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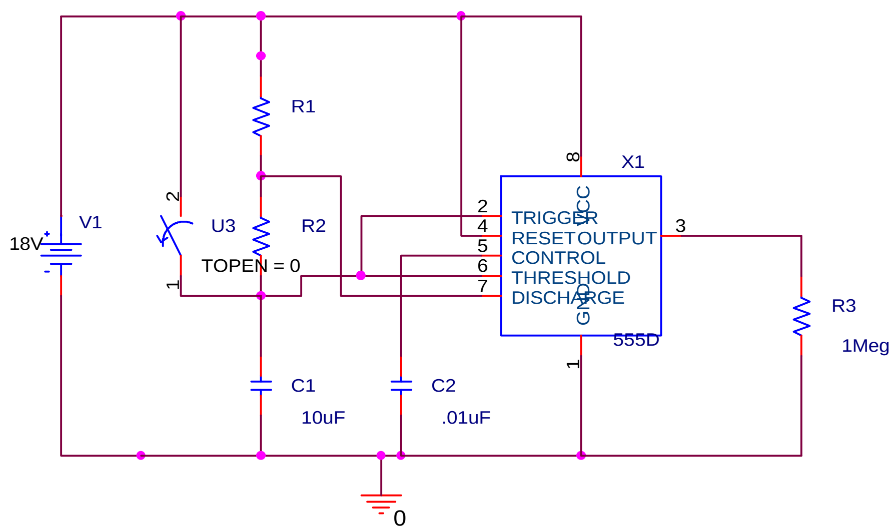
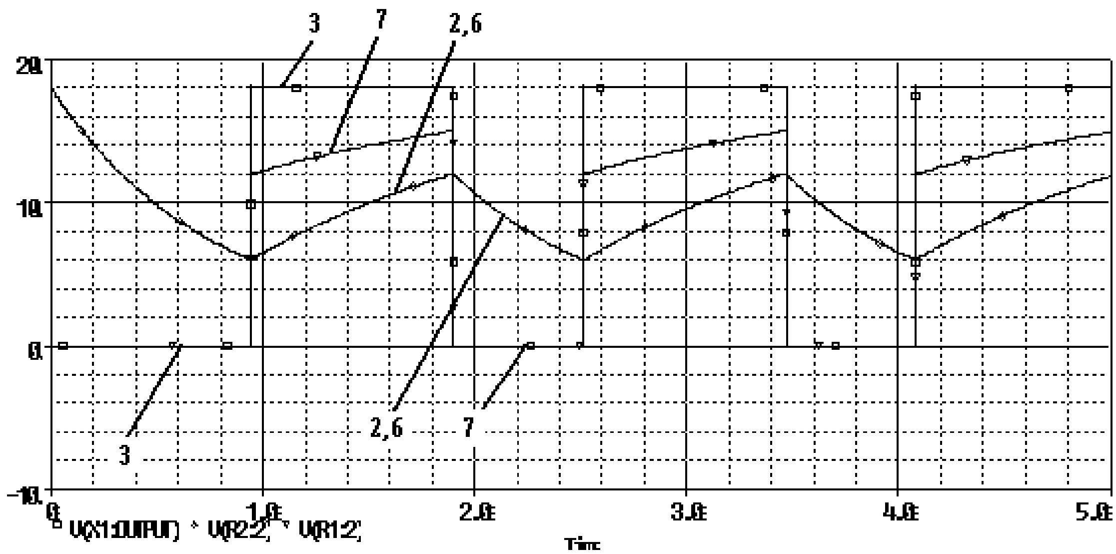
Question 1 -- Astable Multivibrator



The circuit above has been simulated using PSpice. Using PROBE, the voltages at pins 2, 6, 7, and 3 have been displayed.

a. Label which trace goes with which pin (2,3,6,7) in each time period. Be sure that you label the traces in both the on and off parts of the pulse cycle. *(8 points)*



b. What is the duty cycle of the pulses in the plot? *(4 points)*

T1 = 0.96s T2=0.60s T=1.56s

duty cycle = T1/T = .615 ***duty cycle = 61.5% (answers may vary)***

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b. Determine the values of R1 and R2 from the information in this plot. *(4 points)*

