Electronic

Instrumentation

Quiz 2 Solution

Spring 2018

1.	/20
2.	/20
3.	/20
4.	/20
5. Online Quiz	/20
Total	/100

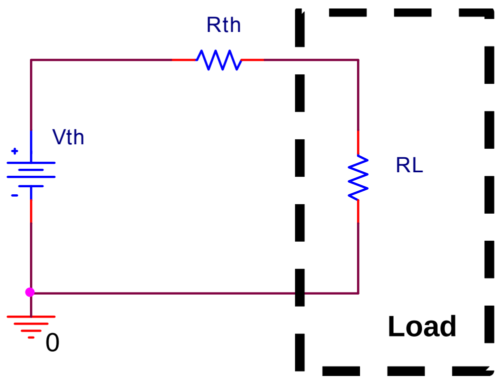
Name ____________________

Please write your name at the top of every page (following this page)!

Notes:
DO NOT WRITE ON THE BACK OF PAGES!! EXTRA PAGES ARE PROVIDED IN QUIZ!
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. Round answers to 3 significant digits.

Name ___________________

Problem 1: Thevenin Equivalent Circuits (20 pts)

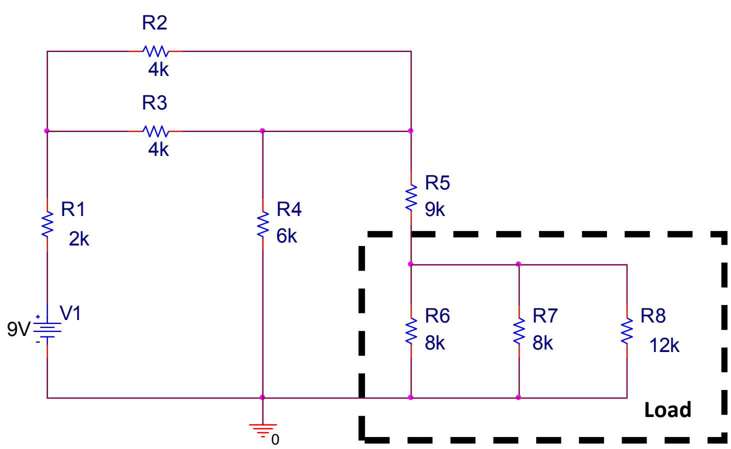


The Thevenin Equivalent circuit consists of a voltage source (Vth) in series with a resistor (Rth), which is then in series with a defined load (RL). Note: A load can be more than one component. If there are mulitple, the value of the load resistance should be calculated to create one component.

In the circuits below, you are to find Vth and Rth and then re-draw the thevenin circuit with the defined RL. It will help you and the grader to redraw the circuit as much as needed to find the answers. Extra space is available in the problem and at the end of the exam if needed! (DO NOT WRITE ON THE BACK OF THE EXAM IF YOU WANT IT TO BE GRADED!!!)

In this problem, you are to find the Thevenin voltage and resistance for a series of related circuits. While the circuits and their analysis are similar, treat each circuits as a separate problem.

1.1: Find and sketch the Thevenin Equivalent for for the following circuit. (4 pts)



$R_{1P1} := 2k\Omega$ $R_{4P1} := 6k\Omega$ $R_{7P1} := 8k\Omega$ $V_{1P1} := 9V$

$R_{2P1} := 4k\Omega$ $R_{5P1} := 9k\Omega$ $R_{8P1} := 12k\Omega$

$R_{3P1} := 4k\Omega$ $R_{6P1} := 10k\Omega$

Take off load, R6,R7,R8 use circuit reduction and then voltage dividers

V_{th}	[V]
R_{th}	[ohms]

More space on next page for calculation and redrawn thevenin circuit!

Name ___________________

Extra space for 1.1:

<u>Thevenin Circuit Drawing</u>

$$R_{23P1} := \frac{R_{2P1} \cdot R_{3P1}}{R_{2P1} + R_{3P1}} = 2 \times 10^{3}\,\Omega$$

$$V_{R678} := V_{1P1} \cdot \frac{R_{4P1}}{R_{23P1} + R_{4P1} + R_{1P1}} = 5.4\,V$$

