ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2015

Name _____ Sol'n. _____

Section ___

Question I (20 points) _____

Question II (20 points) _____

Question III (20 points) _____

Question IV (20 points) _____

Question V (20 points) _____

Total (100 points) _____

On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES <u>AND UNITS</u>. 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.

EI   1   *P. Schoch*

P. Schoch
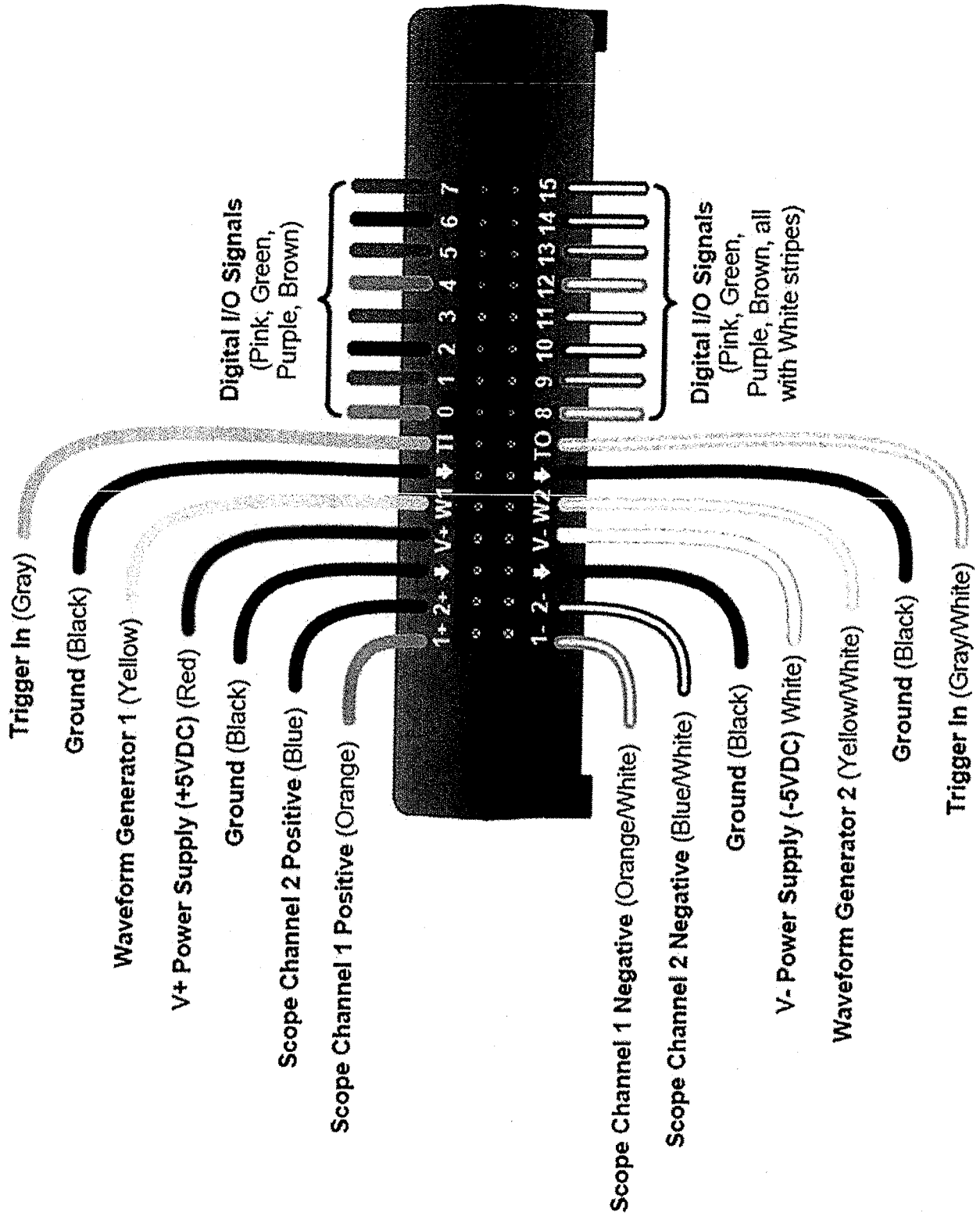
| Type	R_{int} (Ω)	V_{oc} (V)	Capacity[a] continuous, to 1V/cell				Size (in)	Weight (gm)	Connec[b]	Comments
			(mAh)	@ (mA)	(mAh)	@ (mA)				
9V "1604"										
Le Clanche	35	9	300	1	160	10	0.65x1x1.9	35	S	
Heavy Duty	35	9	400	1	180	10	"	40	S	
Alkaline	2	9	500	1	470	10	"	55	S	280mAh@100mA
Lithium	18	9	1000	25	950	80	"	38	S	Kodak Li-MnO$_2$

Partial specs for Agilent 54830 Oscilloscope $3995 on eBay. The company was HP, which split and Agilent became the instrumentation manufacturer, and now it is Keysight.

