ENGR-4300

Electronic Instrumentation

Quiz 2

Fall 2010

Name __________________________

Section ___

Question I (20 points) ____________

Question II (20 points) ____________

Question III (20 points) ____________

Question IV (20 points) ____________

Question V (20 points) ____________

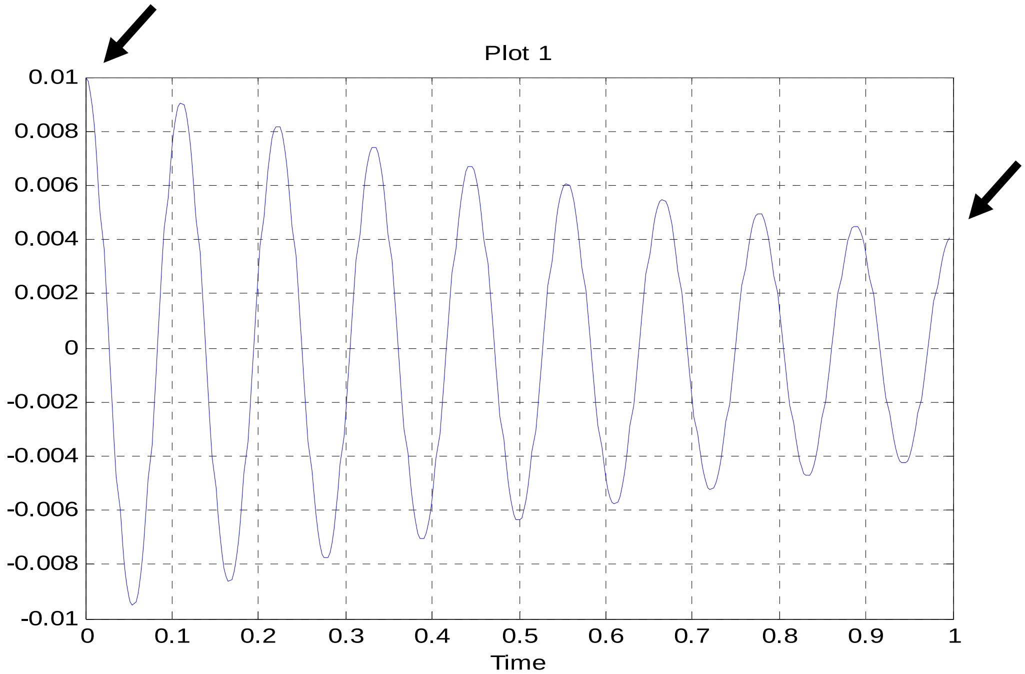
Total (100 points) _______________

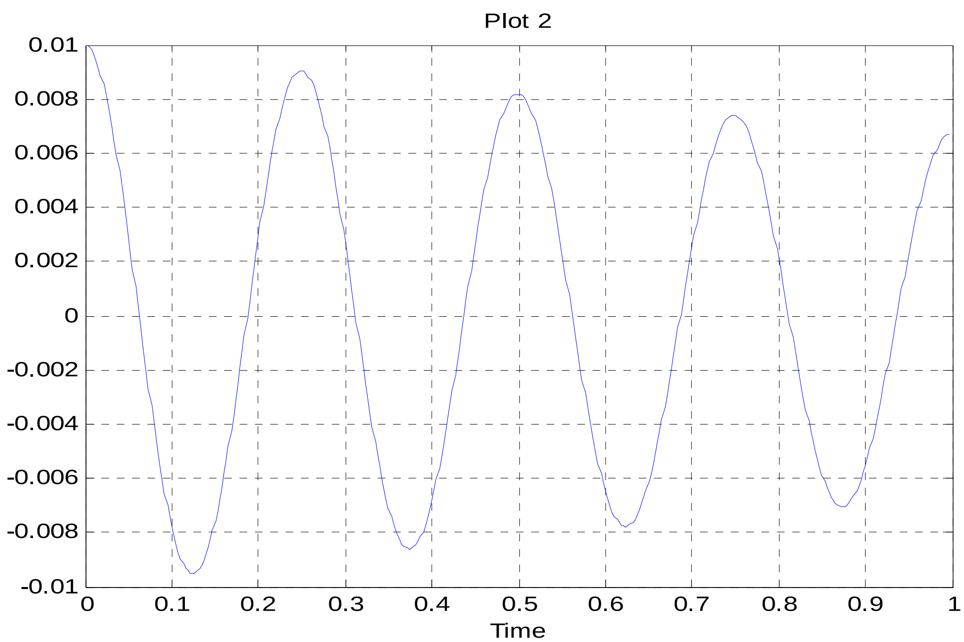
On all questions: SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification.

