ENGR-2300

Electronic Instrumentation

Quiz 1

Fall 2016

Name Soln

Section ___

Question I (20 points) __________

Question II (20 points) __________

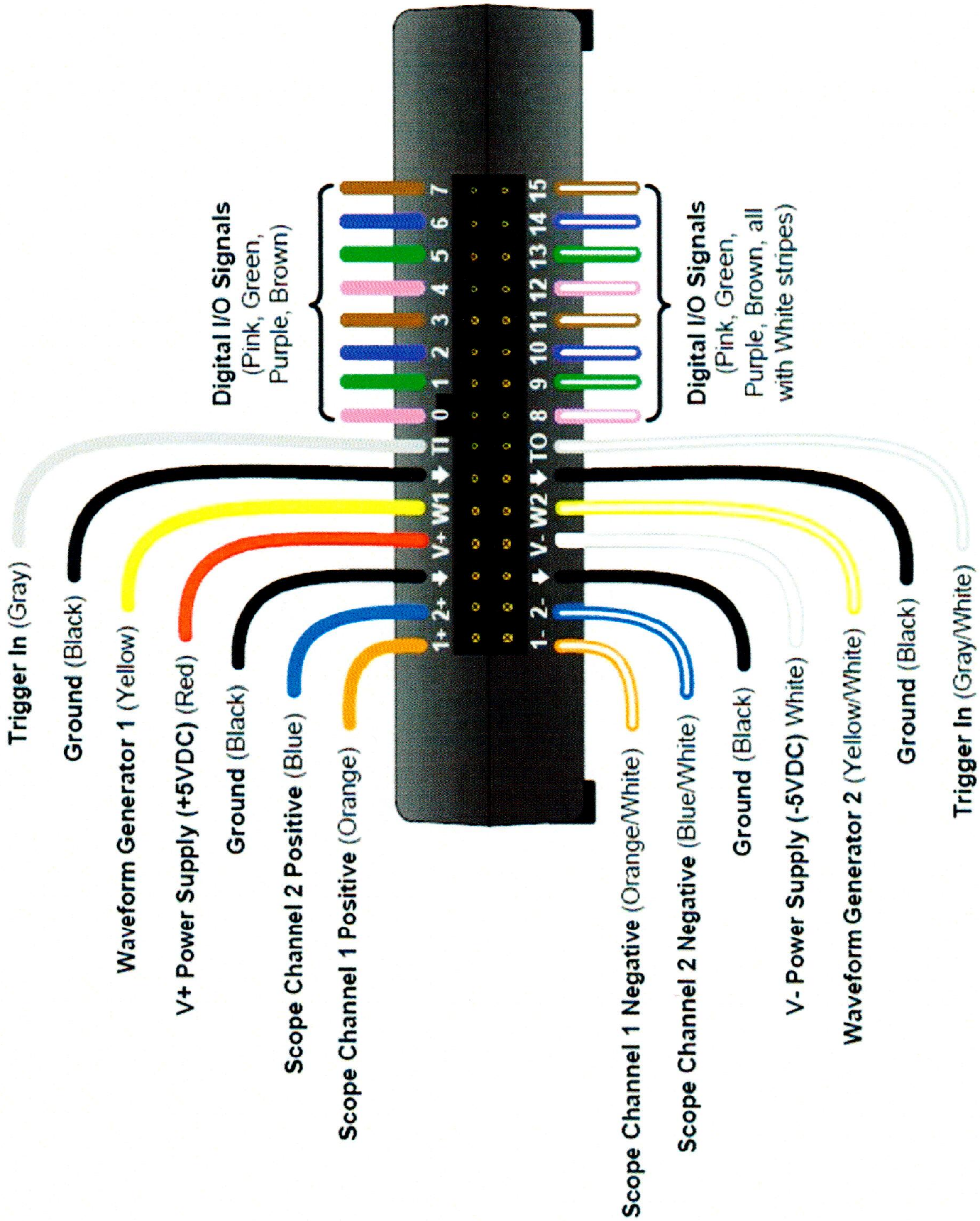
Question III (20 points) __________

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.