T2 = 0.693(R2)(C1) 0.6=0.693(R2)(10EE-6) R2=0.0866EE6 ***R2=86.6K ohms***

T1=0.693(R1+R2)(C1) 0.96=0.693(R1+86.6K)(10EE-6) R1+86.6K=138.5K

R1=51.9K ohms

c. Test A:What could you do to increase the duty cycle of the pulses? *(4 points)*
c. Test B:What could you do to decrease the duty cycle of the pulses? *(4 points)*

duty cycle = T1/T = [0.693(R1+R2)C1]=[0.693(R1+2R2)C1]=[R1+R2]/[R1+2R2]

$$\text{duty cycle} = \frac{\frac{R1}{R2}+1}{\frac{R1}{R2}+2}$$

If R1>>R2 then the duty cycle approaches 100% -- It increases. If R1<<R2 then the duty cycle approaches 50% -- It decreases. Changing the value of the capacitor will influence the frequency, but not the duty cycle.

Test A: increase R1 or decrease R2
Test B: increase R2 or decrease R1

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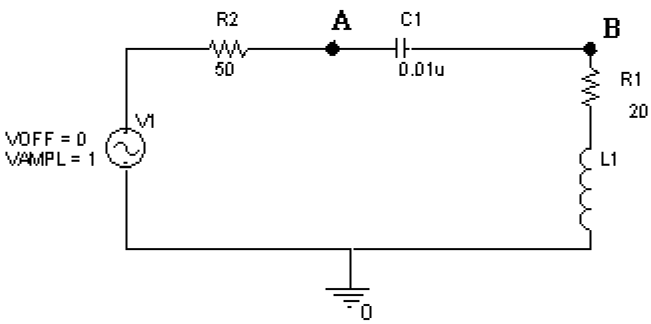
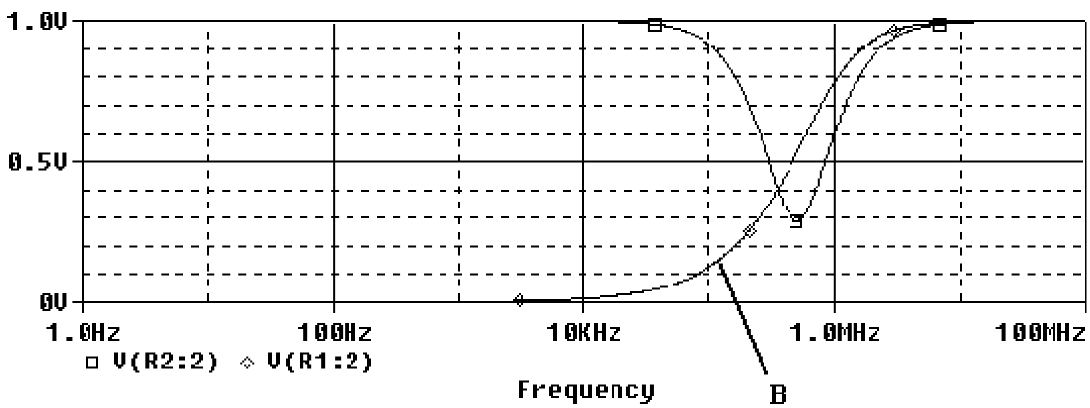
Question 2 – Measuring Inductance ***(20 points)***

This page is Test A: Given the following circuit and its AC sweep below:





a) Find the transfer function, $H(j\omega)$, at point B. Determine the function and the magnitude and the phase at high and low frequencies. *(8 points)*

(2 pts) $H(j\omega)$ =

method 1: excluding R2

H(jw)=[R1+jwL1]/[R1+jwL1+1/jwC1]

H(jw)=[jwR1C1-w²L1C1]/[jwR1C1--w²L1C1+1]

method 2: including R2

H(jw)=[R1+jwL1]/[R2+R1+jwL1+1/jwC1]