NOTE: You can receive half credit for parts of questions worth up to 10 points by circling the point value and writing 'do not grade' next to the question. You cannot select more than 10 points and the values of individual questions vary a lot. If you choose more than 10 points, all questions will be graded. You should only choose to do this if you have no idea how to answer the question and would like at least 5 total points rather than none.

Question I – Bridges and Damped Sinusoids (20 points)

You are given a cantilever beam similar to the one you used in experiment 4. You place two weights on the end of the beam one at a time (0.138 kg and 0.86 kg) and you get the following two plots (may not be in order of mass listed).





Question I – Bridges and Damped Sinusoids (continued)

1) (2pt) What is the frequency of plot 1? (Use at least 2 significant figures)

9 cycles in 1 second = 9.0Hz

2) (2pt) What is the frequency of plot 2? (Use at least 3 significant figures)

4 cycles in 1 second = 4.00Hz

3) (6pt) What is the damping constant for plot 1, mark the points on the plot? (Use at least 3 significant figures)

The signal amplitude drops to 0.4 from 1 in 1 second. $e^{-\alpha 1} = 0.4$ *so that* $-\alpha = \log 0.4 = -0.916$ *where the two points are indicated with the arrows.*

The actual number used in the Matlab program that generates the curves was 0.9

4) (6pt) Given the following formula, $k = (m + m_n)(2\pi f_n)^2$, and assuming that the two data points that you found are ideal, find values for k and m.

$k = (m + m_n)(2\pi f_n)^2$ $k = (m + 0.138)(2\pi 9)^2$ $k = (m + 0.86)(2\pi 4)^2$

gives us k=570, m=0.04

Question I – Bridges and Damped Sinusoids (continued)

5) (2pt) What is the mass of the beam?

$$m_b = \frac{0.04}{0.23} = 0.174kg$$

6) (2pt) Using the chart for Young's Modulus, determine the probable material that the beam is made out of given that the dimensions of the beam are: width = 1.5 cm, length=15 cm, and thickness = 2 mm.

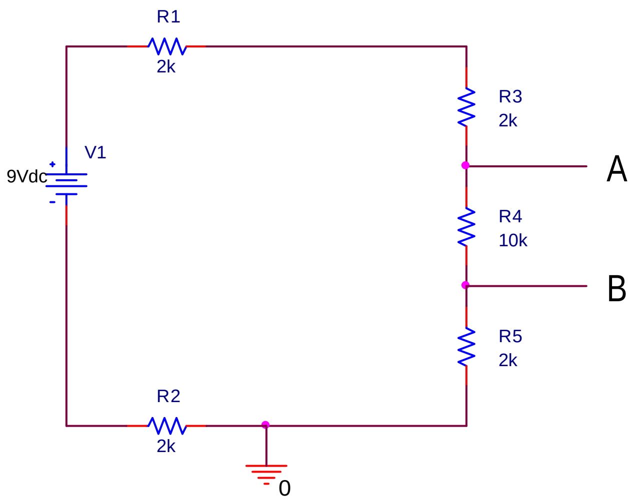
TABLE 9.1

Young's Modulus Table of Values

Metal	Elastic modulus (N/m2)	Metal	Elastic modulus (N/m2)
aluminum, 99.3%, rolled	6.96×10^{10}	lead, rolled	1.57×10^{10}
brass	9.02×10^{10}	platinum, pure, drawn	16.7×10^{10}
copper, wire, hard drawn	11.6×10^{10}	silver, hard drawn	7.75×10^{10}
gold, pure, hard drawn	7.85×10^{10}	steel, 0.38% C, annealed	20.0×10^{10}
iron, wrought	19.3×10^{10}	tungsten, drawn	35.5×10^{10}

$$k = 570 \quad w = 1.5cm \quad l = 15cm \quad t = 2mm \quad E = \frac{k4l^3}{wt^3} = 6.44x10^{10}\frac{N}{m^2} \quad aluminum$$

Question II – Thevenin Equivalents (20 points)



1) (7pt) Find the Thevenin equivalent voltage with respect to A and B for the circuit shown above) *Hint:* $Vth=V_A-V_B$ *so find* V_A *then* V_B

The voltage from A to B is 10/18 of the total voltage of 9V or 5V-V_{th}

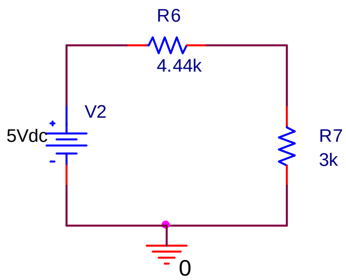
2) (6pt) Find the Thevenin equivalent resistance with respect to A and B for the circuit shown above.