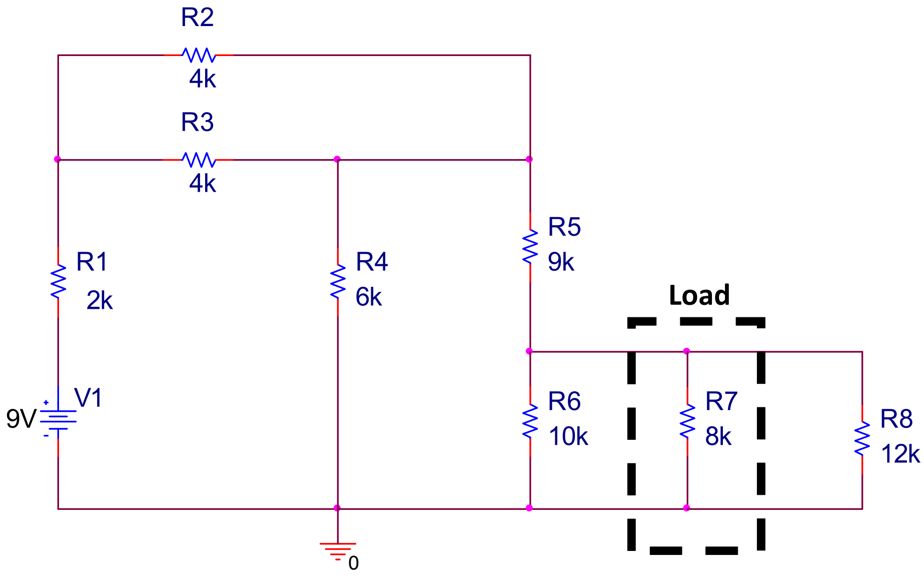
$$V_{th} := V_{R678} = 5.4\,V$$

To find Rth

$$R_{th1} := \left[\frac{(R_{23P1} + R_{1P1}) \cdot R_{4P1}}{R_{23P1} + R_{1P1} + R_{4P1}}\right] + R_{5P1}$$

$$R_{th1} = 1.14 \times 10^{4}\,\Omega$$

1.2: Find and sketch the Thevenin Equivalent for for the following circuit. (6 pts)



Find the voltage across R7. Take out the load and do a few voltage dividers.

Finding VR4 which is the same as VR568. Reducing the circuit...

$$R_{68P1} := \frac{R_{6P1} \cdot R_{8P1}}{R_{6P1} + R_{8P1}} = 5.455 \times 10^{3}\,\Omega$$

$$R_{568P1} := R_{68P1} + R_{5P1} = 1.445 \times 10^{4}\,\Omega$$

$$R_{4568P1} := \frac{R_{4P1} \cdot R_{568P1}}{R_{4P1} + R_{568P1}} = 4.24 \times 10^{3}\,\Omega$$

$$V_{R4568P1} := V_{1P1} \cdot \frac{R_{4568P1}}{R_{1P1} + R_{23P1} + R_{4568P1}} = 4.631\text{ V}$$

$$V_{R68P1} := V_{R4568P1} \cdot \frac{R_{68P1}}{R_{5P1} + R_{68P1}} = 1.748\text{ V}$$

$$V_{th2} := V_{R68P1}$$

To find Rth

$$R_{th2} := \frac{\left[\left[\frac{(R_{23P1} + R_{1P1}) \cdot R_{4P1}}{R_{23P1} + R_{1P1} + R_{4P1}}\right] + R_{5P1}\right] \cdot R_{68P1}}{\left[\frac{(R_{23P1} + R_{1P1}) \cdot R_{4P1}}{R_{23P1} + R_{1P1} + R_{4P1}}\right] + R_{5P1} + R_{68P1}}$$

V_{th}	[V]
R_{th}	[ohms]

More space on next page for calculation and redrawn thevenin circuit!

Name ___________________

Extra space for 1.2:

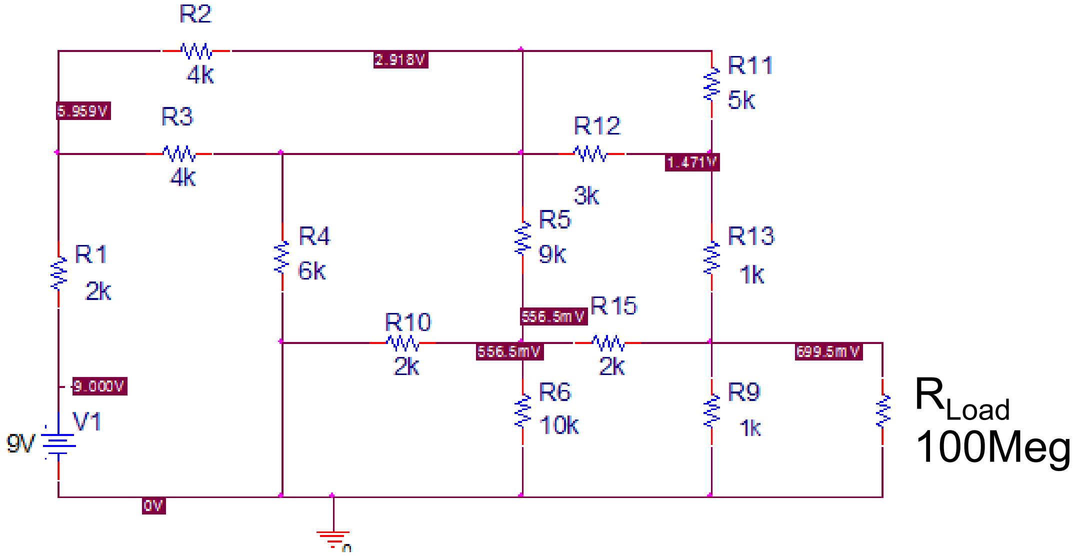
<u>Thevenin Circuit Drawing</u>

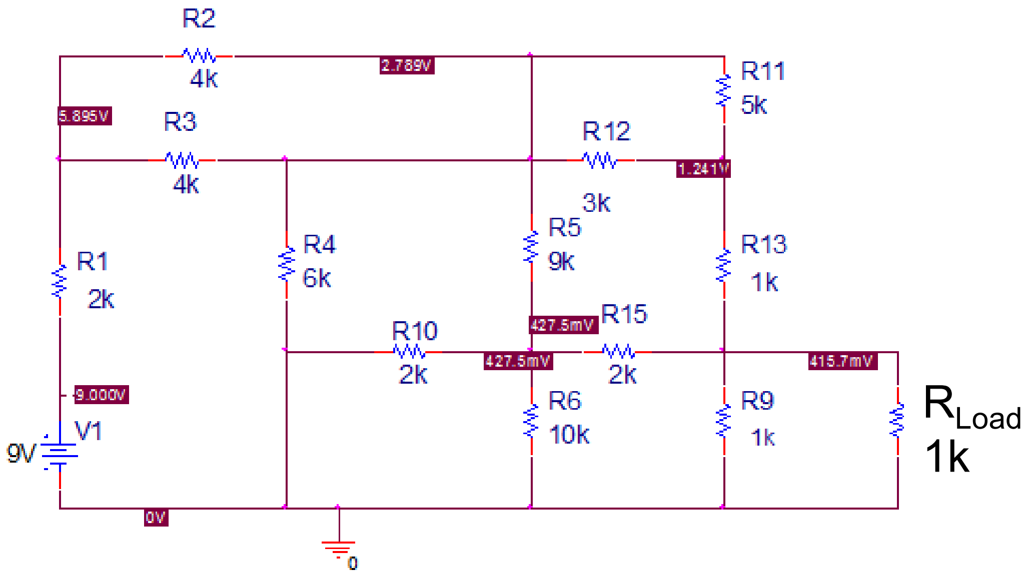
$$R_{th2} = 3.689 \times 10^{3}\,\Omega$$

$$V_{th2} \cdot \frac{1k\Omega}{R_{th2} + 1k\Omega} = 0.373\ V$$

Name ___________________

1.3: The circuit below is much more complicated. PSpice simulation results for node voltages are shown on the diagram. In the first plot the load resistor is very large (100 MΩ) while in the second plot the load resistor is much smaller (1 kΩ). ***Using the given voltages at each of the nodes for both RLoad (open circuit-like and 1kΩ) determine Vth and Rth. Note: A schematic of the thevenin circuit may be helpful to you but it is not necessary for grading. (8 pts)***





V_{th}	[V]
R_{th}	[ohms]

Name ___________________

Vthevenin is open circuit voltage after RLoad is taken off. Therefore, the voltage a the node above 100M ohm RLoad is Vth.

$V_{th3} := 0.7V$ can round up or not

To find Rth, you should use the thevenin equivalent circuit where the voltage across the 1k load is 415.7mV.

$V_{RLoad} := 415.7mV$

Therefore: $V_{RLoad} = \frac{1k\Omega}{1k\Omega + R_{th3}} \cdot V_{th3}$

$$R_{th3} := \frac{V_{th3} \cdot k\Omega}{V_{RLoad}} - 1k\Omega$$

$R_{th3} = 683.907\ \Omega$ $R_{th3} = 684\Omega$

1.4: What is the purpose of a thevenin equivalent circuit? (In other words, if it is an analysis tool, what is it used for?) How does this purpose relate to the procedure to find the thevenin equivalent circuit? (2 pts)

The thevenin equivalent allows you to switch out different loads without doing analysis all over again. It is a design tool to simplify.