Digital I/O Signals (Pink, Green, Purple, Brown)
Digital I/O Signals (Pink, Green, Purple, Brown, all with White stripes)
7 6 5 4 3 2 1 0
15 14 13 12 11 10 9 8
TI W1 V+ 2+ 1+
TO W2 V- 2- 1-
Trigger In (Gray)
Ground (Black)
Waveform Generator 1 (Yellow)
V+ Power Supply (+5VDC) (Red)
Ground (Black)
Scope Channel 2 Positive (Blue)
Scope Channel 1 Positive (Orange)
Scope Channel 1 Negative (Orange/White)
Scope Channel 2 Negative (Blue/White)
Ground (Black)
V- Power Supply (-5VDC) White)
Waveform Generator 2 (Yellow/White)
Ground (Black)
Trigger In (Gray/White)

Type	R_{int} (Ω)	V_{oc} (V)	Capacity[a] continuous, to 1V/cell (mAh)	@ (mA)	(mAh)	@ (mA)	Size (in)	Weight (gm)	Connec[b]	Comments
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

Analog Discovery Specs:

10.1 Analog Inputs (Scope)

- Two fully differential channels1; 14-bit converters; 100 MSPS real-time sample rate
- 500uV to 5V/division2; 1MΩ, 24pF inputs with 5MHz analog bandwidth
- Input voltages up to ±25V on each input (±50V differential); protected to ±50V
- Up to 16k samples/channel buffer length
- Advanced triggering modes (edge, pulse, transition types, hysteresis, etc.)

...

10.2 Analog Outputs (Arbitrary Waveform Generator)

- Two channels; 14-bit converters; 100 MSPS real-time sample rate
- Single-ended waveforms with offset control and up to ±5 V amplitude
- 5MHz analog bandwidth and up to 16k samples/channel.
- Easily defined standard waveforms (sine, triangle, sawtooth, etc.)
- Easily defined sweeps, envelopes, AM and FM modulation15.
- User-defined arbitrary waveforms can be defined within WaveForms software user interface or using standard tools (e.g. Excel)
- Cross-triggering between Analog input channels, Logic Analyzer, Pattern Generator or external trigger

10.6 Power Supplies

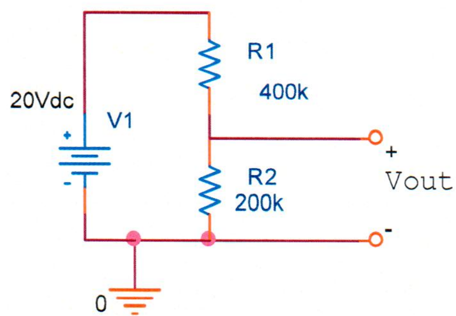
- Two fixed power supplies derive power from USB port
- +5V up to 50mA and -5V up to 50mA (100mA total)

28 September in History

- 1955 - The World Series was televised in color for the first time. The game was between the New York Yankees and the Brooklyn Dodgers. The Dodgers won and then, 2 years later, announced they were moving to LA.
- **Seymour Roger Cray** (September 28, 1925 – October 5, 1996) was a U.S. electrical engineer and supercomputer architect who designed a series of computers that were the fastest in the world for decades, and founded the company Cray Research which would build many of these machines. Called **"the father of supercomputing,"** Cray has been credited with creating the supercomputer industry through his efforts.

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.*** *Note: Pages 2 and 3 of this quiz have background information.*

a) Find the voltage V_{out} in the circuit below. (4 pts)



$$V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_1 = \boxed{6.67V}$$

b) Find the current I in resistor R1. (4 pts)

$$I_{R_1} = I_{R_2} = \frac{6.67V}{200k} = \boxed{33.3\mu A}$$

c) Find the power provided by the source, V1 (4pts)

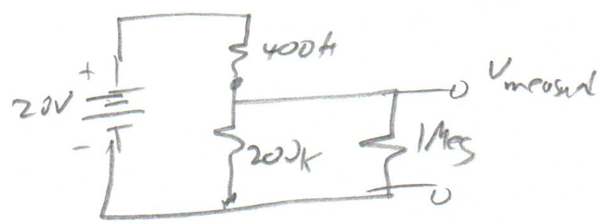
$$Power = W = V \cdot I = (20)(33.3 \times 10^{-6}) = 667\mu W = 0.667mW$$

d) The Analog Discovery board is now connect to measure Vout using the analog channel 1+ and 1- (also called the scope channel.) (8pts)

a. What is the input resistance of the analog channel of the Analog Discovery?

