ENGR-2300

Electronic Instrumentation

Quiz 1

Spring 2017

Soln

Name ______________________________

Section ___

Question I (20 points) ___________

Question II (20 points) ___________

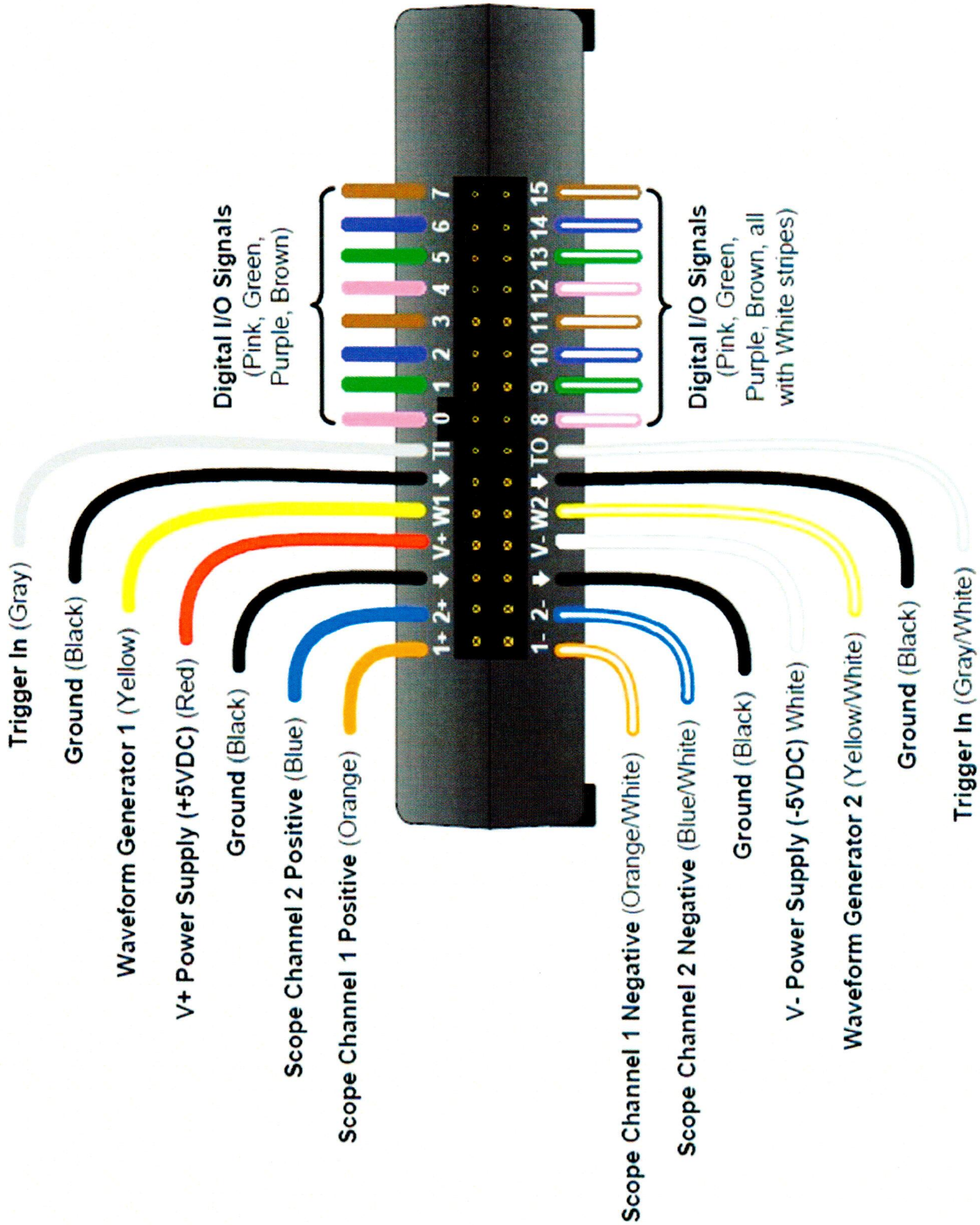
Question III (20 points) ___________

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)