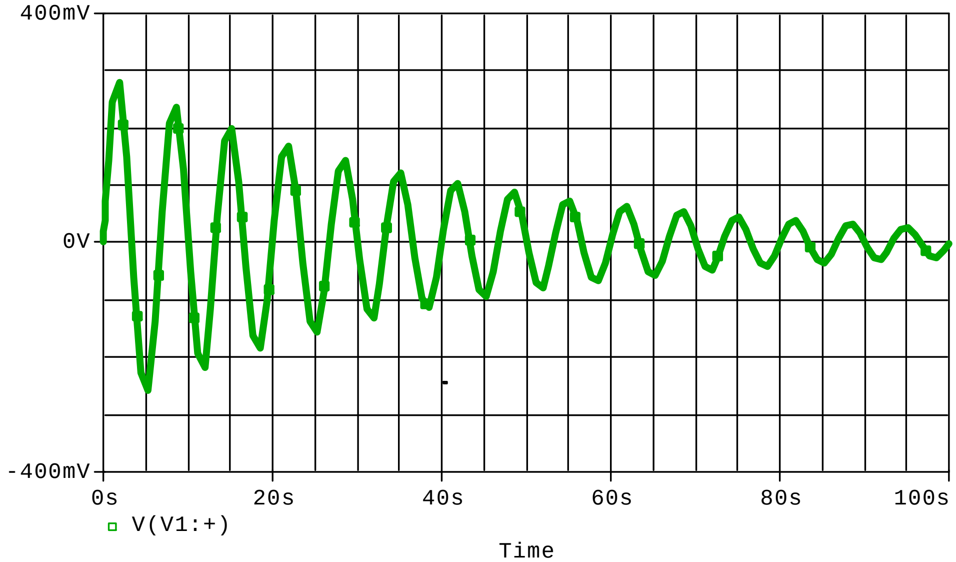
You are looking to find the voltage and resistance ***as the load sees it*** (from the perspective of the thing you are trying to switch out or design for.)

Note to graders there may be a wide range of answers here. Simplifying the circuit and something about the perspective of the load should be written here.

Name ___________________

Problem 2: Harmonic Oscillators (20 pts)

The velocity measured for an oscillating cantilever beam is shown in graphical form as:



2.1: Find the decay constant, α, and the angular frequency, ω, for this function. Pay close attention to axes. ***You must label the graph (arrows) with the points you are using for time and voltage for full credit.*** (6 pts)

$\omega = 2\pi f$

$\text{period} := 6.5s$

anything from 5.1 to 7 period

$f := \dfrac{1}{\text{period}} = 0.154\,\dfrac{1}{s}$

$\omega_{21} := 2\cdot\pi\cdot f = 0.967\,\dfrac{1}{s}$

$V_A = 0.3$

anything from 0.27 to 0.3

$\text{freq} = 0.15$

$DC = 0.025$

Can find it using known voltage and known time on the graph: 100mV at 42 sec

$0.3\cdot e^{-\alpha t} = 100mV$

$\dfrac{100mV}{0.3V} = 0.333$

$-\alpha\cdot 42s = \ln(0.333)$

$\alpha := \dfrac{-\ln(0.333)}{42} = 0.026$

close

ω	
α	

2.2: Write the mathematical expression for the voltage in the form $Ae^{-\alpha t}\sin\omega t$. (3 pts)

$0.3\cdot e^{-0.025t}\cdot\sin(0.967t)$

Name ___________________

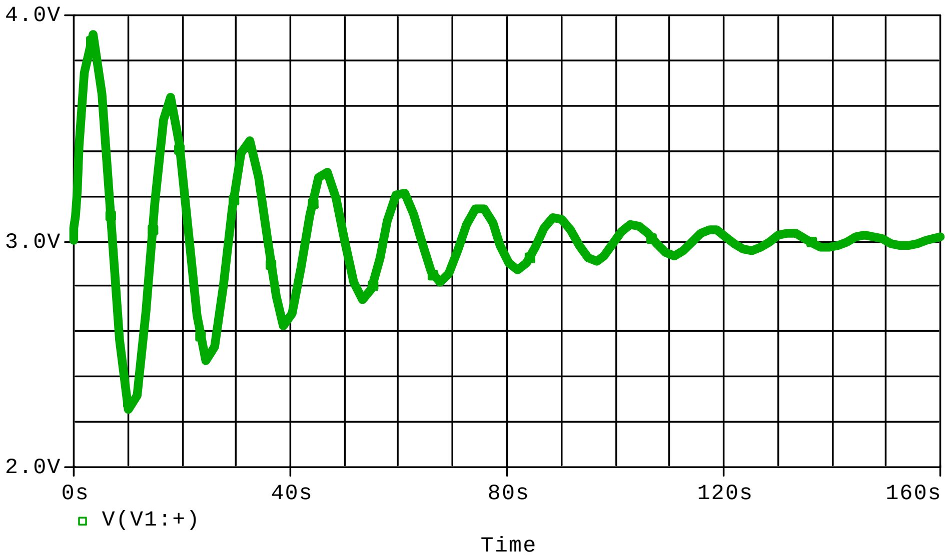
2.3: Find the acceleraton a(t) of the beam from your answer to part 2.2. Again, use real values for the constant and provide units where appropirate. (3 pts)

$$a = 0.3\cdot(-0.025)\,e^{-0.025t}\cdot\sin(0.967t)$$

$$0.3\cdot -0.025 = -7.5\times 10^{-3} \qquad 0.967\cdot 0.3 = 0.29$$

$$a = -7.5\cdot 10^{-3}e^{-0.025t}\cdot\sin(0.967t) + 0.29e^{-0.025t}\cdot\cos(0.967t)$$