$\boxed{1M\Omega}$ 2pts

b. In the space on the right, hand draw the schematic for this circuit including the input loading of the analog channel of the Analog Discovery. 3pts



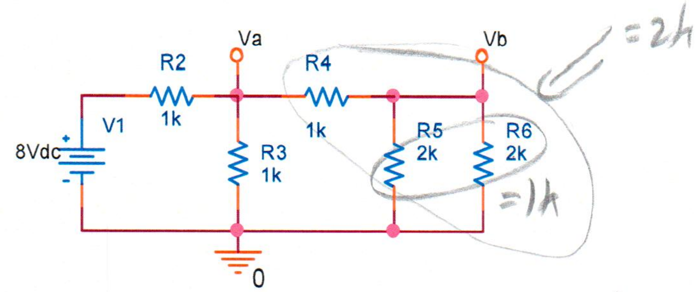
c. What voltage will be measured using the Analog Discovery? Give your answer in volts. (3pts)

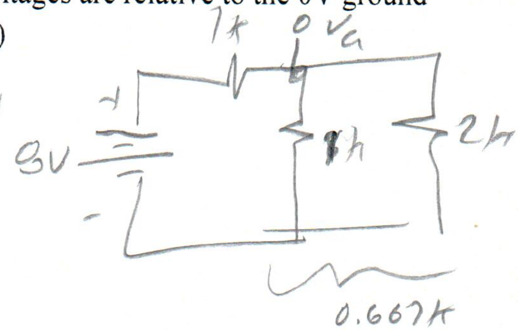
$200k // 1Meg = 167k\Omega$

$$V_{out} = \frac{167k}{167k + 400k} \cdot V_1 = \boxed{5.89V}$$

II. Resistor Combinations, filters, concepts and miscellaneous (20 points) *Please note that pages 2 and 3 of this quiz have background info.*

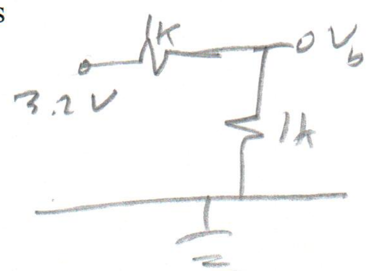
a) Find Va and Vb for the circuit below. Note: these voltages are relative to the 0V ground node. Hint: determine Va first and then do Vb. (6pts)





You must show your intermediate steps to receive credit for this part. Typically this means drawing equivalent circuit diagrams but there are other ways find the values.

$$V_a = \frac{0.667}{0.667 + 1} \cdot 8V = 3.2V$$



if $V_a = 3.2V$

$$V_b = (V_a)\left(\frac{1}{2}\right)$$

$$V_b = 1.6V$$

b) The Analog Discovery board has a +5V power supply. (2pts)

1) What is the color of the wire that has this voltage?

Red (see page 2)

2) What is the maximum current that this supply can provide to a circuit?

50mA (see page 3)

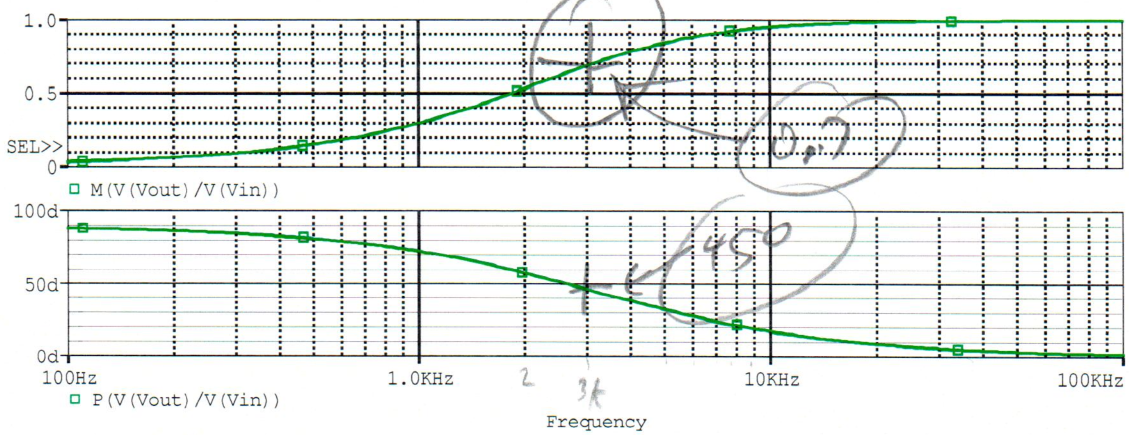
c) What are the color bands for a 100Ω resistor and a 22kΩ resistor? (2pts)