H(jw)=[jwR1C1-w²L1C1]/[jw(R1+R2)C1--w²L1C1+1]

either is ok

(1 pt) $H(j\omega_{lo})$ =***jwR1C1*** (1 pt) $H(j\omega_{hi})$ = **1**

(1 pt) $|H(j\omega_{lo})|$ = **0** (1 pt) $|H(j\omega_{hi})|$ = **1**

(1 pt) $\angle H(j\omega_{lo})$ = $\boldsymbol{\pi/2}$ (1 pt) $\angle H(j\omega_{hi})$ = **0**

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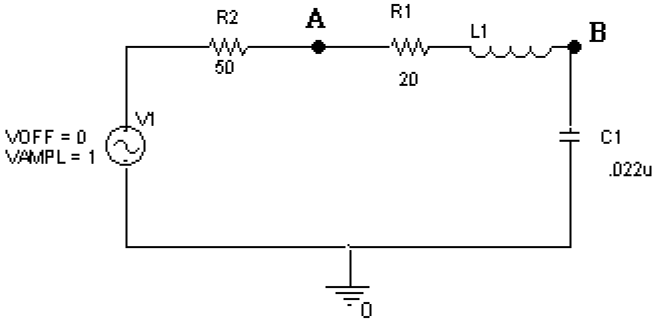
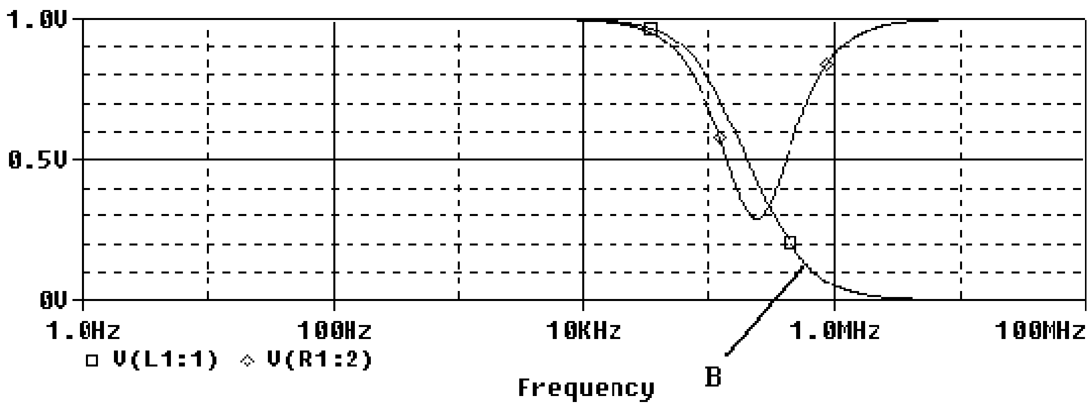
Question 2 – Measuring Inductance ***(20 points)***

This page is Test B: Given the following circuit and its AC sweep below:





a) Find the transfer function, $H(j\omega)$, at point B. Determine the function and the magnitude and the phase at high and low frequencies. *(8 points)*

(2 pts) $H(j\omega)$ = *method 1: excluding R2*

H(jw)=[1/jwC1]/[R1+jwL1+1/jwC1]

H(jw)=[1]/[jwR1C1--w²L1C1+1]

method 2: including R2

H(jw)=[jwC1]/[R2+R1+jwL1+1/jwC1]

H(jw)=[1]/[jw(R1+R2)C1--w²L1C1+1]

either is ok

(1 pt) $H(j\omega_{lo})$ = **1**

(1 pt) $H(j\omega_{hi})$ = ***1/-w²L1C1***

(1 pt) $| H(j\omega_{lo}) |$ = **1**

(1 pt) $| H(j\omega_{hi}) |$ = **0**

(1 pt) $\angle H(j\omega_{lo})$ = **0**

(1 pt) $\angle H(j\omega_{hi})$ = $\boldsymbol{\pi}$

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b) Based on your results from part a), indicate on the plot the trace for the magnitude of the voltage at point B *(2 points)*.