2.4: Find the decay constant, α, and the angular frequency, ω, for this function. Pay close attention to axes. ***You must label the graph (arrows) with the points you are using for time and voltage for full credit.*** (6 pts)



There is a 3V offset given the center of the sinusoid at 3V.

$$\text{period2} := 15\text{s} \qquad f_2 := \frac{1}{\text{period2}} = 0.067\,\frac{1}{\text{s}}$$

anything 0.85 to 1

$$\omega := 2\cdot\pi\cdot f_2 = 0.419\,\frac{1}{\text{s}} \qquad 3.9 - 2.2 = 1.7 \qquad \frac{1.7}{2} = 0.85$$

ω	
α	

$$V_{A1} := 3.9 - 3 = 0.9 \qquad t1 := 4$$

$$V_{A2} := 3.1 - 3 = 0.1 \qquad t2 := 84$$

$$\alpha := \frac{-\ln\left(\frac{V_{A1}}{V_{A2}}\right)}{t1 - t2} = 0.027$$

2.5: Write the mathematical expression for the voltage. (2 pts)

$$3 + 0.85\cdot e^{-0.027t}\cdot\sin(0.419t)$$

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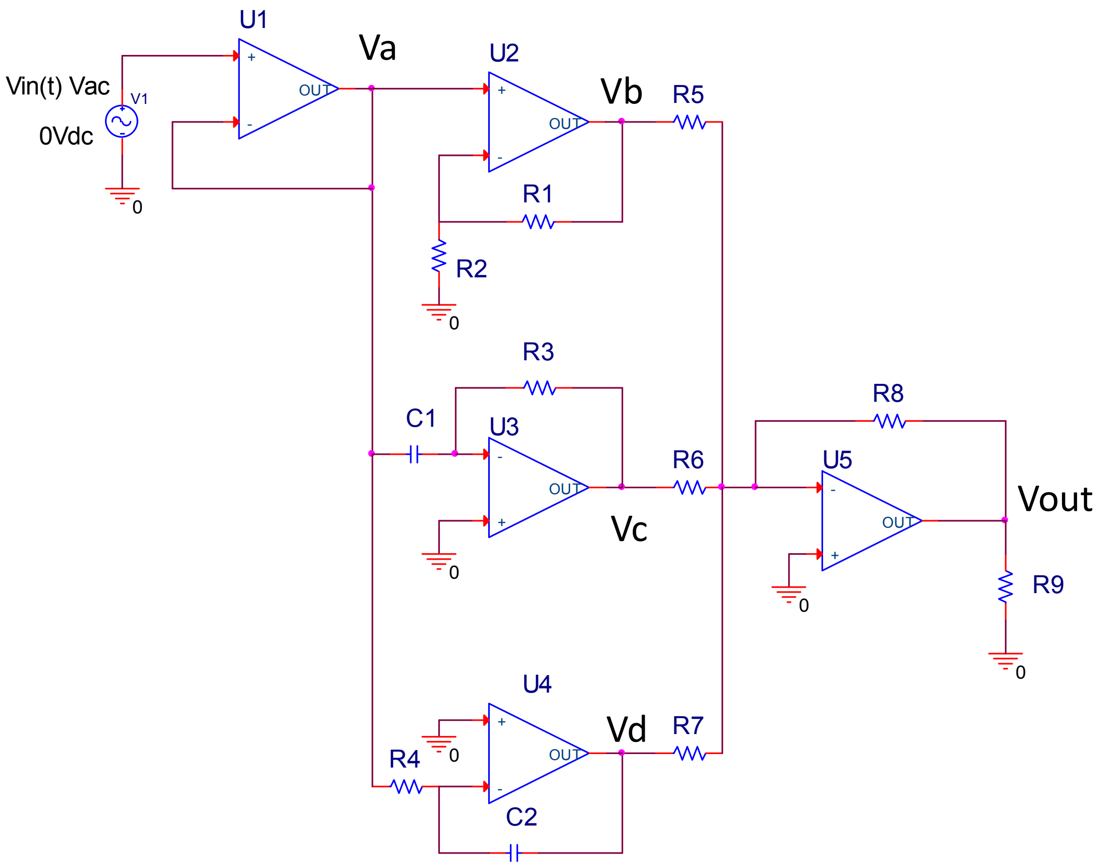
Problem 3: Op Amp Applications (20 pts)



±**9V** power supplies have been properly connected to all five op-amps in the circuit above

3.1: (5 pts) The circuit has 5 op-amps labeled as U1 through U5. State what the op-amp circuit is for each.