100Ω Brown Black Brown 22kΩ Red, Red, Orange

10×10^1 22×10^3

see crib sheet

d) The traces below are the amplitude and phase angle for the transfer function of a simple RC, RL, CR, or LR circuit. (3pts)



1) Is this a low pass or high pass filter? Circle one: Low Pass High Pass

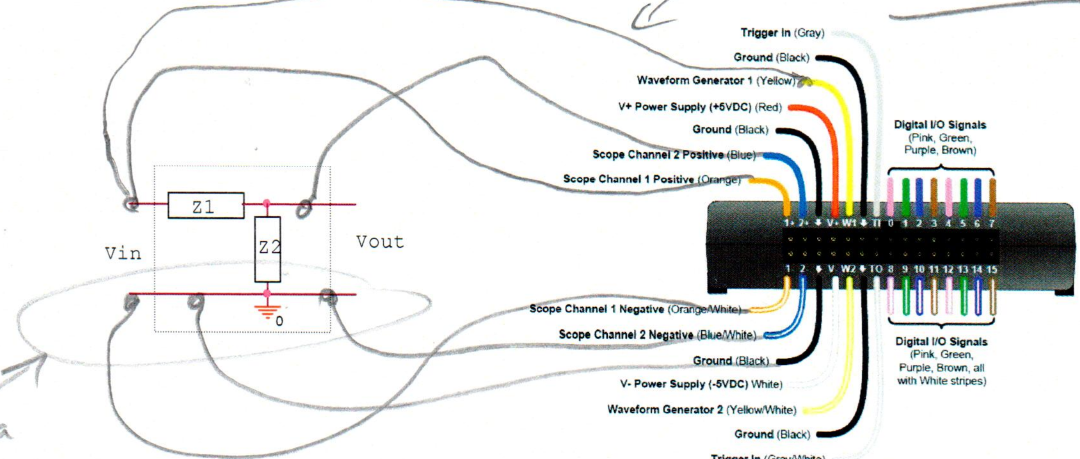
2) What is the corner frequency for this filter? **List the value and also mark both plots.**

fc= 3kHz

amplitude $= \frac{1}{\sqrt{2}}$, phase shift $= 45°$

e) On the figure below, draw lines to represent the wires you need to connect to determine the transfer function of the circuit shown using only the Analog Discovery (no additional instrumentation) (3pts)

Or use WG 2



Need a ground here, any black

Orange/white and Blue/white can connect to other Black wires

f) You built a coil on a plastic tube as you did for experiment 3 in this course and measured the inductance to be 20uH with a resistance of 0.2Ω Your partner built one with twice the amount of wire but wound the turns close together so that the length of the coil and the radius of each turn matched your coil. What would the expected values of the inductance and resistance be for your partner's coil based on what you measured for your coil? (4pts)

L = $(4)(20\mu H) = 80\mu H$

R = $(2)(0.2) = 0.4\Omega$

Crib sheet

Long Coil, ~~Calso~~

$$L = \underbrace{\frac{\mu N^2 \pi r_c^2}{d}}$$

only N^2 changes

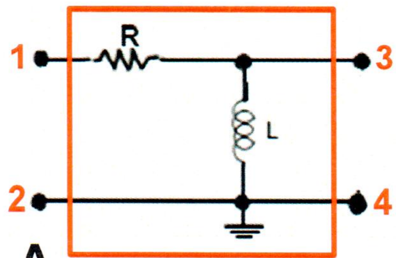
twice the number of turns

$(2N)^2 = 4N^2$

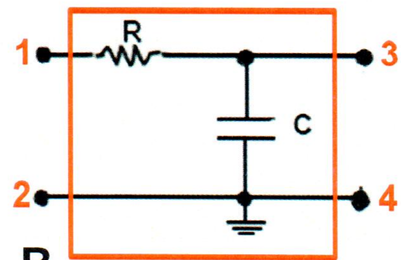
Inductance increases by factor of 4,

$R \propto$ length, twice as long, R increases by factor of 2

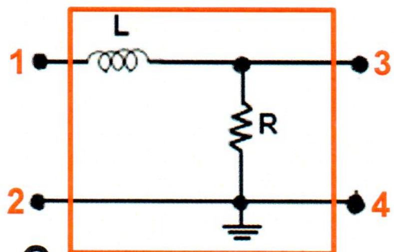
III. Filters & Transfer Functions (20 points)