c) Find the resonant frequency f_0 from the plot. Notice that the x-axis has logarithmic scale. (ie. $10^{0.5} = 3.16$) *(3 points)*

Test A: f_0*=10EE(5.7)=501,187* **f_0=500K Hz (answers may vary)**
Test B: f_0*=10EE(5.4)=251,189* **f_0=250K Hz (answers may vary)**

d) Solve for the unknown inductance. *(5 points)*

Test A*: f_0=1/[2psqrt(L1C1)] L1=1/[C1(2pf_0)^2]*
L1=1/(0.01EE-6)(pEE+6)^2=1/[0.0987EE+6]=10.1EE-6
L1 = 10 uF (answers may vary)
Test B*: f_0=1/2psqrt(L1C1) L1=1/C1(2pf_0)^2]*
L1=1/(0.022EE-6)(5pEE+5)^2=1/[5.43EE+4]=0.18EE-4
L1 = 18 uF (answers may vary)

e) Both of the resistances in this circuit are not physical resistors. They represent the resistance of something else in the circuit. Assuming that these do not represent wire resistance, what do they represent? *(2 points)*

The resistor R2 is the 50 ohm impedance of the function generator.
The resistor R1 is the resistance in the wire of the inductor, L1.

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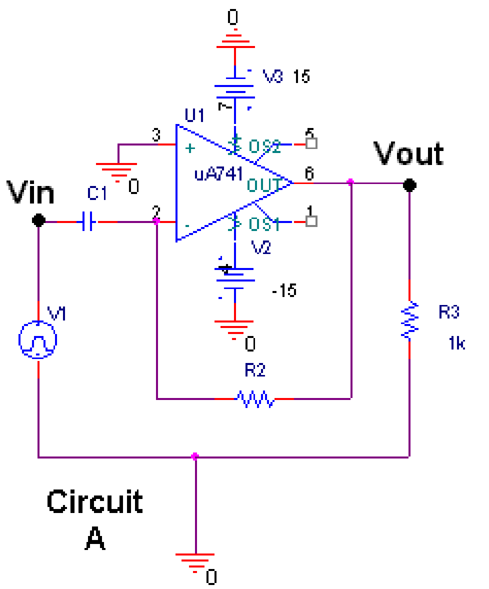
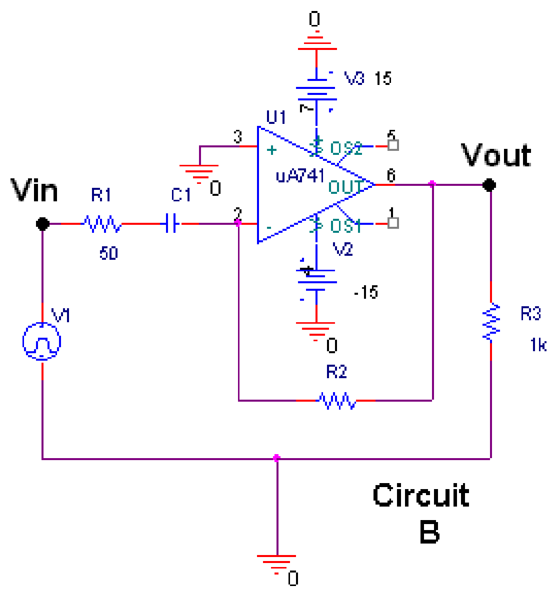
Question 3 -- Op Amp Differentiator ***(20 points)***





Test A: Given: C1=0.001 μF R2= 500 Ω
Test B: Given: C1=0.0022 μF R2= 1000 Ω

In this question, we will look at the effect of the 50 ohm input resistance on the op-amp differentiator.

a) What is the expression for Vout/Vin for circuit A above. Give this in terms of C1, R2, j and ω. *(3 points)*

$$\frac{V_{out}}{V_{in}} = -jw\,R2C1$$

b) Determine the expression for Vout/Vin for circuit B above. (Be sure to include the impedance of the function generator, R1.) Give this in terms of C1, R1, R2, j and ω. *(3 points)*

$$\frac{V_{out}}{V_{in}} = \frac{-jw\,R2C1}{1 + jw\,R1C1}$$

c) Find the corner frequency f_c for circuit B. This should be a numerical value in Hertz. (*4 points)*