Vertical : Analog Channels	54830B, 54831B, 54832B, 54830D, 54831D and 54832D	54845B and 54846B
Input Channels	54830B: 2 analog 54830D: 2 analog + 16 digital 54831B/54832B: 4 analog 54831D/54832D: 4 analog + 16 digital	4 analog
Analog Bandwidth @50 Ω (-3 dB)[*1] Calculated Rise Time[2] @50 Ω	54830B/D, 54831B/D: 600 MHz 54832B/D: 1 GHz 54830D/B, 54831B/D: 583 ps 54832B/D: 350 ps	54845B: 1.5 GHz 54846B: 2.25 GHz 54845B: 233 ps 54846B: 178 ps
Input Impedance*	1 MΩ ± 1% (13 pF typical).	1 MΩ ± 1% (12 pF typical).
Sensitivity[3]	1 mV/div to 5 V/div (1 MΩ) 1 mV/div to 1 V/div (50 Ω)	2 mV/div to 2 V/div (1 MΩ) 1 mV/div to 1 V/div (50 Ω)

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

    a) Find the voltage V_{out} in the circuit below. (4 pts)
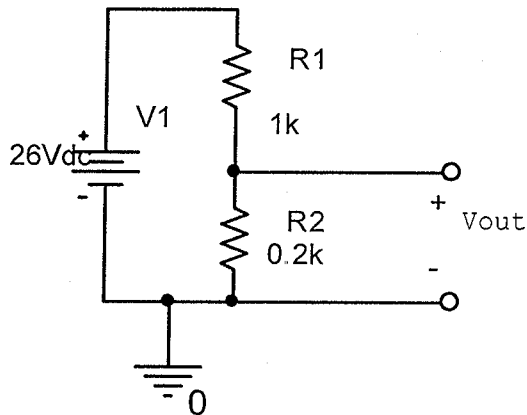
$$V_{out} = \frac{R2}{R1+R2} \cdot V1 = \frac{0.2k}{1.2k} \cdot 26$$

$$V_{out} = 4.33\,V$$

    b) Find the current I in resistor R2. (4 pts)

$$I = \frac{V1}{R1+R2} = \frac{26}{1.2k} = 21.7\,mA$$
$$= 0.0217\,A$$

    c) Find the power dissipated by R2 (4pts)

$$P = VI = I^2 R = V^2/R$$

$$4.33 \cdot 0.0217 = 94\,mW$$

$$P = \frac{4.33^2}{200} = 93.9\,mW \approx 94$$

    d) Find the power dissipated by R1 (4pts)

$$P_1 = I^2 R1 = (0.0217)^2 (1000)$$
$$= 467\,mW$$

    e) Which of the following types of resistors will work for in this experiment? Assume that both resistors are of the same type, and then circle all possible answers. (4 pts)
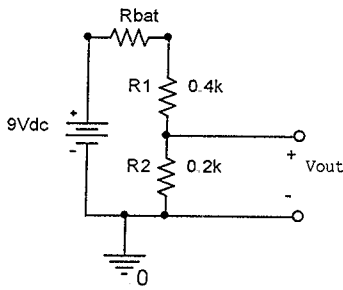
1/4W   ⟨1/2W⟩   ⟨1W⟩   ⟨2W⟩