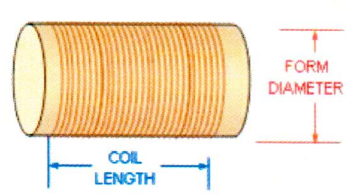
- Two channels; 14-bit converters; 100 MSPS real-time sample rate
- Single-ended waveforms with offset control and up to ±5 V amplitude
- 5MHz analog bandwidth and up to 16k samples/channel.
- Easily defined standard waveforms (sine, triangle, sawtooth, etc.)
- Easily defined sweeps, envelopes, AM and 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)

Notes from Experiment 3: If the core cylinder has a radius equal to r_c and we wind a coil N times around the cylinder to cover a length d, the inductor will, ideally, have an inductance equal to:

$$L = \frac{(\mu_0 N^2 \pi r_c^2)}{d} Henries$$



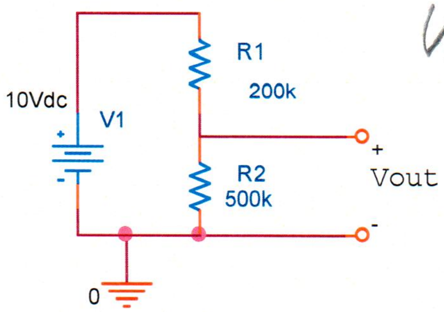
(= $2r_c$)

(= d)

Soln

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

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



$$V_{out} = \frac{R_2}{R_1+R_2} \cdot V_1 = \frac{500}{500+200} \cdot 10$$

$$= 7.14\,V$$

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

$$V_{R_1} = 10 - 7.14 = 2.86\,V$$

$$I_R = \frac{V_{R1}}{200k} = 14.3\,\mu A$$

OR $I_{R_1} = I_{R_2} = \frac{7.14}{500k} = 14.3\,\mu A$

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

$$P = I^2R = V^2/R = VI = (7.14)(14.3\times10^{-6}) = 102\,\mu W$$

$$= 0.102\,mW$$

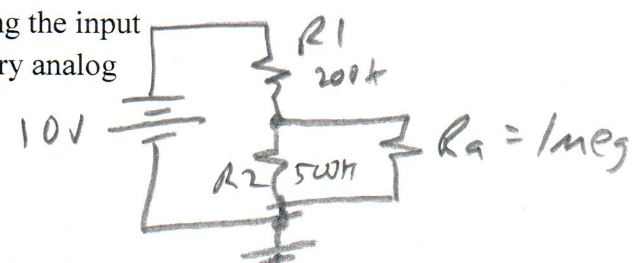
d) The Analog Discovery board is now connect to measure Vout using the analog channel 1+ and 1- (also called the scope channel.) (8pts)

a. What is the input resistance of an Analog Discovery analog channel? (2pts)

see Background info → $1\,M\Omega$, ~~24pF~~

or $1\,Meg\,\Omega$

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



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

$500k \,//\, 1000k = 333k\Omega$

$$V_{out} = \frac{333k}{333k + 200k} \cdot 10 = 6.25\,V$$

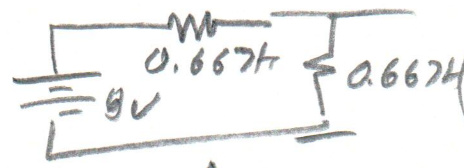
II. Resistor Combinations, filters, concepts and miscellaneous (20 points) *Please note that pages 2 and 3 of this quiz have background info.*

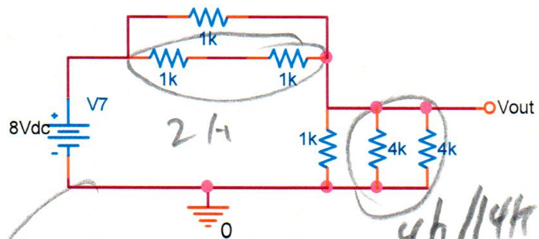
a) Find Vout for the circuit below. Note: unless otherwise stated, all voltages are relative to the 0V ground node.. (4pts)

2k // 1k ⇒ 0.667k

$V_{out} = \frac{1}{2} \cdot V$

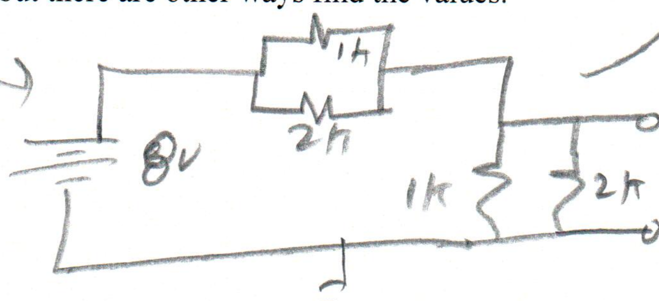
$= 4V$





4k // 4k = 2k, 2k // 1k = 0.667k

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.