Test A: f_c*=1/[2pR1C1]=1/[2p(50)(0.001EE-6)]=3.183EE+6*

f_c=3,183K Hz = 3.2Meg Hz

Test B: f_c*=1/[2pR1C1]=1/[2p(50)(0.0022EE-6)]=1.447EE+6*

f_c=1,447K Hz = 1.4Meg Hz

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d) Does circuit B behave like circuit A above or below the corner frequency? Use limits to show how you know this. *(6 points)*

$$\frac{V_{out}}{V_{in}} = \frac{-jwR2C1}{1 + jwR1C1}$$

$$at\ low\ \ frequencies: \quad \frac{V_{out}}{V_{in}} = \frac{-jwR2C1}{1} = -jwR2C1 \quad differentiator(like A)$$

$$at\ high\ \ frequencies: \quad \frac{V_{out}}{V_{in}} = \frac{-jwR2C1}{jwR1C1} = \frac{-R2}{R1} \quad (inverting\ \ amplifier)$$

Circuit B will behave like circuit A below the corner frequency.

e) At about what frequencies does the 50 ohm impedance of the function generator prevent this circuit from differentiating? (*4 points)*

Circuit B should act like a differentiator at frequencies much less than f_c. Therefore, it will not differentiate above f_c. Minimally we could say that the resistance prevents this circuit from working at frequencies above about 3 Meg Hz for Test A and 1.5 Meg Hz for Test B. Even better, we could estimate that it would not be differentiating even above frequencies a bit lower, perhaps 1Meg Hz for Test A and 1.5Meg Hz for Test B. For a conservative estimate, we have plenty of frequency range available to go down an entire decade. Therefore, I would say conservatively,

Test A: 300K Hz and above
Test B: 150K Hz and above

(answers may vary)

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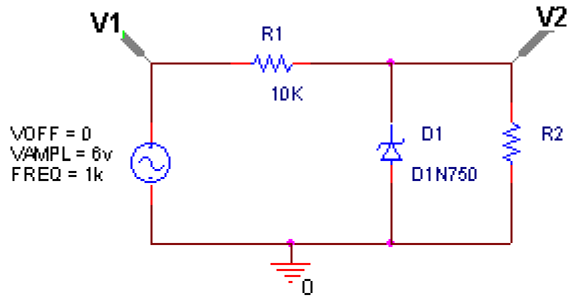
Question 4 – Zener Diodes ***(20 points)***



The circuit above is a zener diode voltage regulator. Assume the zener voltage of the diode is 4.7 volts and its forward bias voltage is 0.7 volts.

1) What does a voltage regulator do? (*2 points)*

> ***A voltage regulator is a circuit which prevents the voltage from exceeding a set voltage limit.***
> *(In this case, the positive limit is +4.7V and the negative limit is –0.7V.)*

2) What would the voltage at V2 be when V1 = 6V if R2 has the following values: *(6 points)*

i) 1K ohms *expected voltage V2=(1K/11K)6V=0.54V (0.54<4.7)*
V2=0.54V

ii) 10K ohms *expected voltage V2=(10K/20K)6V=3V (3<4.7)*
V2=3V

iii) 100K ohms *expected voltage V2=(100K/110K)6V=5.45V (5.45>4.7)*
V2=4.7V

3) What would the voltage at V2 be when V1 = -6V and if R2 has the following values: *(6 points)*

i) 1K ohms *expected voltage V2=(1K/11K)-6V=-0.54V (-0.54>-0.7)*
V2 = -0.54V

ii) 10K ohms *expected voltage V2=(10K/20K)-6V=-3V (-3<-0.7)*
V2 = -0.7V

iii) 100K ohms *expected voltage V2=(100K/110K)-6V=-5.45V (-5.54<-0.7)*
V2 = -0.7V

