ENGR-2300

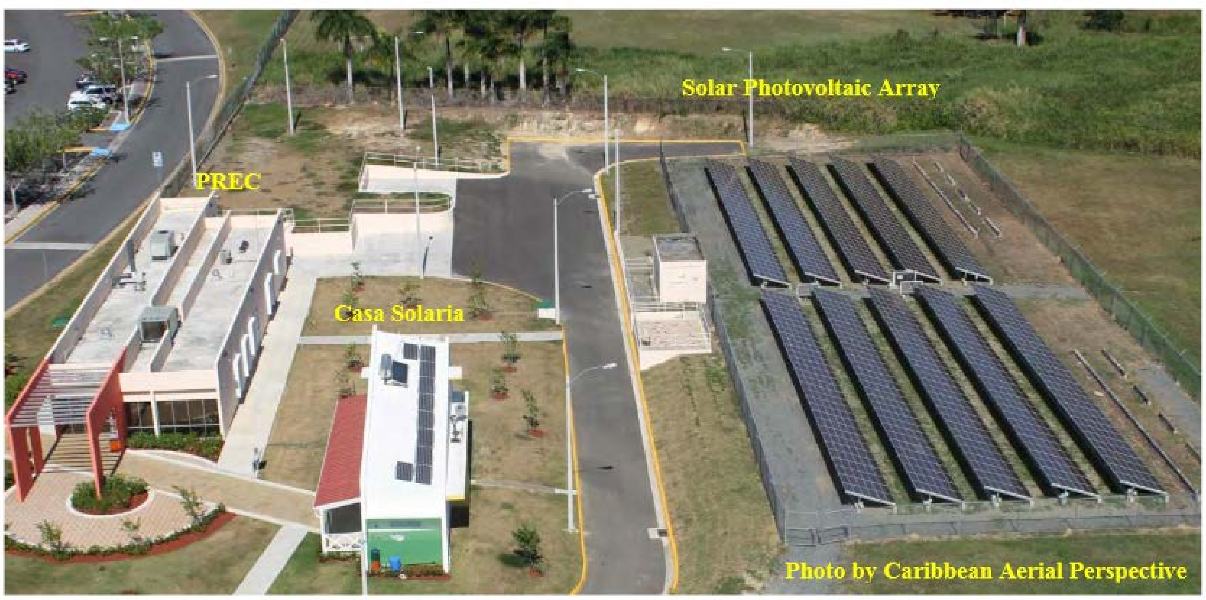
Electronic Instrumentation

Quiz 1

Spring 2015

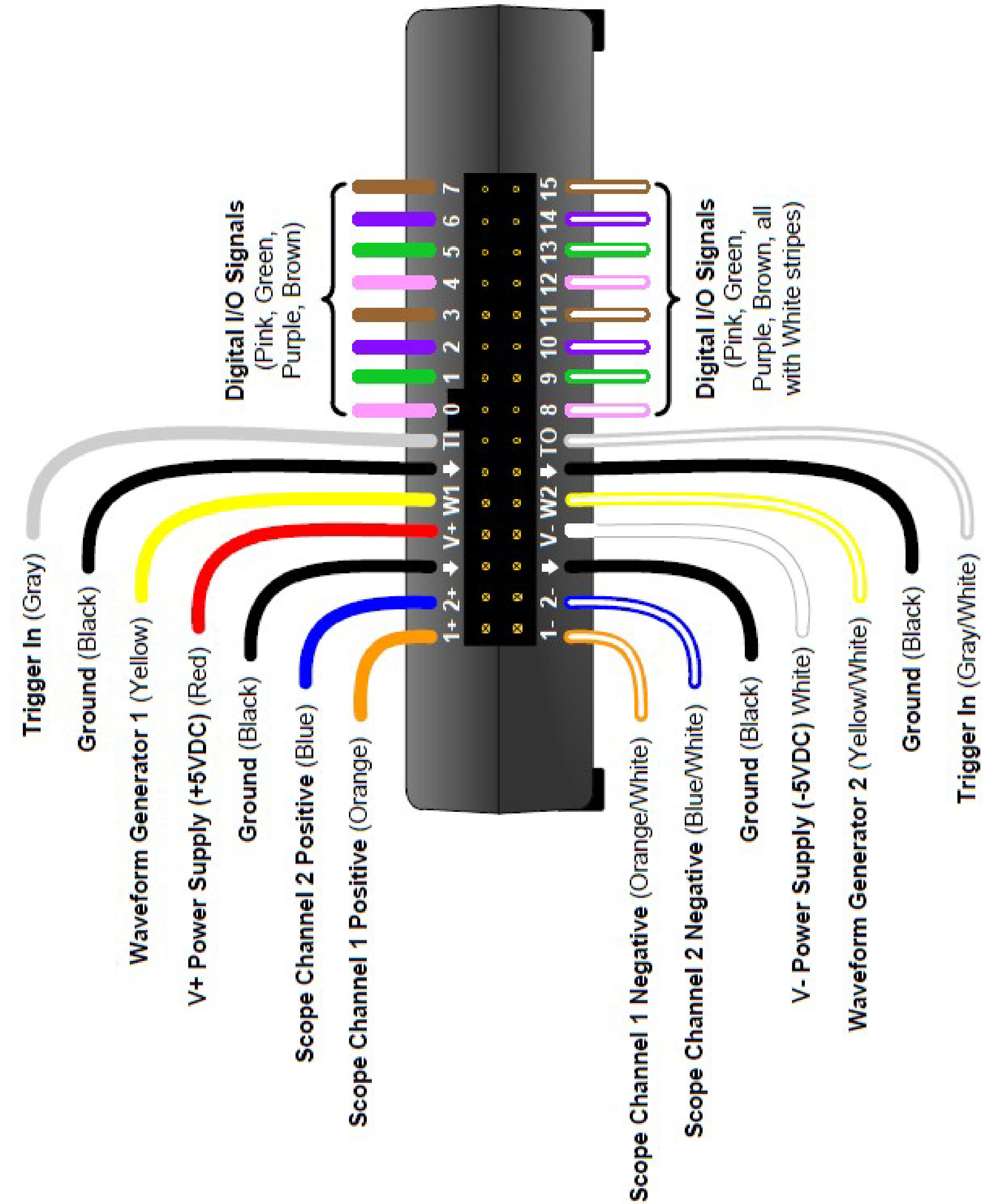
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification. Read the entire quiz before answering any questions. Also it may be easier to answer parts of questions out of order.

The School of Engineering started with 75 students in 1990/91 and currently offers associate degrees in technology, baccalaureate programs in Mechanical Engineering, Electrical Engineering, Computer Engineering, Civil Engineering (as of 2013) and Industrial Management Engineering, and Masters in Administration of Telecommunications and Network Systems and in Mechanical Engineering with concentrations in Alternative Energy and Aerospace Engineering. Presently, the School has 500 students in Associate Degree Programs, 900 in Bachelor Degree Programs and 50 in Masters Programs.



Workshop: *Diffusion of Hands-On Learning in Puerto Rico Using the Analog Discovery Board*
Date: *21 February 2015*
The workshop was attended by about two dozen professors from essentially all Puerto Rican engineering schools. Included in the participant list were RPI graduates. The workshop was organized by Prof Juan Morales, head of Mechanical Eng at Turabo and his colleagues Mary Ruales (ME) and Idalides Vergara-Laurens (Computer Eng). It was led by me (KC) and Prof. Yacob Astatke from Morgan State University. It was 85 degrees but rained a little. Nice change from Troy. As is typically the case in these workshops, you all pick up how to use the equipment faster than most professors. However, they rapidly came up to speed and had lots of fun.