Short the voltage source, then there is an 8k resistor in parallel with a 10k

$$R_{th} = \frac{(8k)(10k)}{18k} = 4.444k$$

Question II – Thevenin Equivalents (continued)

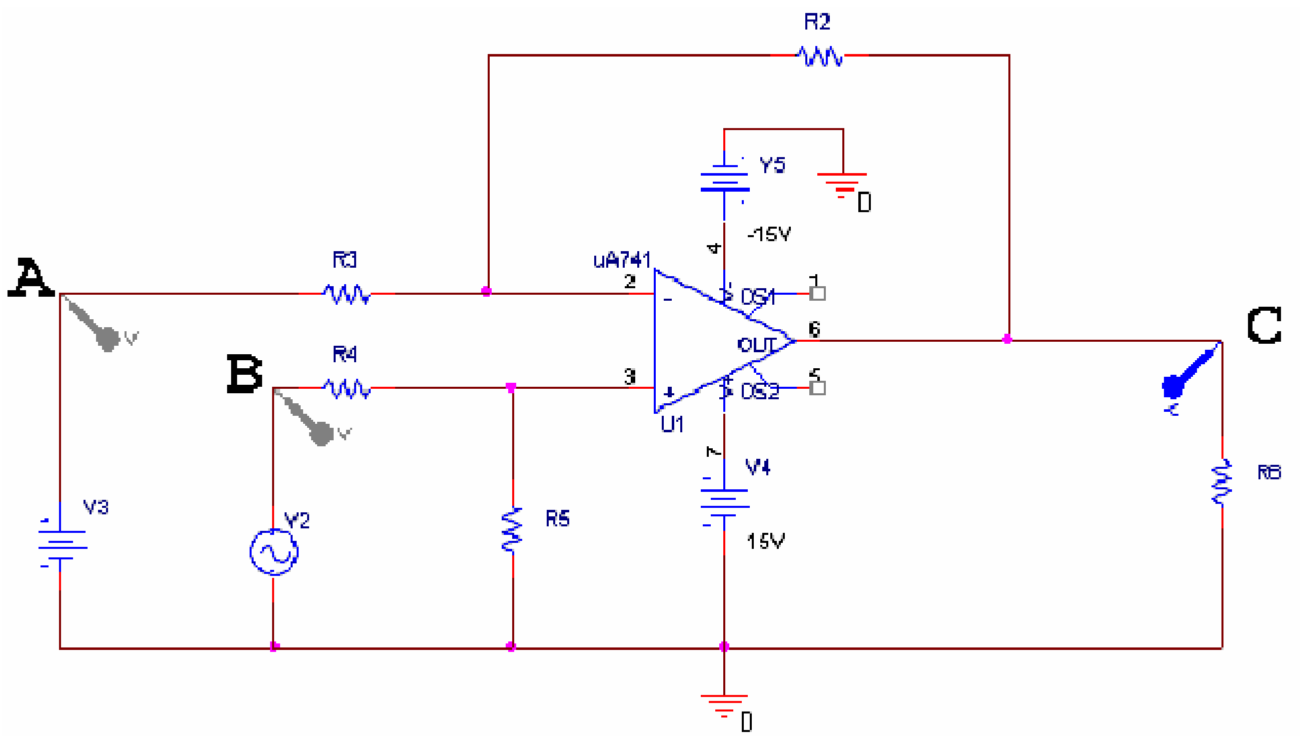
3) (5pt) Draw the Thevenin equivalent circuit with a load resistor RL of 3K between points A and B



4) (2pt) What is the voltage across R_L?

$$V = \frac{3}{7.44}5 = 2.016$$

Question III – Op-Amp Applications (20 points)



Assume the following components in the above circuit:

V_2 : Voff=2V, Vamp=2V, Freq=1k

$V3$:Vdc=2V

$R2 := 16k\Omega$ $R3 := 2k\Omega$ $R4 := 2k\Omega$

$R5 := 16k\Omega$ $R6 := 1k\Omega$

1) (1pt) The circuit above is an amplifier you've seen. What type of amplifier is it?