R1 must be ½ w or higher power
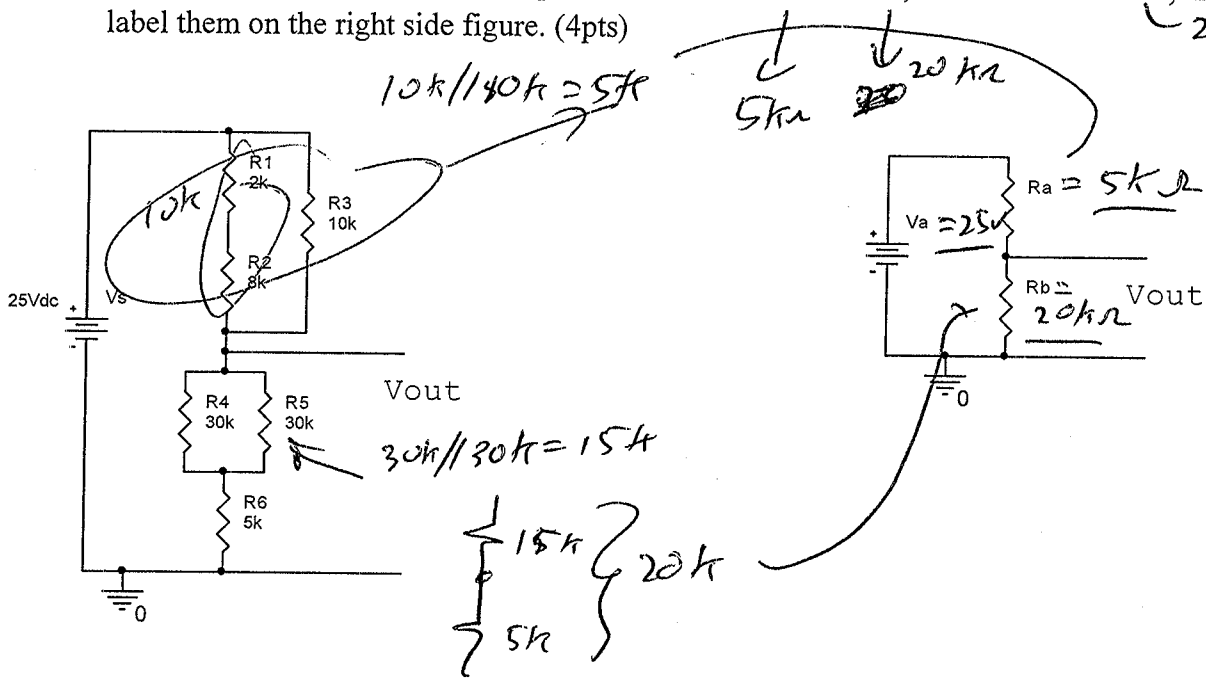
II. Resistor Combinations and loading (20 points)

This circuit uses as Heavy Duty 9V battery.

a) Find Vout for the circuit shown on the left. Provide 3 significant digits in your answer. *Hint: Be sure to check the additional information provided with this quiz.* (4pts)

$$R_{bat} = 35\Omega$$

$$V_{out} = \frac{R2}{R_{bat} + R1 + R2} \cdot 9 V_{dc}$$

$$V_{out} = \frac{200}{200 + 400 + 35} \cdot 9v = \underline{2.83V}$$

b) For the circuit below, reduce the circuit to the form of the circuit shown on the right. In other words, find the values for equivalent resistors Ra and Rb, and the value of Va, and label them on the right side figure. (4pts)

$$10k // 40k = 5k$$

$$5k\Omega \quad 20k\Omega$$

$$2.5v$$

$$Ra = 5k\Omega$$

$$Va = 25v$$

$$Rb = 20k\Omega \quad Vout$$

25Vdc

$$30k // 30k = 15k$$

$$\left\{ \begin{array}{c} 15k \\ 5k \end{array} \right\} 20k$$

Vout

c) What is the value of Vout for the circuit in part b) ? (2pts)

$$V_{out} = \frac{R_b}{R_a + R_b} \cdot V_a = \frac{20}{5 + 20} \cdot 25 = \underline{20 V}$$

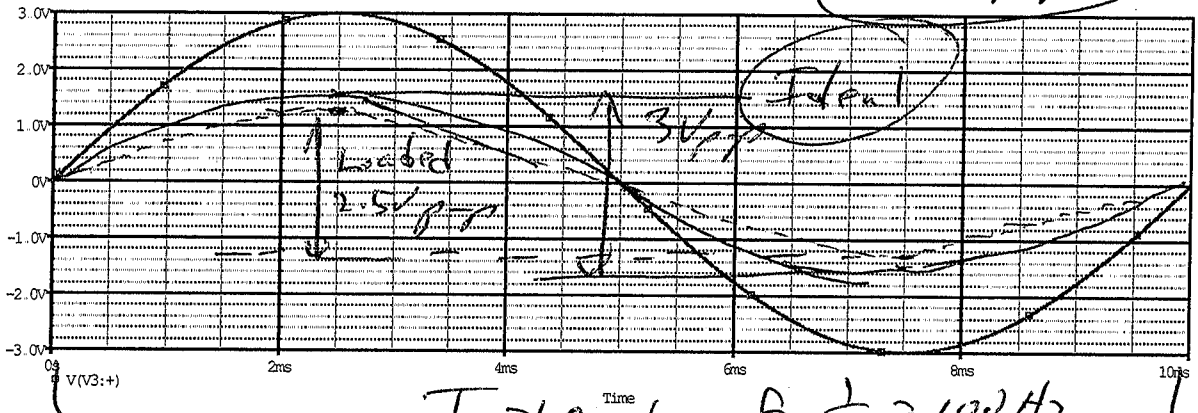**d)** You want to get the time trace of the voltage signal across Rb in the circuit below. (10pts for all 4 parts)
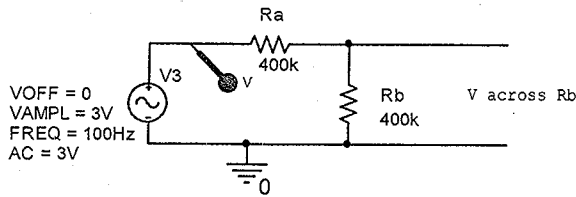
Part 1: Ideal Oscilloscope. The trace below is the signal V3. Sketch V across Rb if you have an ideal Oscilloscope, (or ideal Analog Discovery Board). You must label that amplitude of your trace in addition to sketching the curve. (2pts)
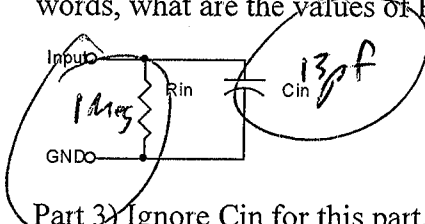
Circuit:
- Ra 400k
- VOFF = 0, VAMPL = 3V, FREQ = 100Hz, AC = 3V
- V3
- Rb 400k — V across Rb
- ground 0