Analog Discovery Connections

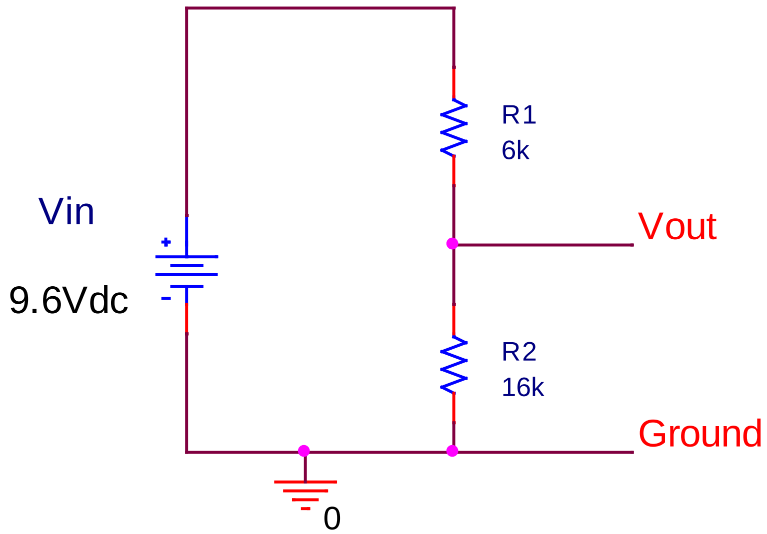


Standard Resistor Values (±5%)						
1.0	10	100	1.0K	10K	100K	1.0M
1.1	11	110	1.1K	11K	110K	1.1M
1.2	12	120	1.2K	12K	120K	1.2M
1.3	13	130	1.3K	13K	130K	1.3M
1.5	15	150	1.5K	15K	150K	1.5M
1.6	16	160	1.6K	16K	160K	1.6M
1.8	18	180	1.8K	18K	180K	1.8M
2.0	20	200	2.0K	20K	200K	2.0M
2.2	22	220	2.2K	22K	220K	2.2M
2.4	24	240	2.4K	24K	240K	2.4M
2.7	27	270	2.7K	27K	270K	2.7M
3.0	30	300	3.0K	30K	300K	3.0M
3.3	33	330	3.3K	33K	330K	3.3M
3.6	36	360	3.6K	36K	360K	3.6M
3.9	39	390	3.9K	39K	390K	3.9M
4.3	43	430	4.3K	43K	430K	4.3M
4.7	47	470	4.7K	47K	470K	4.7M
5.1	51	510	5.1K	51K	510K	5.1M
5.6	56	560	5.6K	56K	560K	5.6M
6.2	62	620	6.2K	62K	620K	6.2M
6.8	68	680	6.8K	68K	680K	6.8M
7.5	75	750	7.5K	75K	750K	7.5M
8.2	82	820	8.2K	82K	820K	8.2M
9.1	91	910	9.1K	91K	910K	9.1M

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

I. Voltage Dividers (20 points)

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

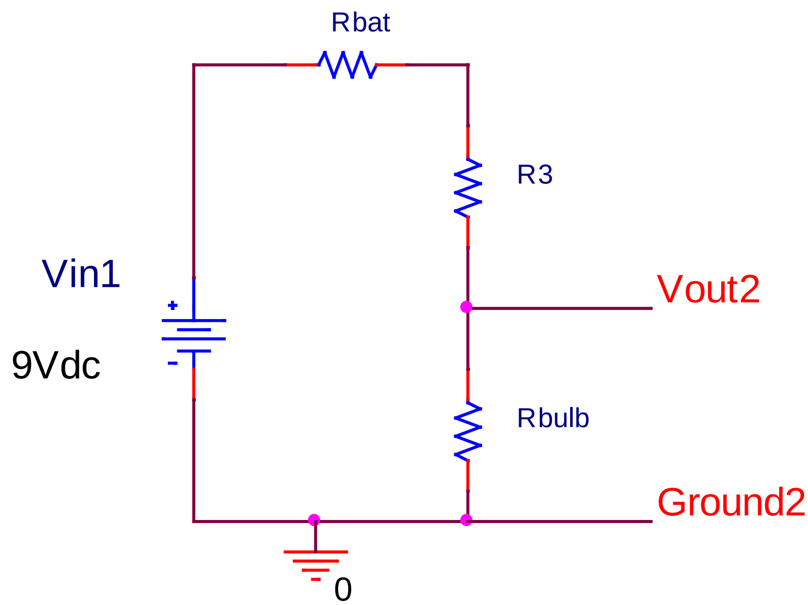


$$V_{out} = V_{in}\frac{16}{16+6} = 9.6\frac{16}{22} = 6.98 \approx 7$$

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

$$I = 2.6/6 = 0.44mA$$

c) 100W incandescent lightbulbs were banned in 2012 (followed soon by 75W, 60W, and 40W bulbs) because only about 5% of the energy they use comes out as light. They are mostly heat producers. Since 20% of the energy we use goes to lighting our homes and businesses, the impact of this ban is potentially very great. Basically, a traditional lightbulb is just a resistor that gives off a little light. How large is that resistance? At 120V, $R = V^2/P$ where P is average power. (120V is an RMS AC voltage, which is what we use to obtain average power for an AC signal.) Then, $R = 120^2/100 = 144\Omega$. You decide to measure the resistance, but you do not have a Multimeter so you use a voltage divider configured with a Heavy Duty 9V battery, a