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

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

White

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

50mA

c) What are the color bands for a 1kΩ resistor and a 220Ω resistor? (2pts)

Brown, Black, Red

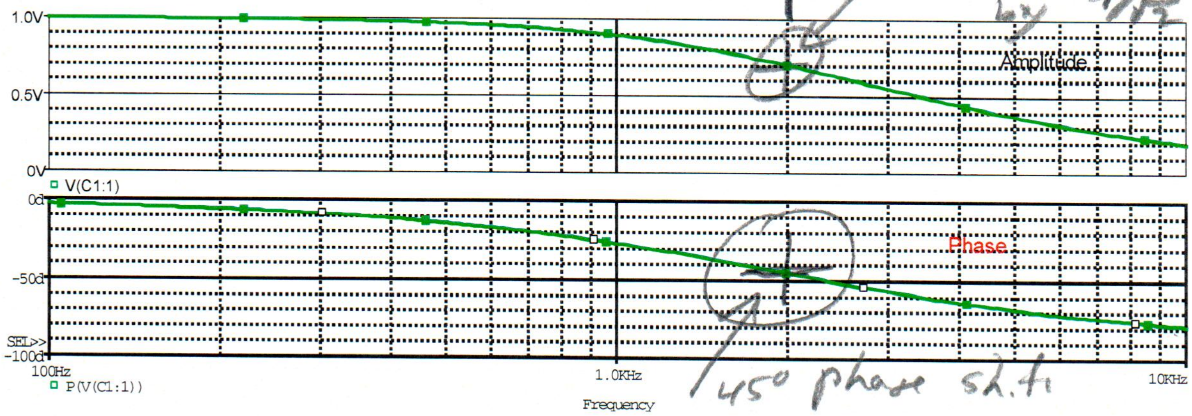
~~100Ω~~ 1k ______ 1 0 2

~~22kΩ~~ 220Ω ______

220 Ohms, 221
Red, Red, Brown

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

2kHz amplitude down by $1/\sqrt{2}$



45° phase shift

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.**

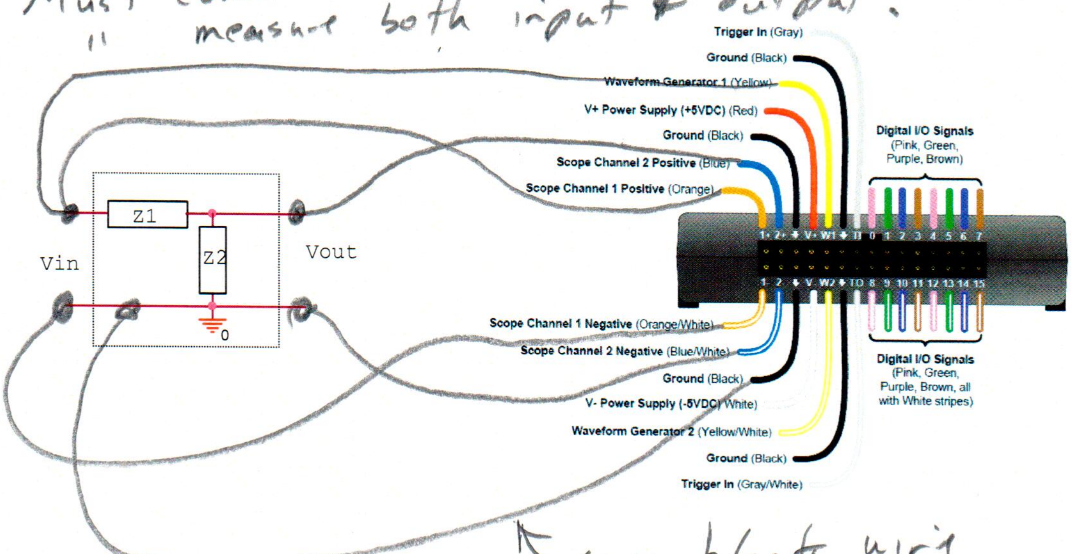
$f_c \Rightarrow$ magnitude $= \frac{1}{\sqrt{2}} \cdot$ peak

phase shift $= 45^{\circ}$

f_c= 2kHz

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)