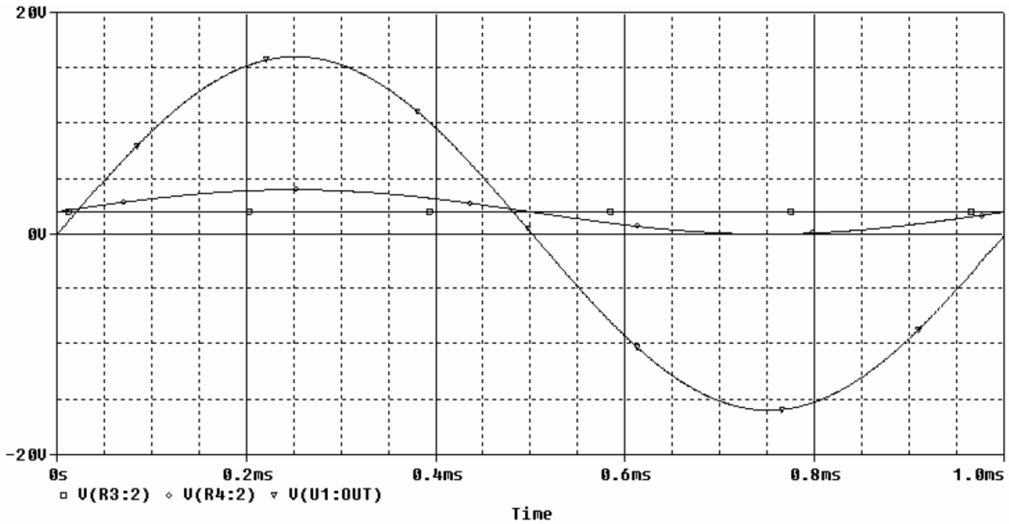
Difference amplifier or differential or instrumentation amp

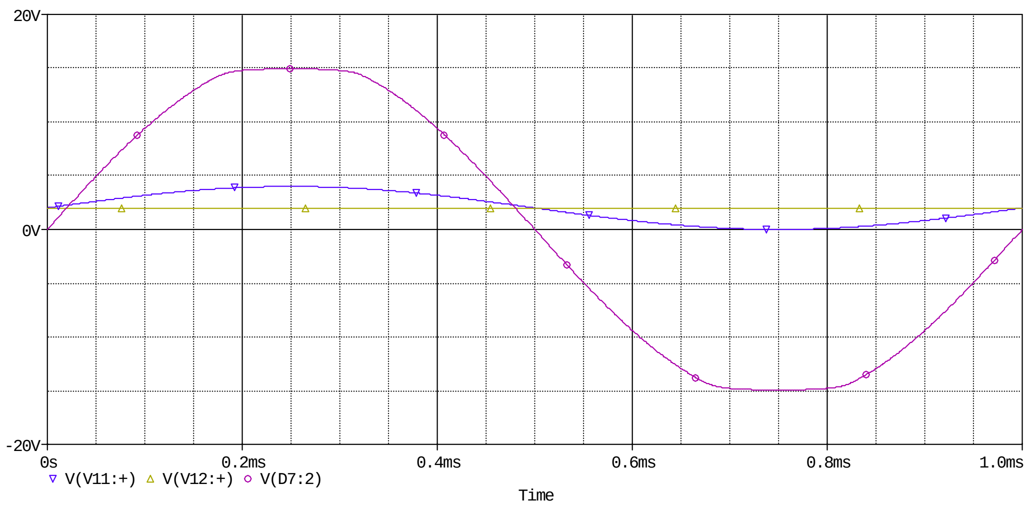
2) (3pt) Write the general equation for the output C (Vc) in terms of the input voltages V2 and V3. Simplify (Do not enter specific voltage values but use the values of the resistors)

$$V_{out} = \frac{R_f}{R_{in}}(V_2 - V_3) \qquad V_{out} = 8(V_2 - V_3)$$

Question III – Op-Amp Applications (continued)