standard resistor and the bulb. Using the standard resistance that is closest in value to *144*Ω, you measure an output voltage of 0.4V. Using this information, find the value of the bulb resistance. This is called the cold resistance, because the bulb will not be turned on at these low voltages. *Hint: Be sure to check the additional information provided with this quiz.* (8 pts)

Rbat = 35 Ohms, closest R to 144 is 150 Ohms

$0.4 = 9\frac{R}{35+150+R}$ *then solve for R= 8.6 Ohms (5% error OK)*

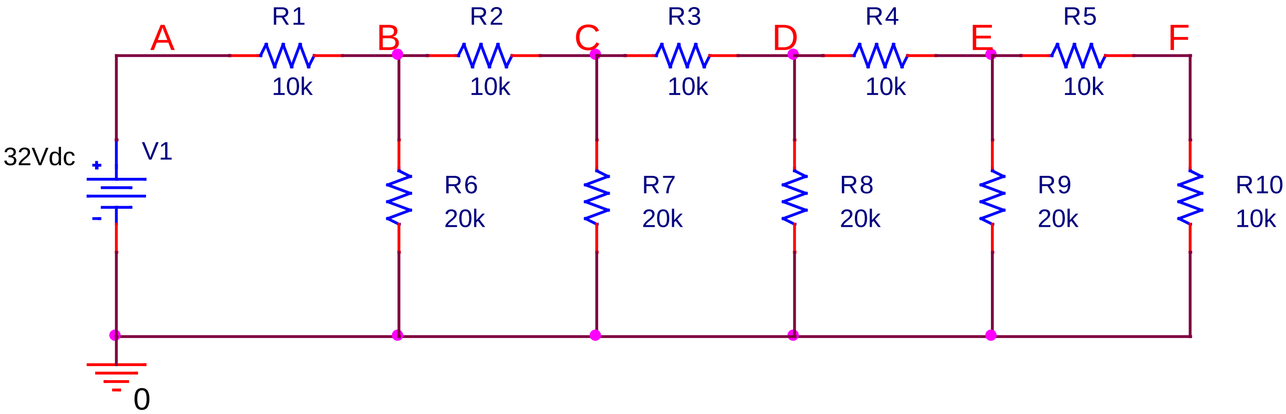
d) To do the cold resistance measurement experiment, you must be sure that the standard resistor you use can handle enough power. Which of the following types of resistors will work in this experiment? Determine the power delivered to resistor R3 and then circle all possible answers. (4 pts)

1/4W 1/2W 1W 2W

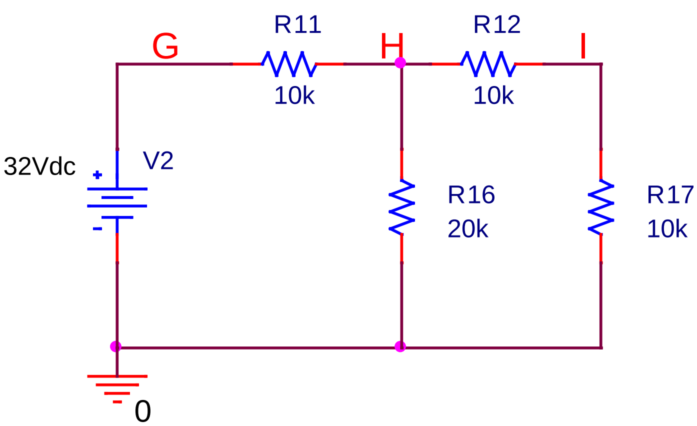
The current is 0.4/8.6 = 47mA

$I^2R = 324mW$ *so the quarter Watt resistor will not work, but the other three will.*

II. Resistor Combinations (20 points)



One of the important things you should learn about electronics is to never throw away a power supply from obsolete or broken equipment. For example, a power supply for HP printers outputs 32V or 16V DC. Assume you have such a supply and build the resistor ladder circuit shown above to provide a series of reference voltages.



