuit A mag $= \frac{\omega RC}{1} = \omega RC$

phase $= j = 90°$

Circuit B mag $= \frac{\omega L}{R}$

phase $= 90°$

c) (2pts) What type of filter is each? Choices are as shown on the Crib Sheet: low pass, high pass, band pass or band reject.

Circuit A ~~Low~~ High pass

Circuit B high pass

d) (4pts) Given: L=40mH, R=2kΩ, and C=0.20nF Find the corner frequency or this question for each circuit. Give the value of both ω_C and f_C.

Circuit A

corner when $|1| = |j\omega RC|$

$\omega = \frac{1}{RC} = 2.5\times10^6$ radian/sec

$f = 398$ kHz

Circuit B corner $R = |j\omega L|$

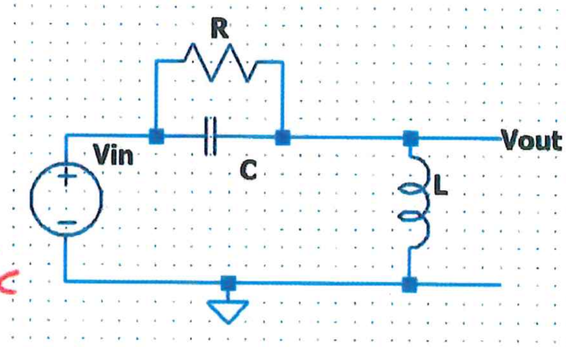
$\omega = R/L$

$\omega = 5\times10^4$ radians/sec

$f = 7.96$ Hz

2) Transfer functions: Use the figure shown to answer the following questions

a. (5 pts) 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)



$$R /\!/ \frac{1}{j\omega C} = \frac{R/j\omega C}{R + 1/j\omega C} = \frac{R}{1+j\omega RC}$$

$$V_{out}/V_{in} = \frac{j\omega L}{j\omega L + R /\!/ \frac{1}{j\omega C}} = \frac{j\omega L}{j\omega L + \frac{R}{1+j\omega RC}} = \frac{j\omega L + j^2\omega^2 RLC}{j\omega L + j^2\omega^2 RLC + R}$$

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

b. (4 pts) What is the magnitude and phase of the transfer function when the frequency is very small (approaches zero)? And what is the magnitude and phase of the transfer function when the frequency is very large (approaches infinity)?

ω small $H(j\omega) \sim \frac{j\omega L}{R}$ mag $= \frac{\omega L}{R}$ phase $= 90°$

ω large. $H(j\omega) \sim 1$. mag $= 1$. phase $= 0$.

c. (1 pts) Is it possible for the magnitude of the transfer function to be greater than unity?

Circle one: (Yes) or No

RLC resonance

For example, let $\omega^2 = \frac{1}{LC}$

$$H(j\omega) = \frac{j\frac{L}{\sqrt{LC}} + \frac{1}{LC}\cdot R\cdot LC}{j\omega L + (R - \frac{1}{LC}\cdot R\cdot LC)}$$

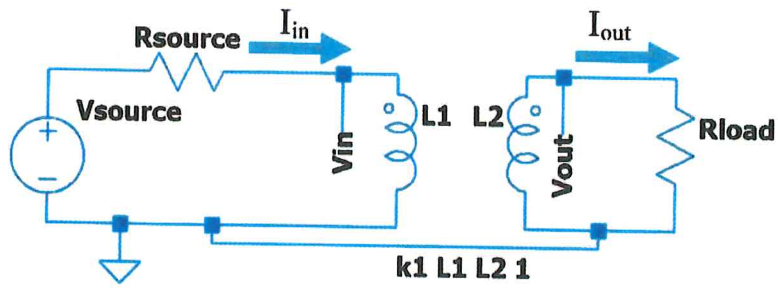
$$= \frac{j\sqrt{\frac{L}{C}} + R}{j\sqrt{\frac{L}{C}}}$$

$$H(j\omega) = \frac{\sqrt{\left(\frac{L}{C}\right)^2 + R^2}}{\sqrt{\left(\frac{L}{C}\right)^2}}$$

|numerator| > |denominator|

Soln.

IV – Phasors and Transformers (20 points)



1) Assume L1 and L2 form an ideal transformer with full coupling. The transformer has these specifications: **L1= 180mH, L2=20mH, Rsource=90Ω, Rload=20Ω**

a. (8pts) For the given information, determine the turns ratio, a. And determine the ratios Vout/Vin, Iout/Iin and the transformer input resistance, **Rin. (Rin is Vin/Iin)** This isn't the resistance seen by Vsource.