U1 Circuit: _______________ U2 Circuit: _______________ U3 Circuit: _______________

Follower Non-inverting Differentiator

U4 Circuit: _______________ U5 Circuit: _______________

Integrator Adder (inverting summer)

3.2 (4 pts): Using values listed below, determine the voltage values at Va(t), Vb(t), Vc(t) and Vd(t) as function fo Vin(t). ***Please include the symbolic solutions with R1, R2...as preliminary steps. Then you can substituve resistor values. (Vin(t) will be part of your final answer)***

$R_1 := 10k\Omega$ $R_2 := 2.5k\Omega$ $R_3 := 2k\Omega$ $R_4 := 4k\Omega$ $R_5 := 20k\Omega$ $R_6 := 40k\Omega$

$R_7 := 10k\Omega$ $R_8 := 10k\Omega$ $R_9 := 2k\Omega$ $C_1 := 100\mu F$ $C_2 := 47\mu F$

a) Voltage at point Va(t):

$Va(t) = Vin(t)$

Name ___________________

b) Voltage at point Vb(t):

$$Vb(t) = \left(1 + \frac{R_1}{R_2}\right) V_a(t) = \left(1 + \frac{10k}{2.5k}\right) \cdot Vin(t) = 5 \cdot Vin(t)$$

$$\left(1 + \frac{R_1}{R_2}\right) = 5$$

c) Voltage at point Vc(t):

$$Vc(t) = -\left(R_3 \cdot C_1\right) \cdot \frac{dVa(t)}{dt} = -0.2 \cdot \frac{dVin(t)}{dt}$$

$$-\left(R_3 \cdot C_1\right) = -0.2\,s$$

d) Voltage at point Vd(t):

$$Vd(t) = \frac{-1}{R_4 \cdot C_2} \cdot \int Va(t)\,dt = -5.319 \cdot \int Vin(t)\,dt$$

$$\frac{-1}{R_4 \cdot C_2} = -5.319\,\frac{1}{s}$$

3.3: (3 pts) Determine the output voltage, Vout(t), as a function of Vb(t), Vc(t) and Vd(t).

$$V_{out}(t) = \frac{-R_8}{R_5} \cdot V_b(t) - \frac{R_8}{R_6} \cdot V_c(t) - \frac{R_8}{R_7} \cdot V_d(t)$$

$$\frac{-R_8}{R_5} = -0.5 \qquad \frac{-R_8}{R_6} = -0.25 \qquad \frac{-R_8}{R_7} = -1$$

$$V_{out}(t) = -0.5 \cdot V_b(t) - 0.25\,V_c(t) - V_d(t)$$

Name ________________

3.4: (3 pts) Find Vout(t) as a function of Vin(t).

$$V_{out}(t) = -0.5\cdot(5\cdot Vin(t)) - 0.25\left(-0.2\cdot\frac{dVin(t)}{dt}\right) - \left(-5.319\cdot\int Vin(t)\,dt\right)$$

$$-0.5\cdot5 = -2.5$$

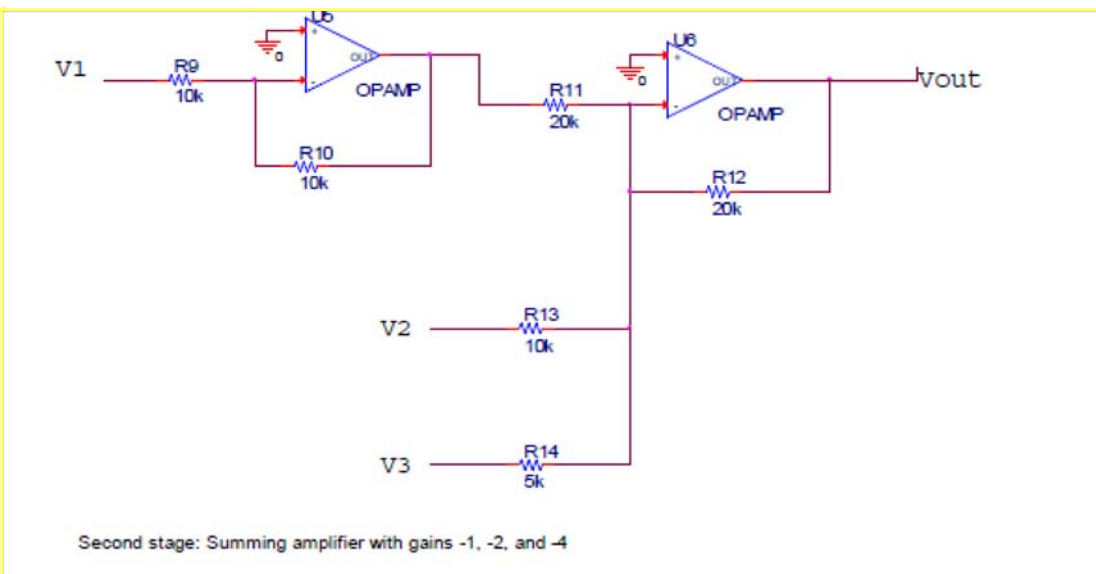
$$-0.25\cdot-0.2 = 0.05$$

$$V_{out}(t) = -2.5\cdot Vin(t) + 0.05\cdot\frac{dVin(t)}{dt} + 5.319\cdot\int Vin(t)\,dt$$

3.4 (5 pts) Design and draw an amplifier circuit (multiple stages may be needed) with three inputs (V1, V2, and V3) such that:

Vout = V1 - 2V2 - 4V3   (note: all values of of input voltages are positive to start.)