$$V_{Rb} = \frac{R_b}{R_a + R_b} \cdot V3 = 0.5 \, V_{amp} = 1.5 V_{amp}$$
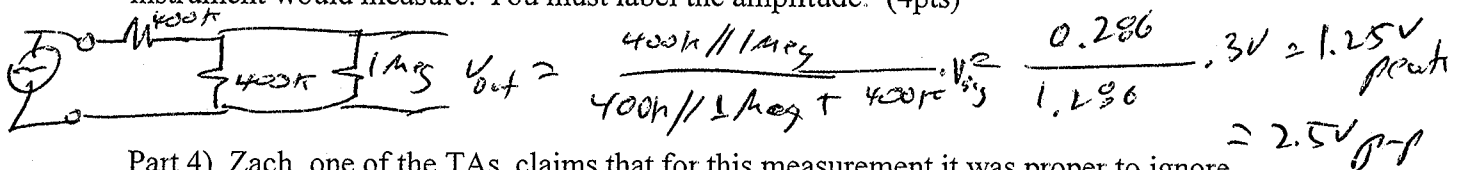
$$\cancel{3V} = 3V_{p-p}$$

$$T = 10 \text{ ms}, \quad f = \frac{1}{T} = 100 \text{ Hz}$$

Part 2: You can use an Agilent 54830 Oscilloscope. Using the additional information provided with this exam, what is the input circuit model for this instrument? In other words, what are the values of Rin and Cin for the circuit below? (2pt)

- Input
- Rin 1 Meg
- Cin 13pf
- GND

Part 3) Ignore Cin for this part. The Agilent 54830 is used to measure the voltage across Rb, (circuit at top of page.) On the plot for Part 1, add a sketch of the trace that this instrument would measure. You must label the amplitude. (4pts)

400k ... 400k ∥ 1 Meg

$$V_{out} = \frac{400k \parallel 1 Meg}{400k \parallel 1 Meg + 400k} \cdot V = \frac{0.286}{1.286} \cdot 3V = 1.25 V_{peak}$$

$$= 2.5 V_{p-p}$$

Part 4) Zach, one of the TAs, claims that for this measurement it was proper to ignore Cin of the Agilent 54830. Is Zach correct and why? Hint: Zach is usually correct and he suggested that you calculate the magnitude of Z for Cin for this experiment. (2pts)

$$\left| \frac{1}{j \omega c} \right| = \frac{1}{\omega c}$$

$$\omega = 2\pi \cdot 100 \quad C = 13 \times 10^{-12}$$
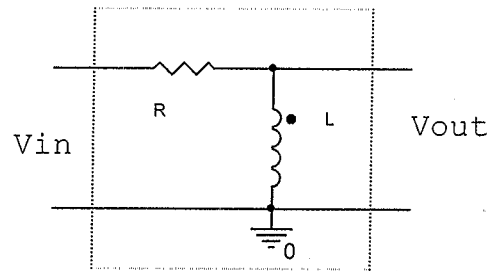
$$\frac{1}{\omega c} = 122 \times 10^{6}$$

$|Z|$ of cap is $\gg R_a$
$\gg R_b$
$\gg R_{in}$

effectively 0 current in cap, can be ignored *P. Schoch*

Yes

E I

6

III. Filters & Transfer Functions (20 points) Assume that these circuits are in AC Steady State.

a) Determine the general complex transfer function for this circuit in terms of R, L, and frequency ω, by modeling the circuit as a voltage divider. (1 pt)

$$\frac{V_{out}}{V_{in}} = \frac{j\omega L}{R + j\omega L}$$

Vin   R   L   Vout

b) Find the magnitude and phase angle of the transfer function given R=1kΩ, L=20mH, and the frequency of the input signal is f=1.6kHz. (2pts) $\omega = 2\pi f = 10,000$ (3 sign. fig) $= 10,053$