10k+10k = 20k

20k||20k = 10k

H is middle of voltage divider

Made with two 10k resistors

Voltage at I is also half H

G: 32V   H: 16V   I: 8V

Before building and analyzing the full ladder, you put together the smaller one to be sure you understand how it works.

a) Determine the voltages at points G, H and I in the smaller ladder. *Hint: Begin by simplifying the circuit until it looks like a standard voltage divider.* (4 pts)

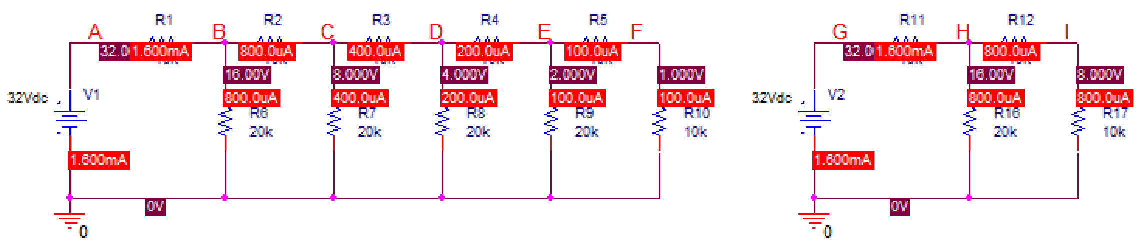
See above. The voltage at G is 32V, the voltage at H is 16V and the voltage at I is 8V

b) Now, determine the voltages at the points A, B, C, D, E and F in the larger divider. (10 pts) *Hint: The voltage divider is also useful for this.*

Each divider halves the voltage because the resistors are identical. Thus, the voltage at A is 32V, at B is 16V, at C is 8V, at D is 4V, at E is 2V and at F is 1V.

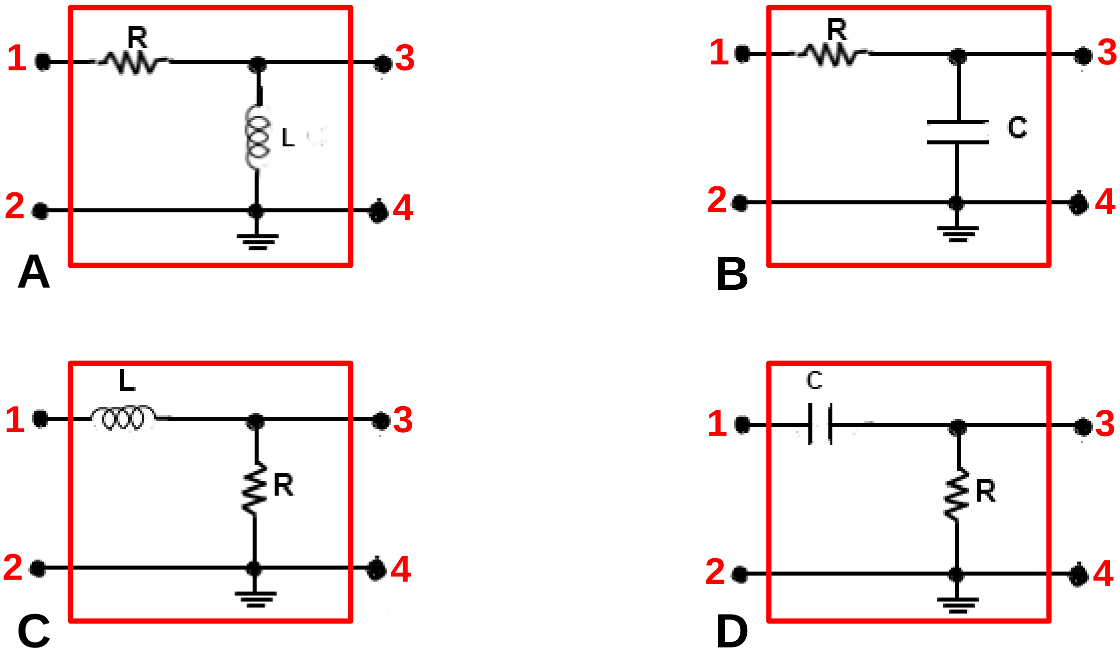
c) Determine the current drawn from the power supplies for both circuits. Then use this current to determine the power for both circuits. Can this power supply produce enough power to drive either or both of these ladder circuits? *Explain your answer.* (6 pts)