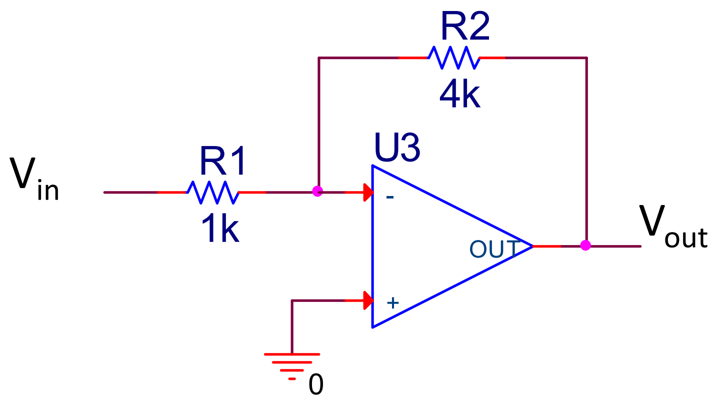
This is one solution. There are a few...

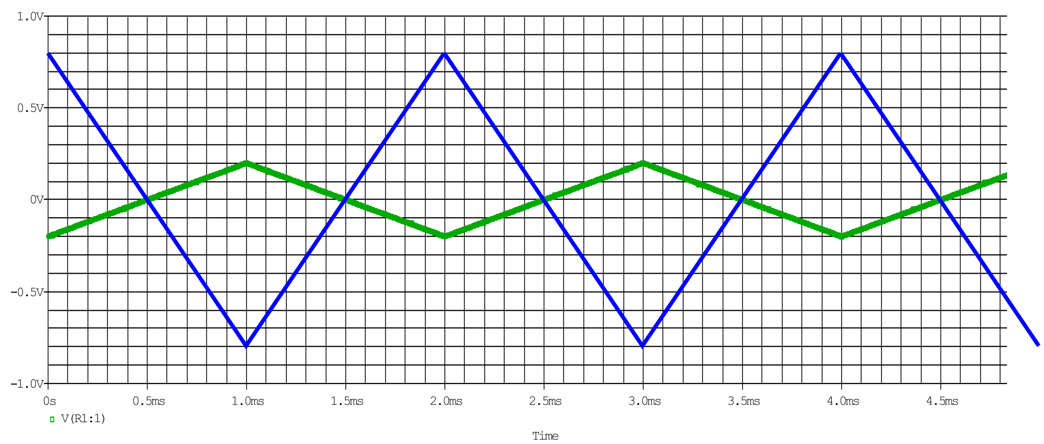


Name ___________________

Problem 4: Op Amps (20 pts)

4.1: (5 pts) The input voltage is shown below. Solve for and sketch the output voltage for the following circuit.

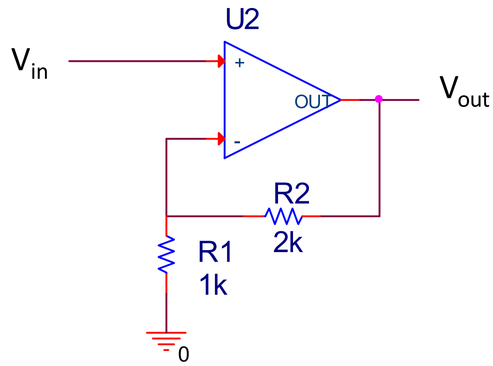


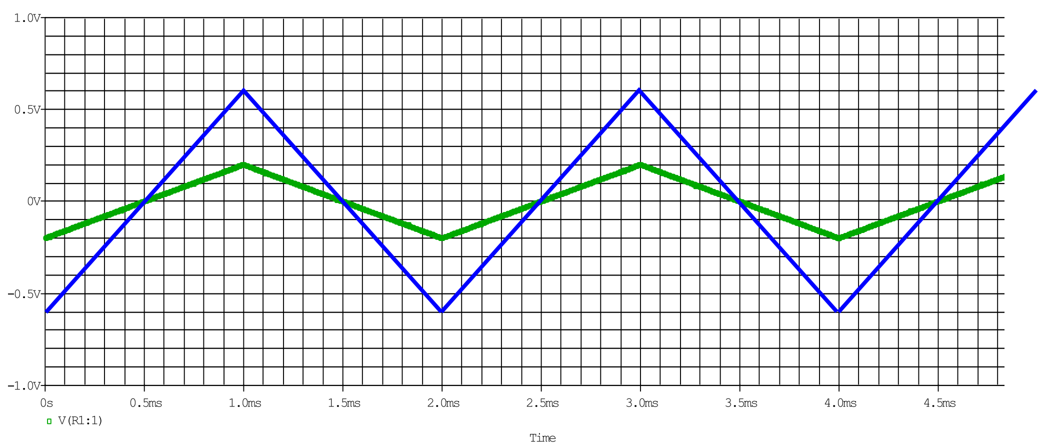


$$V_{out} = \frac{-R_2}{R_1} \cdot 0.2V$$

$V_{out} := -4 \cdot 0.2V = -0.8\,V$ peak at -0.2 goes to +0.8, peak at +0.2 goes to -0.8