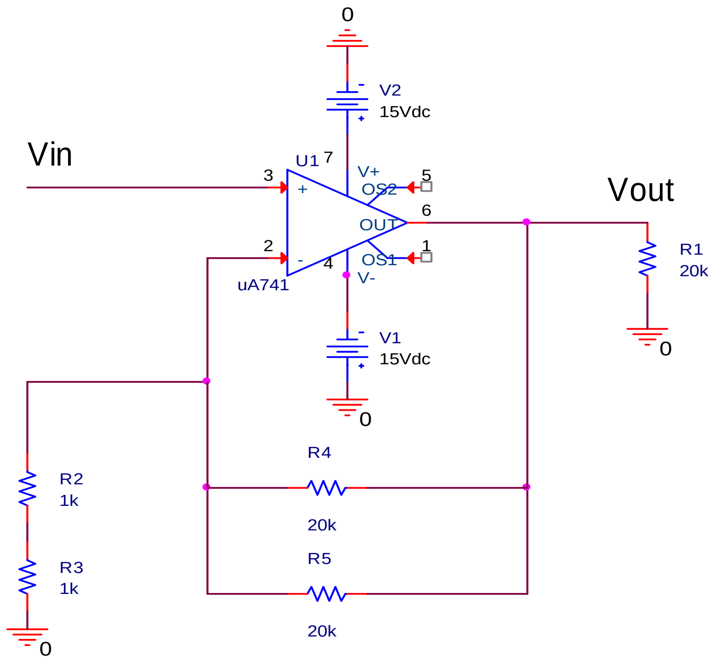
3) (16pt) Sketch and label one cycle of the input at V2 (point B), the input at V3 (point A) and the output at C (Vc) on the plot below





(extra credit +2 if plotted second graph with ±15V supplies clipping output)

Question IV – Op-Amp Analysis (20 points)

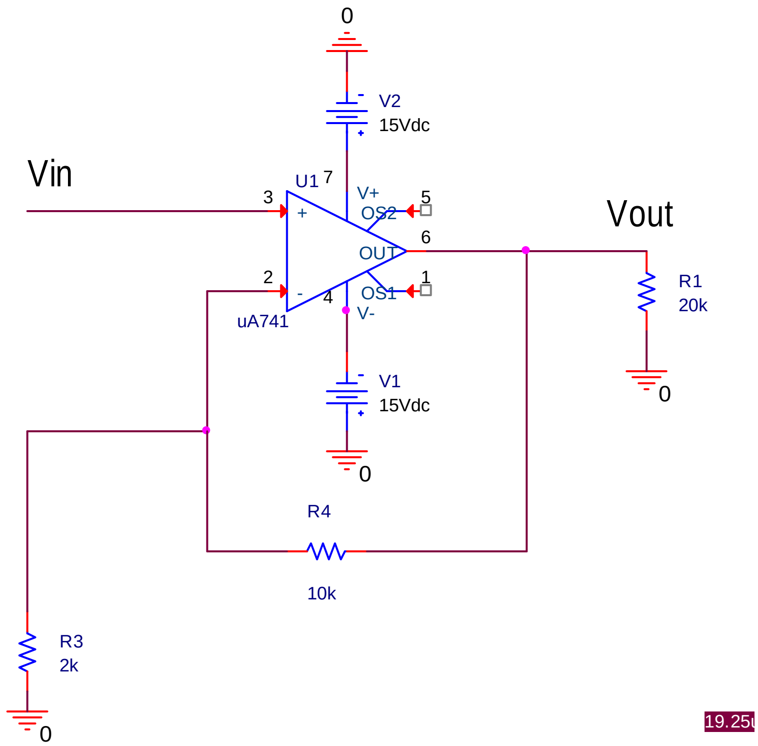


1) (2pt) What op-amp circuit given on your crib sheet does this circuit most closely represent?

a. Inverting Amplifier b. *Non-inverting Amplifier* c. Adder d. Differential Amplifier

e. Practical Active Differentiator

2) (2pt) Simplify and redraw the circuit by combining and resistors that are in parallel or series and find the combined values.


0
V2
15Vdc
Vin
U1
7
3
V+
5
OS2
Vout
OUT
6
2
1
OS1
4
V-
uA741
R1
20k
0
V1
15Vdc
0
R4
10k
R3
2k
0
19.25u

Question IV – Op-Amp Analysis (continued)

3) (2pt) What are the two golden rules of op-amp analysis?