Since the voltage between A and B is 16V and between G and H is also 16V, the current is 16/10mA or 1.6mA as confirmed by PSpice



The power is 32 times 1.6 mW or 51.2mW. The power supply can source 375mA at 32V so no problem at all.

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

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

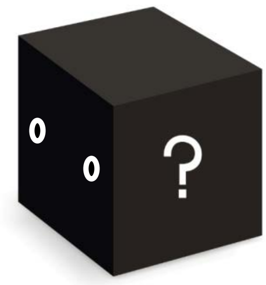
C) LR: $\dfrac{V_{OUT}}{V_{IN}} = \dfrac{V_{34}}{V_{12}} = \dfrac{R}{R + j\omega L}$

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

Either form of the solutions is OK.

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) Assume that one of the four circuits is enclosed in an unmarked, black box, like the one shown at the left. That is, we know that the box contains one of the circuits and decide to make a series of measurements to identify which one it is by making various connections with the inputs and outputs. We first try the identification by making the DC resistance measurements listed in the table below. Identify the circuit tested by adding its name to the table in the column labeled Circuit. Explain your answer. *Hint: The R, L & C are realistic circuit components and, thus, are not necessarily represented by just their ideal circuit elements.* (4 pts)



R_{12}	R_{13}	R_{34}	R_{24}	Circuit	R_{12} SC Load
1.1kΩ	100Ω	1kΩ	0	C or LR	100 Ohms

Explanation: *At DC treat the inductor as a 100Ohm resistor. Then it is a voltage divider.*

d) What input resistance R_{12} would be measured when the load is a short circuit (SC)? Add your answer to the table. (4 pts)

See table.

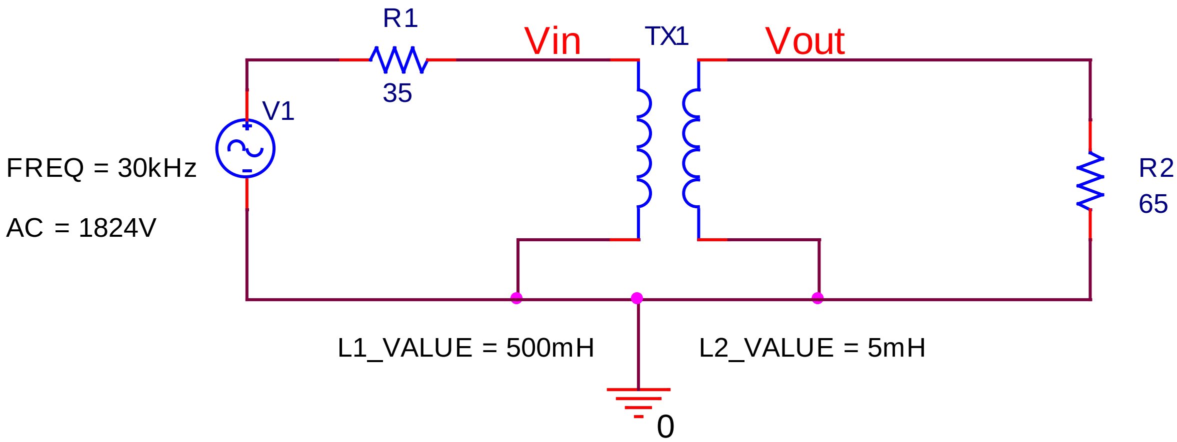
e) A function generator (amplitude = 1V) is connected to the input of the circuit and the output voltage is measured as a function of frequency. The frequency of the function generator is changed and the phase shift between the input and output voltage is measured, as shown in the table below.