$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{\omega L}{|R + j\omega L|} = \frac{\omega L}{(R^2 + \omega L^2)^{1/2}} = 0.196$$

$0.196 \angle 11.3°$, $2 \angle 11°$, $2 \angle 0.2 \text{ radius}$

$\angle \frac{V_{out}}{V_{in}} = \angle j\omega L - \angle(R + j\omega L)$ $90° \quad tan^{-1}\frac{\omega L}{R}$ $78.7°$

$90 - 78.7 = 11.3°$

c) Using the results of part b) what is the time domain equation for Vout if Vin=10Vsin(2π1600t+0°) Vout must have the form of Vout=Asin(ωt+θ) (2pts)

$$V_{out} = |V_{in}| \cdot |H(j\omega)| = (10)(0.196) = 1.96 \approx 2$$ OR 0.2 radius

$$V_{out} = 2V \sin(2\pi 1600t + 11.3°)$$ OR 0.2 radius

d) Assume the components are ideal. Identify this as a low pass or high pass filter by circling the correct answer. (1pt)   Low Pass   (High Pass)

E I   7   P.

e) Determine the general complex transfer function for this circuit in terms of R, C, and frequency ω, by modeling the circuit as a voltage divider. (1 pts)

Vin   Vout

C   R   0

$$\frac{V_{out}(j\omega)}{V_{in}(j\omega)} = \left(\frac{R}{R + \frac{1}{j\omega c}}\right) \quad OR \quad \left(\frac{j\omega RC}{1 + j\omega RC}\right)$$

f) Find the magnitude and phase angle of the transfer function given R=1kΩ, C=0.1uF, and the frequency of the input signal is f=1.6kHz. (2pts) $\omega RC = 1$

$$\omega = (2\pi)(1600)$$
$$R = 1000$$
$$C = 0.1\mu F$$

$$|H(s)| = \frac{|j\omega RC|}{|1 + j\omega RC|} = \frac{\omega RC}{(1^2 + \omega^2 R^2 c^2)^{1/2}} = \frac{1}{(1+1)^{1/2}} = 0.707$$

$$\angle H(s) = \angle j\omega RC - \angle(1 + j\omega RC) = 90° - 45° = 45°$$
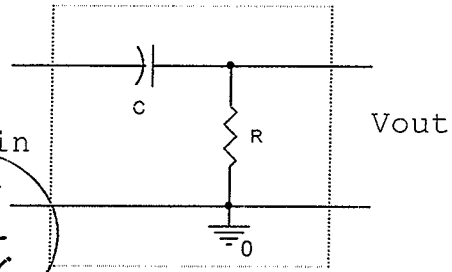
g) Using the results of part b) what is the time domain equation for Vout if   or π/4   or 0.79 rad.
Vin=10Vsin(2π1600t+0°) Vout must have the form of Vout=Asin(ωt+θ) (2pts)

$$|V_{out}| = |H(j\omega)||V_{in}| = 0.707 \cdot 10 = 7.07 \quad OR \quad π/4$$
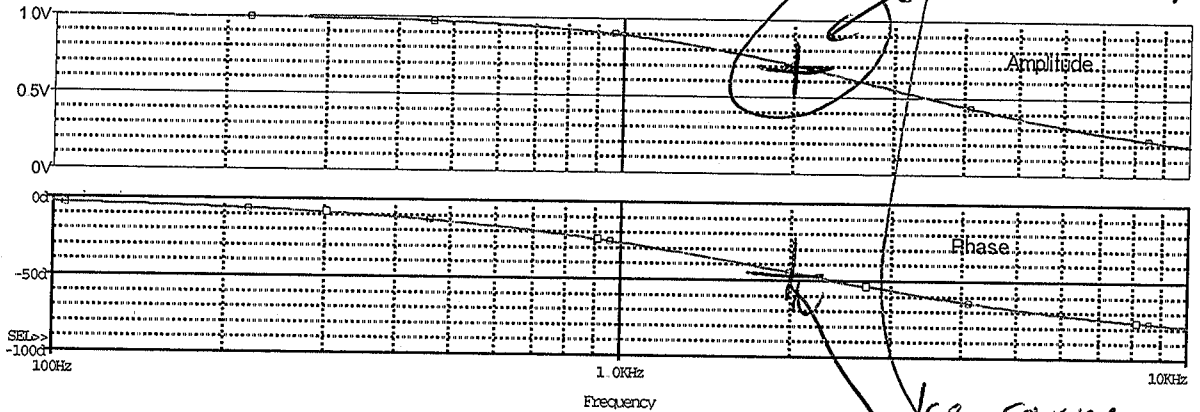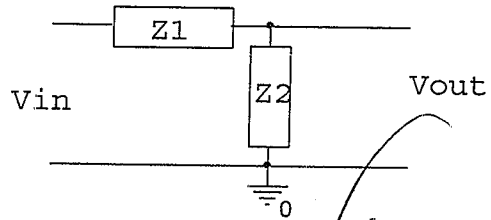
$$V_{out} = 7.07 V \sin(2\pi \, 1600 \, t + 45°)$$

h) Assume the components are ideal. Identify this as a low pass or high pass filter by circling the correct answer. (1pt)   Low Pass   (High Pass)

i) In the diagram, Z1 and Z2 each represent one ideal R, L, or C. There are only 2 components total. The plots below are the amplitudes and phase of the transfer function, $H(j\omega) = Vout(j\omega)/Vin(j\omega)$