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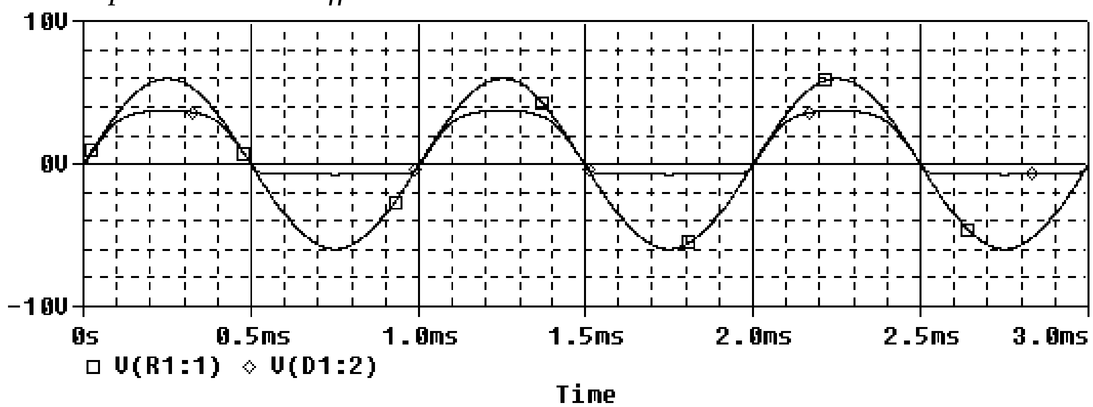
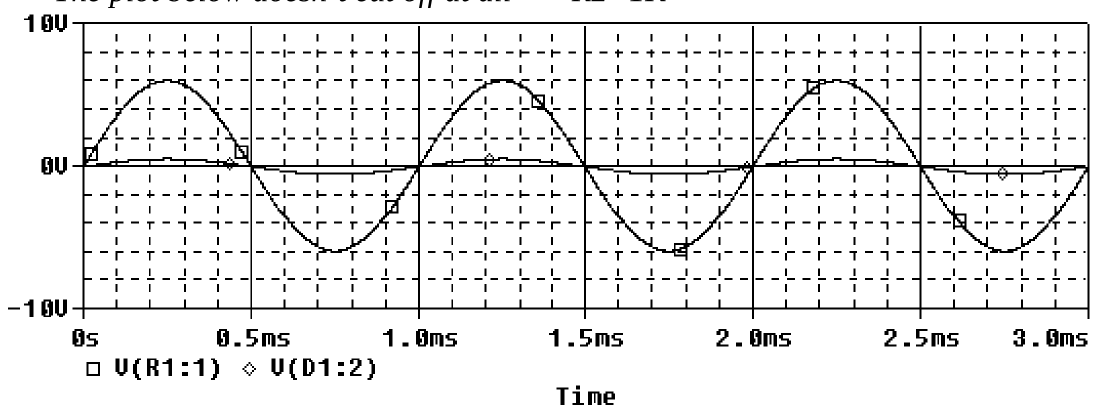
3) Each of the following three plots was made with a different value for R2: 1K ohms, 10K ohms and 100K ohms. Indicate which plot was made with which value for R2. *(6 points)*

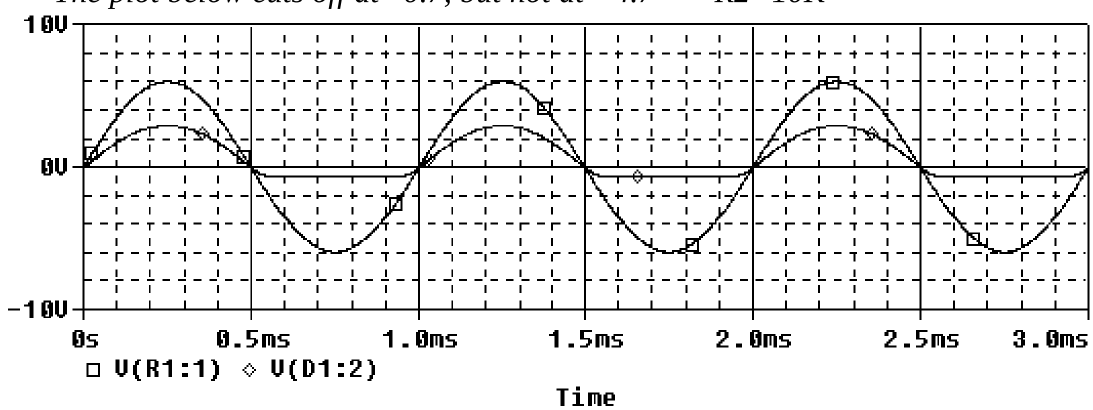
The plot below cuts off at 4.7 and –0.7 --> R2=100K