Phase Shift	0 Deg	-15 Deg	-30 Deg	-45 Deg	-60 Deg	-75 Deg	-90 Deg
Frequency	30Hz	4.7kHz	10.3kHz	17.6kHz	30.4kHz	65.5kHz	10MHz

From the information in the table, determine the value of the inductance L or capacitance C for the circuit. (4 pts)

The phase shift at the corner frequency is 45 degrees. Thus the corner freq is 17.6kHz or ω is 110,584. $L = \frac{R}{\omega_c} = \frac{1100}{110584} = 10mH$

IV – Signals, Transformers and Inductors (20 points)



Given the circuit above, 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. (6 pts)

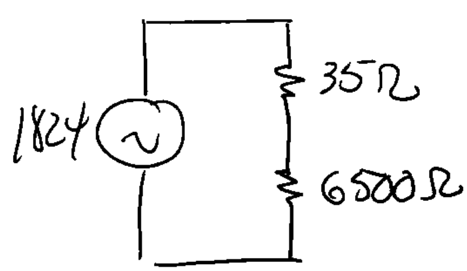
$$a = \sqrt{\frac{5mH}{500mH}} = \frac{1}{10} = \frac{N_2}{N_1} = \frac{V_{out}}{V_{in}} = \frac{I_{in}}{I_{out}} \; or$$

$$10 = \frac{I_{out}}{I_{in}} \; and$$

$$Z_{in} = 100R_2 = 6500\Omega$$

b) Draw the circuit diagram for the voltage divider consisting of the transformer input impedance Rin and the resistance R1. Then solve for Vin, the voltage across the input terminals of the ideal transformer. (4 pts)

Because the Z_{in} is 6.5kΩ and the other resistor is 35Ω, essentially all of the voltage appears across Z_{in} so V_{in} is 1824V.



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

V_{out} is 10 times smaller so it is 182.4V

d) Determine both the primary and secondary currents (I1 and I2). (4 pts)

This can be done several ways, but the easiest is I_{in} is 1824/6500) or 280mA and I_{out} is 10 times larger or 2.8A.

e) Determine the power delivered to the load R2. (3 pts)

182.4(2.8) = 510W (actually 506.4W with nothing rounded off) 5% error OK.

f) What is the significance of the number 1824 in the history of RPI? What is the significance of the number 35 in the history of RPI? (Up to 2 pts extra credit)

RPI was founded in 1824 and the 1985 men's RPI hockey team had 35 wins in its national championship season. Actually, any clever answer for 35 will be accepted, but 1824 must be correct.

V – Misc & Concepts (20 points)

The following questions all come from the daily videos and were asked at the beginning of class. 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+ and Orange with white stripe/1-

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

Blue/2+ and Blue with white stripe/2-

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

This one is a little tricky. Yellow/W1 for one wire and Black/Ground for the other

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

Yes.

e) In a resistive voltage divider, will the output voltage always be less than the input?

Lower because the output is taken across only one of the two resistors

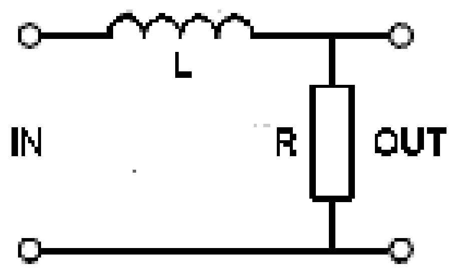
f) What is the input impedance of an Analog Discovery scope channel?

1 M Ohms

g) What is a typical internal resistance for a 9V heavy duty battery?

30-40 Ohms

h) What is the magnitude and phase of the transfer function for the LR circuit above at high (not infinite) frequencies?



Trans Func = $R/(R+\omega jL)$ so

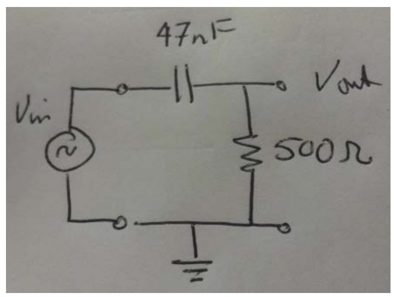
Mag is $R/\omega L$, phase is -90degrees

i) 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 *R << 1/(ωC) for low (other direction for high)*

ii. RL *R >> ωL for low (other direction for high)*

iii. RLC *for low, both low conditions above … or high, other set*



j) In the CR circuit above, is the current in R large or small when the frequency is low?