Part 1: Mark and label the corner frequency for this circuit on the plots. (2pts)
Part 2: What is the magnitude and phase of $H(j\omega)$ at the corner frequency? (2pts)
Part 3: Determine if Z1 is a resistor, capacitor or inductor and determine its value. (2pts)
Part 4: Determine if Z2 is a resistor, capacitor or inductor and determine its value. (2pts)

only need to label 1 of these plots

Answer Parts 2, 3 and 4 below:

Part 2 $\left| H(j\omega) \right|_{corner\,freq} = 0.7$ $\angle H(j\omega)\big|_{corner} = -45°$ or $-\pi/4$
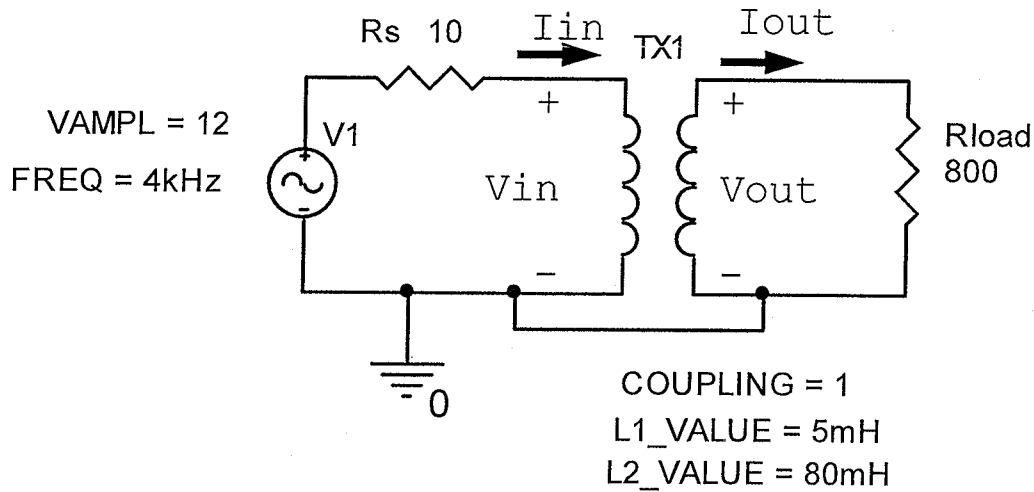
Part 3   Low Pass

H.P.   H.P.   LP   LP
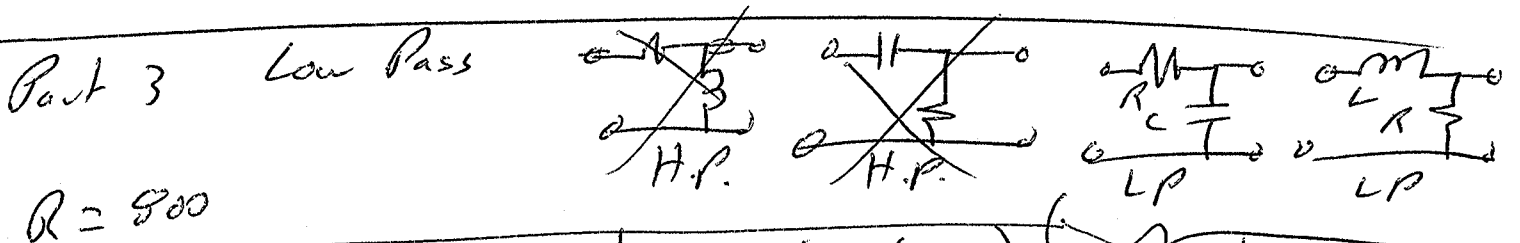
$R = 800$

$RC \Rightarrow$ corner at $\omega = \frac{1}{RC}$ $\omega = (2\pi)(2000)$
$R = 800$

$C \approx 0.1\mu F$

OR

$LR \Rightarrow$ corner at $\omega = \frac{R}{L}$ $L = \frac{V}{R} = \frac{(2\pi)(2000)}{800} =$

$L = \frac{R}{\omega} = \frac{800}{2\pi \cdot 2000} \approx 64 \mu H$

choose one of these

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IV – Signals, Transformers and Inductors (20 points)