Must connect WF Generator
" measure both input & output.



any black wire

f) You built a coil on a plastic tube as you did for experiment 3. The measured inductance was 30μH with a resistance of 0.3Ω Your partner built one using the same gauge and length of wire at the one you built, but put in on a plastic tube that has ½ the diameter of yours. Your partner wound her/his coil so that the length of the coil was the same as yours and still used all of the wire. 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 = 30μH

see page 3

R = 0.3Ω

$$L = \frac{\mu_0 N^2 \pi r_c^2}{d}$$

wire lenght doesn't change, R doesn't change

for L μ_0, π, d are the same

r_c drops by $\frac{1}{2}$

But since wire length $= 2\pi r_c \cdot N$

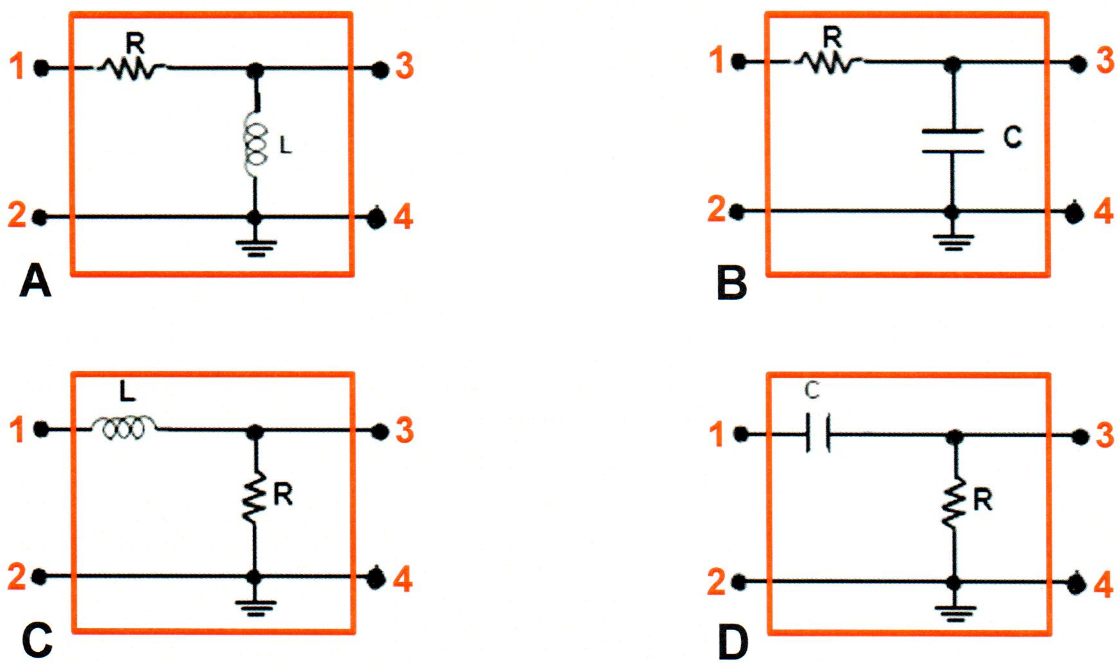
lenth is const., N goes up by 2

$N^2 r_c^2 \simeq$ const.

$L \simeq$ const.

Soln.

III. Filters & Transfer Functions (20 points)



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

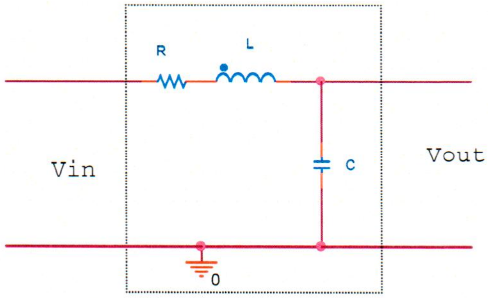
B) RC: $\frac{V_{OUT}}{V_{IN}} = \frac{V_{34}}{V_{12}} = \frac{1/j\omega C}{R + 1/j\omega C} = \frac{1}{j\omega RC + 1}$

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

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

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

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.