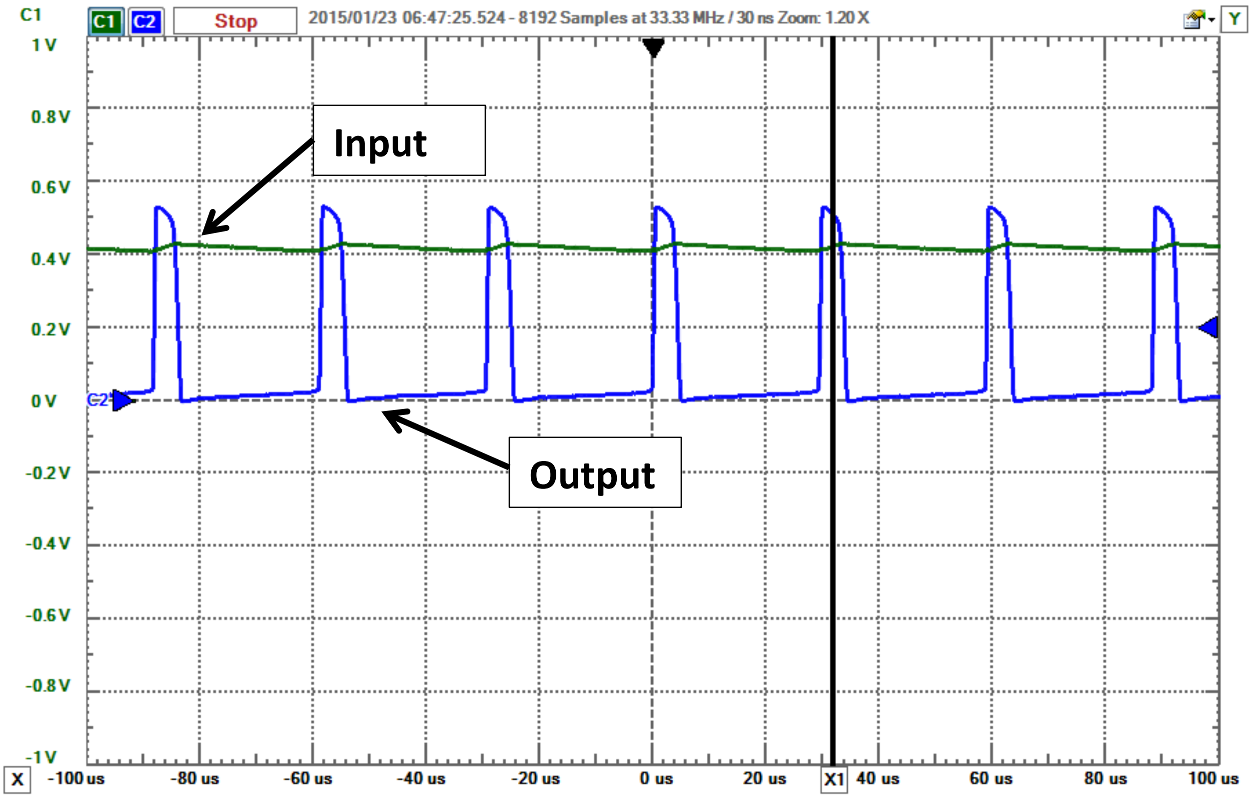
Low frequency, C is open, current is small.

k) What is the purpose of an ideal model for an inductor if the analytical formula we can derive from it does not provide a particularly accurate prediction of inductance?

It is used to estimate inductance values so other circuit parameters can be selected to be near what is needed.

l) 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?

Either wind the two coils to be the same length or wind them on a magnetic core. Either answer is OK



m) In the figure above, showing input and output voltages from a Joule Thief circuit, determine the approximate frequency of the train of pulses. The horizontal scale is 20μs/div. (4 pts)

7 pulses in 200μs = 35kHz (any answer from 30k to 40k is OK)

n) What is the color code for a 1kΩ resistor? (2 pts)

Brown-Black-Red