Rs 10   Iin   TX1   Iout

VAMPL = 12

FREQ = 4kHz

V1   + Vin   + Vout   Rload 800

COUPLING = 1
L1_VALUE = 5mH
L2_VALUE = 80mH

Given the circuit above, assume an ideal transformer with full coupling (until part e). In your answers to the following questions, use all available and useful information.

a) For the given information, write out the expressions for the ratios Vout/Vin, Iout/Iin and the transformer input impedance Rin. (Rin is Vin/Iin) (6 pts)
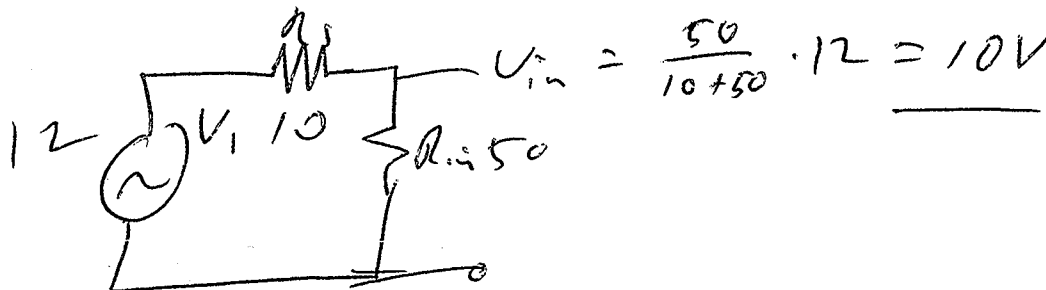
$$a = \sqrt{\frac{L_2}{L_1}} = \sqrt{\frac{80}{5}} = 4$$

$$R_{in} = \frac{R_{load}}{a^2} = \frac{800}{16} = 50\,\Omega$$

$$\frac{V_{out}}{V_{in}} = a = 4$$

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

b) Draw the circuit diagram for the voltage divider consisting of the transformer input impedance Rin and the resistance Rs. Then solve for Vin, the voltage across the input terminals of the ideal transformer. (4 pts)

$$V_{in} = \frac{50}{10+50} \cdot 12 = 10V$$

$$R_{in} = 50$$

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c) Find Vout from your value for Vin. (3 pts)

$$V_{out} = a \, V_{in} = 4 \cdot 10 = 40V$$

d) Determine both the primary and secondary currents (Iin and Iout). (4 pts)

from part b) $I_{in} = \dfrac{V_{in}}{R_{in}} = \dfrac{10}{50} = 0.2A$

$$I_{out} = \dfrac{I_{in}}{a} = \dfrac{0.2}{4} = 0.05A = 50mA$$

OR $I_{out} = \dfrac{V_{out}}{R_{load}} = \dfrac{40}{800} = 50mA$ . . . .

e) Up to this point, the ideal transformer model has been used. Check to determine if this assumption is valid. Compare the magnitude of the impedance for L1 to Rs and compare the magnitude of the impedance for L2 to Rload. Is it reasonable to use the ideal transformer model? Justify your conclusion.(3 pts)

$|j \omega L_1| \gg R_s$ $|j\omega L_2| \gg R_{load}$

$\omega = 2\pi \cdot 4000 \quad L_1 = 5mH$ $\omega = 2\pi \cdot 4000 \, rad/s \quad L_2 = 80mH$

$\omega L_1 = 126\Omega$ $\omega L_2 = 2010\Omega$

this is much   2010 isn't that much
larger than R_s larger than 800

so answer is Yes it
is reasonable

OR Better to say
it is marginal and
a pspice analysis
is appropriate

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V – Misc & Concepts (20 points)

The following questions mostly come from the daily videos and class discussion. The answers for all questions are worth (1 pt) each, except where noted.

a) What are the colors & names of the two wires for 'Scope Ch1?

Orange   1+ or channel 1 positive
Orange/white   1- or channel 1 negative

b) What are the colors & names of the two wires for 'Scope Ch2?

Blue   2+ or channel 2 positive
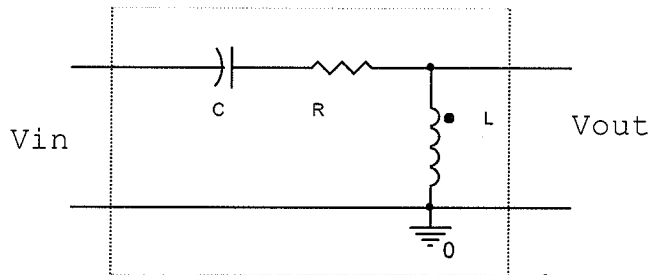Blue/white   2- or channel 2 negative

c) What are the colors & names of the two wires for Waveform Generator 1 (W1)?