For all parts, the solution is in terms of R, L, C, and jω

1) Write the transfer function for Vout/Vin as a ratio of polynomials, (in terms of R, L, C, and jω.) (2pts)

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

$$= \frac{1}{1 - \omega^2 LC + j\omega RC}$$

2) What is the magnitude and phase angle of the transfer function at very low (but not zero) frequencies? (1pt)

$|H(\omega)| = 1$ at small ω

$\angle H(j\omega) = 0°$ at small ω

pure real

3) What is the magnitude and phase at very high (but not infinite) frequencies?(1pt)

$H(j\omega) \simeq \frac{1}{-\omega^2 LC}$ at ω large Magnitude $= \frac{1}{\omega^2 LC}$

angle $= -180°$ or $+180°$

or $-\pi$ or $+\pi$

4) What is the magnitude and phase of the transfer function at the resonant frequency? (2pt)

$\omega = \frac{1}{\sqrt{LC}}$ at ω_0

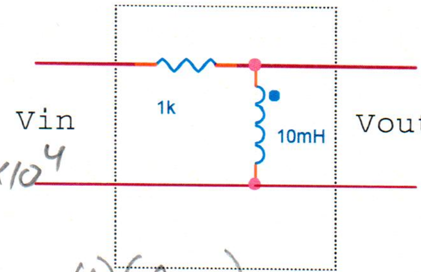
$$H(j\omega) = \frac{1}{1 - \frac{LC}{LC} + (jRC)\left(\frac{1}{\sqrt{LC}}\right)} = \frac{1}{j\left(\frac{RC}{\sqrt{LC}}\right)} = -j\frac{\sqrt{LC}}{RC}$$

Mag $= \frac{\sqrt{LC}}{RC}$ or $\frac{1}{R}\sqrt{\frac{L}{C}}$ OR $= -j\frac{1}{R}\sqrt{\frac{L}{C}}$

angle $= -90°$ or $-\pi/2$

Soln

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 8kHz. To receive credit, you must show your work for this and all problems. (4pts)
Give the phase in degrees.



$\omega = 2\pi f = 5.03\times10^4$

$$H(j\omega) = \frac{j\omega L}{R + j\omega L} = \frac{(j)(5.03\times10^4)(0.01)}{1000 + j(5.03\times10^4)(0.01)}$$

$$= \frac{j\,503}{1000 + j\,503} = \frac{503\angle 90^\circ}{1120\angle 26.7^\circ} = .449\angle 63.3^\circ$$

$$\text{Mag} = \sqrt{1000^2 + 503^2} = 1.12\times10^3$$

$$\arg = \tan^{-1}\frac{503}{1000} = 26.7^\circ$$

$$\text{OR} \quad H(j\omega) = \frac{(j503)(1000 - j503)}{(1000 + j503)(1000 - j503)} \Rightarrow$$

e) Using the results of part d) what is the time domain equation for Vout if Vin=10Vsin(2π8000t+0°) Vout must have the form of Vout=Asin(ωt+θ) (2pts)

$$\text{Mag} = (10)(0.449) = 4.49$$

$$\angle = 0^\circ + 63.3^\circ$$

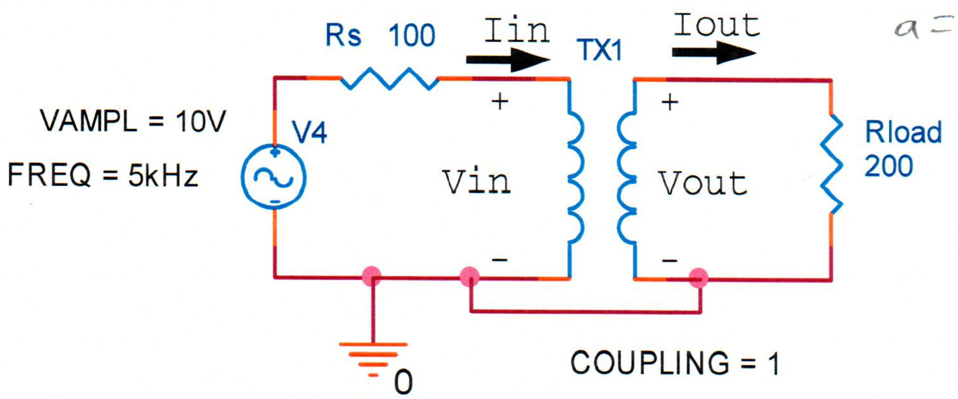
$$V_{out} = 4.49V \sin(2\pi 8000t + 63.3)$$

$$\text{OR} \quad 4.49V \sin(2\pi 8000t + 1.1\,\text{radians})$$

Soln

IV – Signals, Transformers and Inductors (20 points)

$$a = \frac{N_2}{N_1} = \frac{1000}{500} = 2$$



Given: N1=500, the number of turns on the primary. N2=1000, the number of turns on the secondary. Assume an ideal transformer with full coupling. In your answers to the following questions, use all available and useful information.