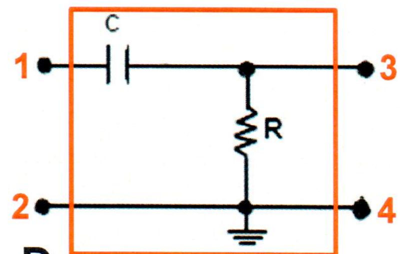
A



B



C



D

a) Shown above are the four basic, two-element, passive filter configurations made with RL and RC 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. (4 pts)

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

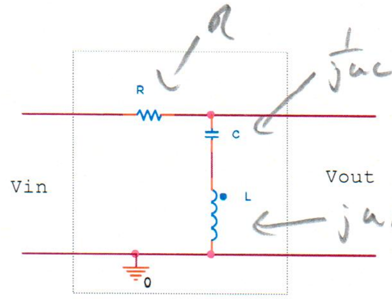
B) RC: $\frac{V_{OUT}}{V_{IN}} = \frac{V_{34}}{V_{12}} = \frac{\frac{1}{j\omega C}}{R + \frac{1}{j\omega C}} = \frac{1}{1 + j\omega RC}$

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

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

b) Assume all four circuits are made with ideal components. Identify which are high pass filters and which are low pass filters by circling the high pass and underlining the low pass in the following list (4 pts): RC CR RL LR

c) For this question use the circuit below. C is the value of the capacitor in Farads, L is the value of the inductor in Henries, and R is the value of the resistor in Ohms. Assume Vin is a sinewave. This is an AC steady state problem.



1. Write the transfer function for Vout/Vin as a ratio of polynomials. (2pts)

$$H(j\omega) = \frac{V_{out}}{V_{in}} = \frac{j\omega L + \frac{1}{j\omega C}}{R + j\omega L + \frac{1}{j\omega C}} = \frac{1 - \omega^2 LC}{j\omega RC + 1 - \omega^2 LC}$$

2. What is the magnitude and phase angle of the transfer function at very low frequencies? (1pt)

ω small, $H(j\omega) \simeq \frac{1}{1}$ magnitude $= 1$ phase angle $= 0^\circ$

3. What is the magnitude and phase at very high frequencies?(1pt)

large ω $H(j\omega) \simeq \frac{-\omega^2 LC}{-\omega^2 LC} = 1$ magnitude $= 1$ phase angle $= 0^\circ$

4. What is the magnitude and phase of the transfer function at the frequency where $\omega = 1/\sqrt{LC}$? (1pt)

magnitude $= 0$

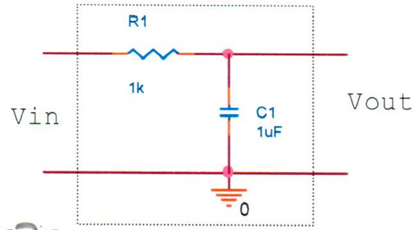
$H(j\omega) = \frac{1-1}{j\omega RC + (1-1)} = \frac{0}{j\omega RC}$ phase not well defined and jumps from -90 to $+90$ at this ω

allow any answer

5. Which type of filter is this circuit? Circle one of the following: (1pt)

Low pass High Pass Band Pass Band Reject qst 1 kHz

d) Find the magnitude and phase angle of the transfer function for the circuit shown on the right given that Vin is a sinewave with a frequency of 320Hz. To receive credit, you must show your work for this and all problems (4pts)



$$H(j\omega) = \frac{\frac{1}{j\omega C}}{\frac{1}{j\omega C} + R} = \frac{1}{1 + j\omega RC}$$

$\omega = (2\pi)(320)$

$R = 100$

$C = 10^{-6}$

$$\frac{1}{1 + j(2\pi)(320)(1000)(10^{-6})}$$

e) Using the results of part c) what is the time domain equation for Vout if Vin=10Vsin(2π320t+0°) Vout must have the form of Vout=Asin(ωt+θ) (2pts)