4.2: (5 pts) The input voltage is shown below. Solve for and sketch the output voltage for the following circuit.



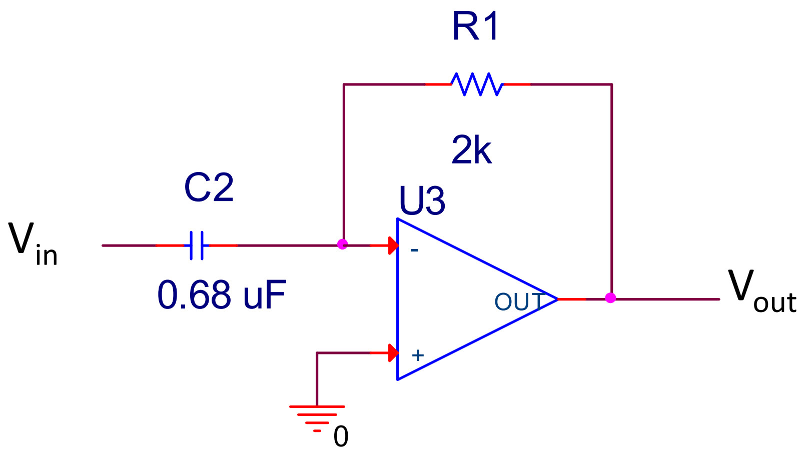


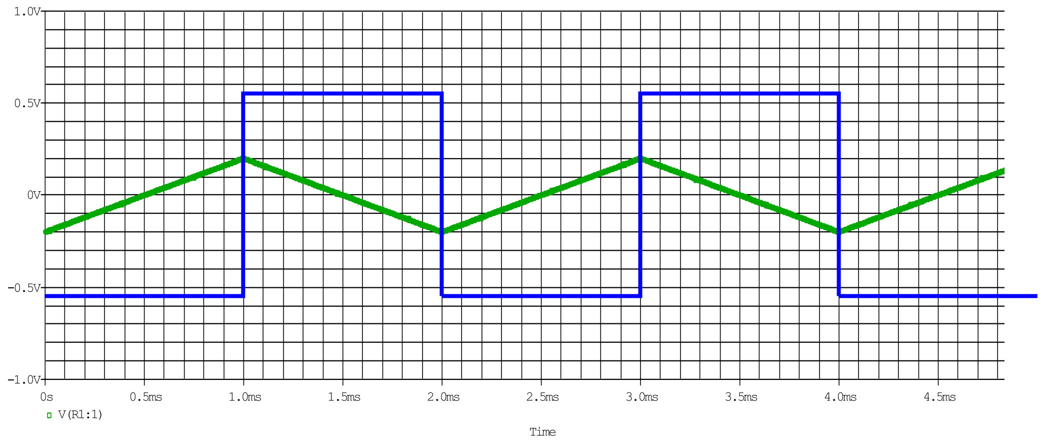
$$V_{out} = \left(1 + \frac{R_2}{R_1}\right) \cdot V_{in}$$

peak at -0.2 goes to -0.6, peak at +0.2 goes to +0.6

$$1 + \frac{2k}{1k} = 3$$

4.3: (5 pts) The input voltage is shown below. Solve for and sketch the output voltage for the following circuit.





$$V_{out} = -R_1 \cdot C_2 \cdot \frac{dVin}{dt} \qquad V_{in}(t) = \frac{0.4V}{1ms} \cdot t \qquad 0.68\mu F \cdot 2k\Omega \cdot 400 = 0.544\ s$$

$$V_{in}(t) = 400t$$

From 0 to 1 +400 slope * -RC = -0.544 line

From 1 to 2 -400 slope * -RC = +0.544 line

Basic Lab Questions

4.4: (3 pts) What circuits were used to create a velocity output from the strain gauges in the cantilever beam experiment? (Extra credit 2 pts: Draw them as one connected circuit, no partial credit)

Bridge circuit, difference amp, differentiator circuit

4.5: (2 pts) Name at least two names of the TAs from your section of EI. (You can write first names only if that's all you can remember.)

Section 1:	Section 2:
Waleed	Joe
Olivia	Michael
Ziyi	Kun