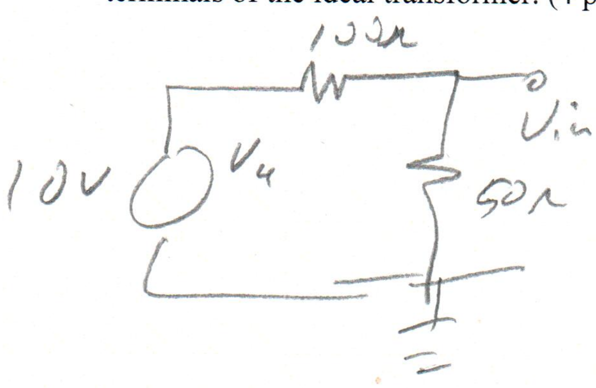
a) For the given information, write out the expressions for the ratios Vout/Vin, Iout/Iin and the transformer input impedance Rin. (Rin is Vin/Iin) (6 pts)

$$\frac{V_2}{V_1} = \frac{V_{out}}{V_{in}} = a = 2 \quad \frac{V_{out}}{V_{in}} = 2$$

$$\frac{I_{out}}{I_{in}} = \frac{1}{a} = \frac{1}{2}$$

$$R_{in} = \frac{R_{load}}{a^2} = \frac{200}{4} = 50\Omega$$

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)



$$V_{in} = \frac{50}{50+100} \cdot 10 = 3.33V$$

Soln

c) Find Vout from your value for Vin. (2 pts)

$$\frac{V_{out}}{V_{in}} = 2 \qquad V_{out} = 2V_{in} = \underline{6.67V}$$

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

$$I_{out} = \frac{V_{out}}{200} = 33.3\,mA$$

$$I_{In} = 2I_{out} = 66.7\,mA$$

e) Determine the power loss in both Rs and Rload. (2 pts)

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

$$\cancel{R_S} = W_{RS} = (66.7\,mA)^2(100) = \underline{0.444W}$$

$$W_{RLoad} = V \cdot I = 6.67V \cdot 33.3\,mA = \underline{0.222W}$$

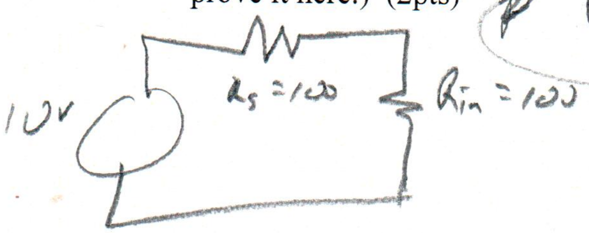
f) Assume that Rs and Rload are set by the system and can't change them. You can change the number of turns in the secondary of the transformer, with the goal of getting the maximum power into Rload. It can be shown that maximum power transfer will occur when input resistance at the transformer (Rin, part b) equals the source resistance, Rs. **Determine the turns ratio, a,** that will result in Rin=Rs (Rin as stated in part b). **What N2 will give you this ratio**? (N1 is also fixed) (2pts)

$$R_{in} = \frac{R_{Load}}{a^2} = R_S \qquad \frac{200}{a^2} = 100 \qquad \frac{N_2}{N_1} = 1.41 = \frac{N_2}{500}$$

$$a^2 = 2 \qquad a = 1.41 \qquad \underline{N_2 = 705}$$

g) What is the power loss in Rs and Rin with the new N2? (Note: It can also be proved that the power loss in what we call Rin equals to the power delivered to the Rload, but don't prove it here.) (2pts)

$$\cancel{P} \quad W_{RS} = \frac{V_{RS}^2}{R_S} = 5^2/100 = 0.25W$$



$$\cancel{P} \quad W_{R_{in}} = \frac{V_{R_{in}}^2}{R_{in}} = 5^2/100 = 0.25W$$