$$\frac{1}{1 + j(2)}$$

$$\boxed{\text{Mag} = \frac{1}{\sqrt{1+4^2}} = \underline{0.45}}$$

$\measuredangle = \measuredangle\,\text{num} - \measuredangle\,\text{den}$

$= \measuredangle(1) - \measuredangle(1+2j)$

$= 0^\circ - \tan^{-1}\frac{2}{1}$

$$\boxed{= \underline{-63^\circ}}$$

$|V_{out}| = |V_{in}| \cdot |H(j\omega)|$

$= 10 \cdot 0.45$

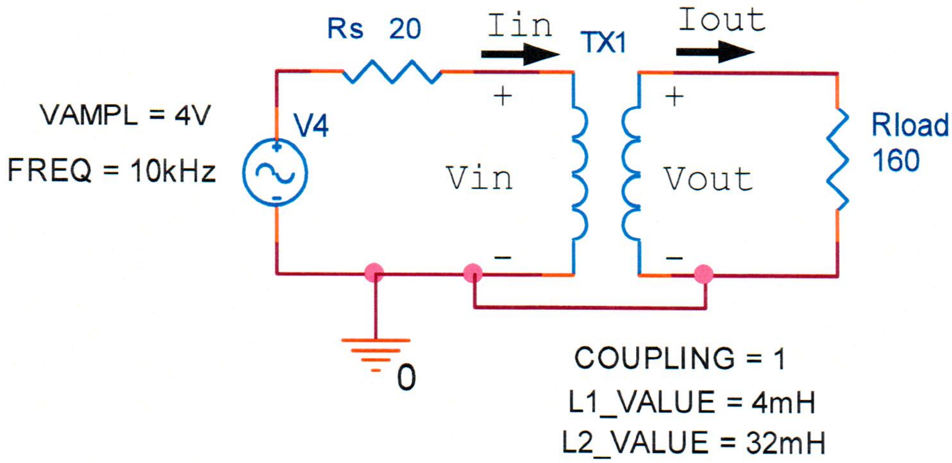
$= 4.5$

$\measuredangle V_{out} = \measuredangle V_{in} + \measuredangle H(j\omega)$

$= 0 - 63^\circ$

$$\boxed{V_{out} = 4.5 \sin(2\pi \cdot 320t - 63^\circ)}$$

IV – Signals, Transformers and Inductors (20 points)



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.

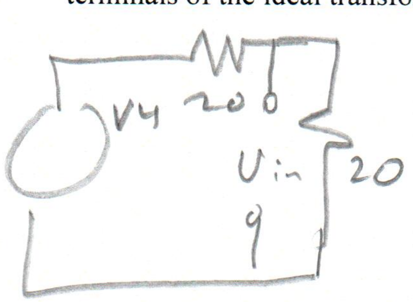
a) For the given information, write out the expressions for the ratios Vout/Vin, Iout/Iin and the transformer input impedance Rin. (Rin is Vin/Iin) (6 pts)

$$a = \sqrt{\frac{L_2}{L_1}} = \sqrt{\frac{32}{4}} = 2\sqrt{2} = 2.83$$

$$\boxed{\frac{V_{out}}{V_{in}} = a = 2.83} \quad \boxed{\frac{I_{out}}{I_{in}} = \frac{1}{a} = 0.354}$$

$$R_{in} = \frac{R_{load}}{a^2} = \frac{160}{8} = \boxed{20\Omega}$$

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)



$$V_{in} = \frac{20}{20+20} \cdot V_{ampl} = 2V \text{ amplitude}$$
$$= 4V_{p-p}$$

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

$V_{out} = (2.83)(V_{in}) = 5.66V$ (amplitude)

d) Determine both the primary and secondary currents (Iin and Iout). (2 pts)

$I_{in} = \frac{V_{in}}{R_{in}} = \frac{2}{20} = 0.1A$

$I_{out} = \frac{I_{in}}{a} = 35mA$ OR $I_{out} = \frac{V_{out}}{160} = 35mA$

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)

$|Z_{L1}| = |j\omega L1| = (2\pi)(10^4)(4\times10^{-3}) = 251\Omega$

$R_s = 20$ $|Z_{L1}| >> R_s$ so yes the ideal is resonable

$|Z_{L2}| = |j\omega L2| = (2\pi)(10^4)(32\times10^{-3}) = 2010 >> R_{Load}$

→ good approx.

f) Would you answer to part e) change if the frequency of the source was 500Hz rather than 10kHz? Justify your answer. (2pts)

if $f = 500Hz$ $|Z_{L1}| \approx 12.6\Omega \gtrsim R_s$

shouldn't ignore the effect of L1

So answer is that now the ideal model doesn't work.