The plot below doesn't cut off at all --> R2=1K



The plot below cuts off at –0.7, but not at +4.7 --> R2=10K



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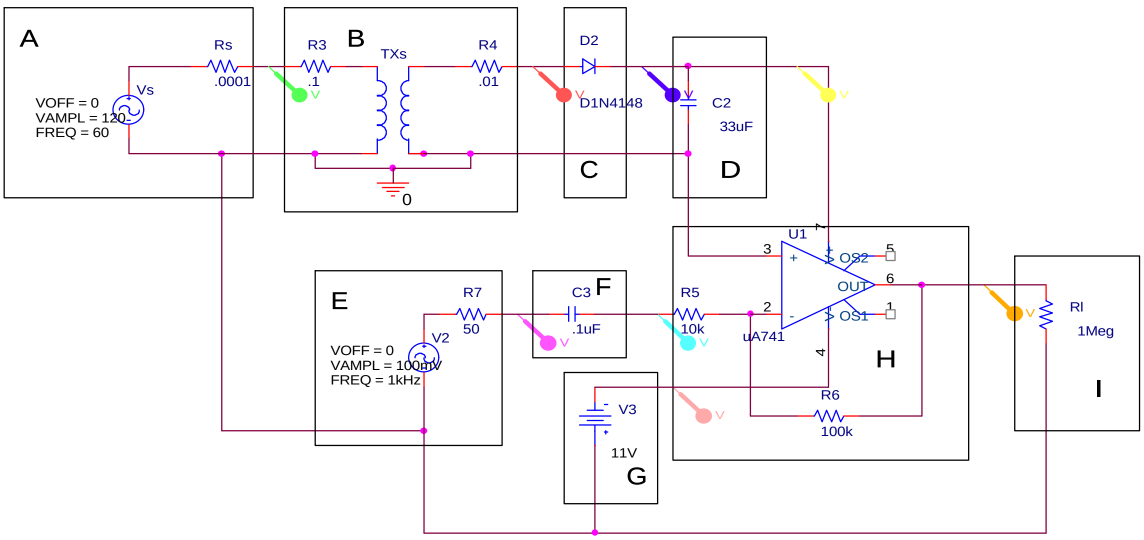
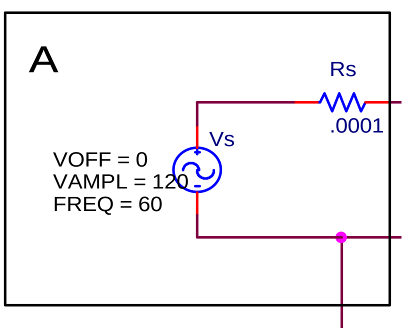
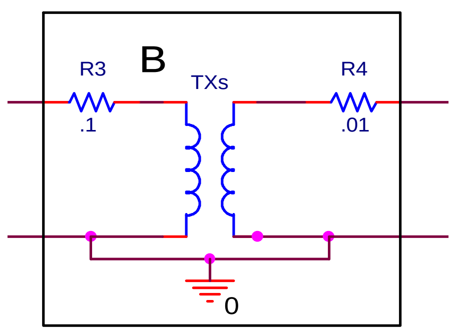
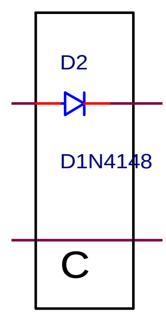
Question 5 -- Circuit functionality and transformers *(20 points)*

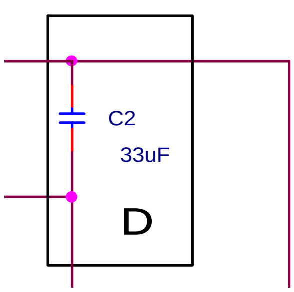
The following circuit was constructed to test two DC power supplies. One is a battery and one is a wall wart (connects to a normal 120V outlet). The boxes surrounding each part of the circuit identify the functional blocks (each has a specific purpose). Each of the boxes is also shown expanded for clarity.