Yellow   W1 or Waveform Generator 1
Black   Ground   (any black)

d) Is it always necessary to measure both the input and output voltage or current for every circuit studied?

Yes

e) What is the transfer function for this circuit? Leave it as a ratio of polynomials of ω. (2pts)

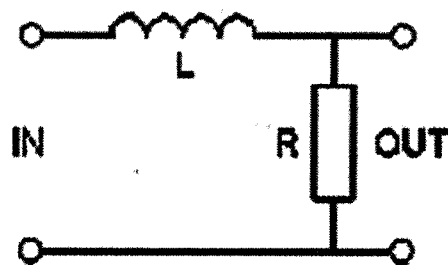$$\frac{Vout}{Vin} = \frac{j\omega L}{R + \frac{1}{j\omega c} + j\omega L}$$

OR

$$\frac{-\omega^2 L c}{j\omega c R - \omega^2 L c + 1} \Rightarrow \frac{-\omega^2 L c}{-\omega^2 L c + j\omega R C + 1}$$

f) For the circuit in part e), what is the transfer function for small ω? (Small but not zero.)

Keep lowest power of ω in numerator & denominator

$$H(j\omega) \approx \frac{-\omega^2 L c}{1}$$

g) What is the magnitude and phase of the transfer function for the LR circuit shown to the right at high (not infinite) frequencies?

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

at large ω $H(j\omega) \approx \frac{R}{j\omega L}$

$$Mag = \frac{R}{\omega L} \quad phase = \angle j^{-1} = -90° \text{ or } -\frac{\pi}{2} \text{ radians}$$

E I   P. Schoch

h) What is the input impedance of an Analog Discovery scope channel?

$1M\ \Omega$

i) What is a typical internal resistance for a 9V alkaline battery?

$2\ \Omega$

j) What is meant by a low frequency or a high frequency when dealing with RC, RL or RLC circuits? (3 pts) *Be specific for each configuration.*
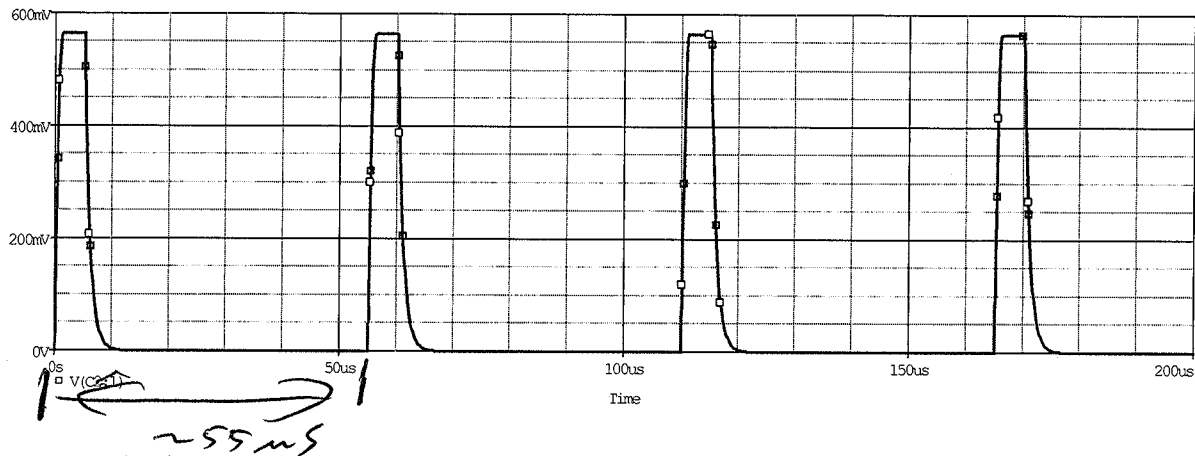
   i. RC

   Low freq
   $\left|\frac{1}{j\omega c}\right| >> R \qquad \omega << \frac{1}{RC}$
   $R << \frac{1}{\omega c}$

   High freq
   $\left|\frac{1}{j\omega c}\right| << R \qquad \omega >> \frac{1}{RC}$
   $R >> \frac{1}{\omega c}$

   ii. RL

   $\left| j\omega L \right| << R \qquad \omega << \frac{R}{L}$

   $\left| j\omega L \right| >> R \qquad \omega << \frac{R}{L}$

   iii. RLC

   Both of above

   Both of above

k) What could you do to improve the coupling of your transformer so that it will work equally well in both step up and step down modes?

   → wind coils same length
   → add magnetic core

l) What is the color code for a 100Ω resistor? (2 pts)

   Brown – Black – Brown

E

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~55 μS

n) In the figure above represents the control signal of a switching power supply. Determine the approximate frequency of the train of pulses. Mark the plot to show points used for you calculation. (4 pts)

$$T = 55 \mu S$$

$$f = \frac{1}{T} = 18.2 \, kHz$$

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