$a = \sqrt{\frac{L_2}{L_1}} = 0.33$ $\quad \frac{V_{out}}{V_{in}} = a = 0.33$

$\frac{I_{out}}{I_{in}} = \frac{1}{a} = 3$ $\quad R_{in} = \frac{R_{load}}{a^2} = 9 \cdot R_{load}$

$= 9 \cdot 20 = 180\Omega$

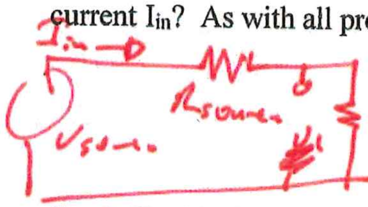
a= 0.33

Vout/Vin= 0.33

Iout/Iin= 3

Rin= 180Ω

b. (2pts) If Vsource is a sinewave with a 10V amplitude at 5kHz, what is the amplitude of current I_{in}? As with all problems, include units and show your work for partial credit.



$|I_{in}| = \frac{|V_{source}|}{R_{source} + R_{in}}$

$= \frac{10}{90+180} = 37mA$

I_{in}(amplitude)= 37mA

c. (3pts) The ideal transformer model assumes that self-inductance L1 and L2 are infinite, |jωL1| and |jωL2| approach infinity. On the practical side the transformer is close to ideal if |jωL1| >10*Rsource and |jωL2| >10*Rload. Just looking at L2, for what range of frequencies will this transformer be close to the ideal?

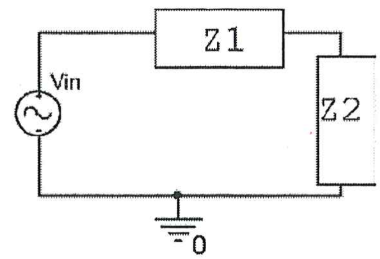
$\omega \cdot L2 > 10 \cdot R_{load}$

$\omega > \frac{10 \cdot R_{load}}{L_2} = \frac{10 \cdot 20}{.02} = 10{,}000$ radians/sec

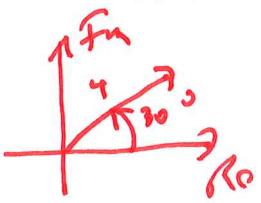
$f = \frac{10^4}{2\pi} = 1.59kHz$

Conditions on f: 1.59 kHz

2. Phasors: This circuit shown has 2 complex impedances, Z1 and Z2, connected as shown.
Given the polar form of the phasor of Vin: $Vin = 10V\angle 0^o$ where 10 is the amplitude and 0^o is the phase angle. And that phasor for Vz1 is $Vz1 = 4V\angle 30^o$ (Again this format is a magnitude and a phase angle.)



a. (1pts) Give Vz1 in Cartesian form, Vz1 = a +jb, find a and b.



$a = Re = 4\cos 30^\circ = 3.46$ $\quad a = 3.46,\ b = 2$

$b = Im = 4\sin 30^\circ = 2$ $\quad V_{Z1} = (3.46 + 2j)$ Volts

b. (2pts) If Z1 is made of just two components, one of which is a resistor, is the other a capacitor or an inductor?

Phase of Z1 is positive ⇒ Inductor

(series R–L) $Z = R + j\omega L$ ⇒ positive phase

(parallel R–L) $Z = \frac{j\omega LR}{R + j\omega L}$ phase of Z = phase of numerator − phase of denominator = 90 − (something less than 90°)

phase of Z = positive

RC will have a negative phase

c. (3pts) Determine Vz2, the voltage across Z2 in Cartesian and polar form.

$V_{in} = V_{Z1} + V_{Z2}$ use Cartesian $10 + j0 = 3.46 + j2 + V_{Z2}$

$V_{Z2} = 6.54 - 2j$

Polar $|V_{Z2}| = \sqrt{6.54^2 + 2^2} = 6.84$ $\quad 6.84\angle -17^\circ$

$\angle V_{Z2} = \tan^{-1}\frac{2}{6.54} = -17^\circ$

3. (1pt) Give the names of 2 of the people teaching this course. This can be first names or last names and can be the professors, teaching assistants, or undergraduate student assistants. Spelling doesn't count. Using their Discord name is also valid.

Paul, Schoch, Dylan, Rees, Zhizhao, Liang, Saad, AliReza, Sagdipta, Paul, Derek, Chen, Xinyu, Jiang, Chris, Salerno, Amy, Fraser, Kim, Davis