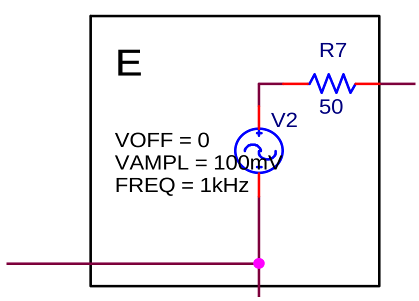


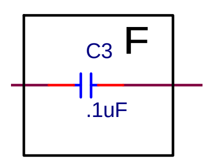












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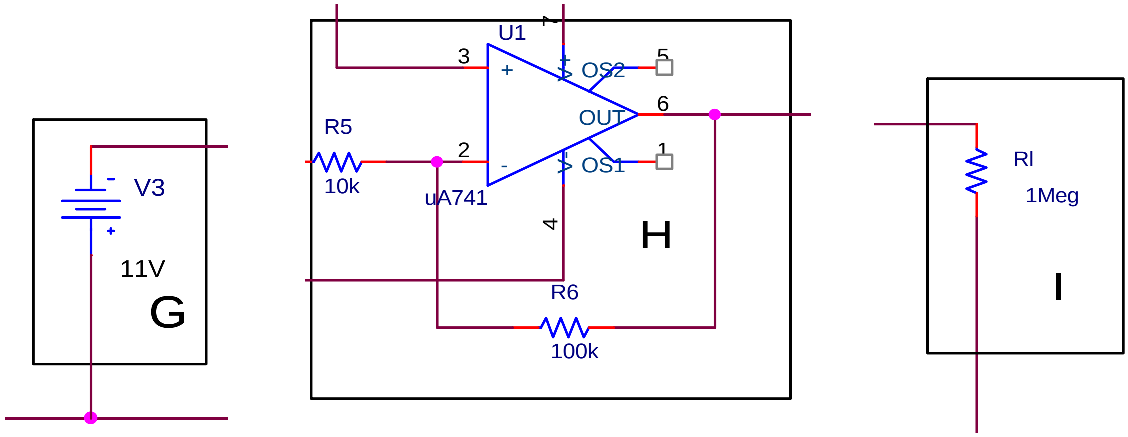

a. Identify the function of each of the nine blocks. (Draw a line to connect the letter of the block to its function). *(9 points)*

A
B
C
D
E
F
G
H
I

1. Measure output voltage
2. Rectify AC voltage
3. Input signal voltage
4. Block DC voltage while passing AC voltage
5. Smooth ripples to improve DC output voltage
6. Step AC voltage down from 120V to 12V
7. Provide AC power for DC supply
8. Amplify signal voltage
9. −12V power supply

b. On the next page are plotted six voltages measured at various points in the circuit. Identify each of the voltages by indicating the block for which this is the output voltage. Note that there are only six voltages but there are eight output points for the blocks. *(6 points)*

c. Based on the voltages you have just identified, what is the ratio of the input voltage to the output voltage of the transformer? Note that a real transformer is modeled here so that it has finite resistance in its windings. However, you can neglect these small resistances in the rest of this problem. *(3 points)*

120V : 12V = ***10 : 1***

d. If the primary winding of the transformer has 10000 turns, how many turns does the secondary winding have to produce this change in voltage? *(2 points)*

Test A: N2/10000 = 1/10 ***N2 = 1000 turns***

Test B: N2/20000 = 1/10 ***N2 = 2000 turns***

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