The voltages are the same at the two inputs and no current flows into either input

4) (2pt) If Vin = 1V on the '+' input of the op-amp, what is the voltage on the '–' input?

Must be the same so 1V

5) (3pt) How much current is flowing through either of the 1k resistors to ground for Vin = 1V?

The same as the current through the 2k resistor. The voltage across both resistors is given by the voltage divider action. The voltage at the output is 6V so the voltage across the 2k is 1V, which is was part 4 says. Thus the current is 1V/2k or 0.5mA

6) (3pt) By the Golden Rules, how much current is flowing through either of the 20k resistors from Vout to V^- for Vin = 1V?

The voltage drop is 5V so that the current is 5V/20k or 0.25mA. This is also consistent with the current splitting equally through the two resistors.

7) (3pt) What is Vout for Vin = 1V?

6V from the formula for the non-inverting amp

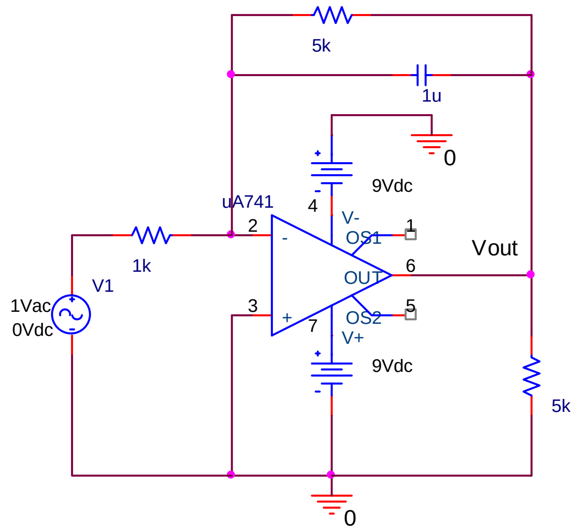
8) (2pt) What is the gain of this op-amp circuit?

The gain is 6.

9) (1pt) What is the approximate maximum value the input voltage Vin can have before the output will not be able to exhibit the full amplification from 8)?

For ideal conditions, the output has to be less than 15V so that the input has to be less than 15/6 or 2.5V

Question V – Op-Amp Integrators and Differentiators (20 points)



1) (2pt) What function is this circuit designed to perform?

Integration, actually practical Miller integration

2) (4pt) Write the transfer function Vout/V1 for this circuit. (Substitute in the values provided for the components.)

$$\frac{V_{out}}{V_1} = -\frac{R_f}{R_{in}\left(1 + j\omega R_f C_f\right)} = -\frac{5k}{1k(1 + j\omega 5k \cdot 1\mu)} = -\frac{5}{1 + j\omega(.005)} = -\frac{1000}{200 + j\omega}$$

3) (3pt) For which frequencies will the circuit perform the desired function?

a. Low frequencies below ω_c b. Only a mid band of frequencies around ω_c

c. *High frequencies above ω_c*

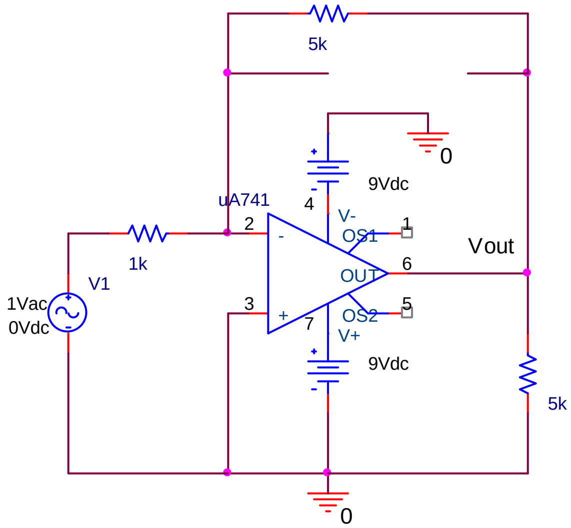
4) (3pt) Find the corner frequency for the circuit in Hz.

$$f_c = \frac{1}{2\pi R_f C_f} = \frac{1}{2\pi 5k \cdot 1\mu} = 31.83Hz$$

Question V – Op-Amp Integrators and Differentiators (continued)

5) (2pt) Redraw the circuit with an appropriate substitution for the capacitor as f → 0 for when the input V1 has a very low frequency.

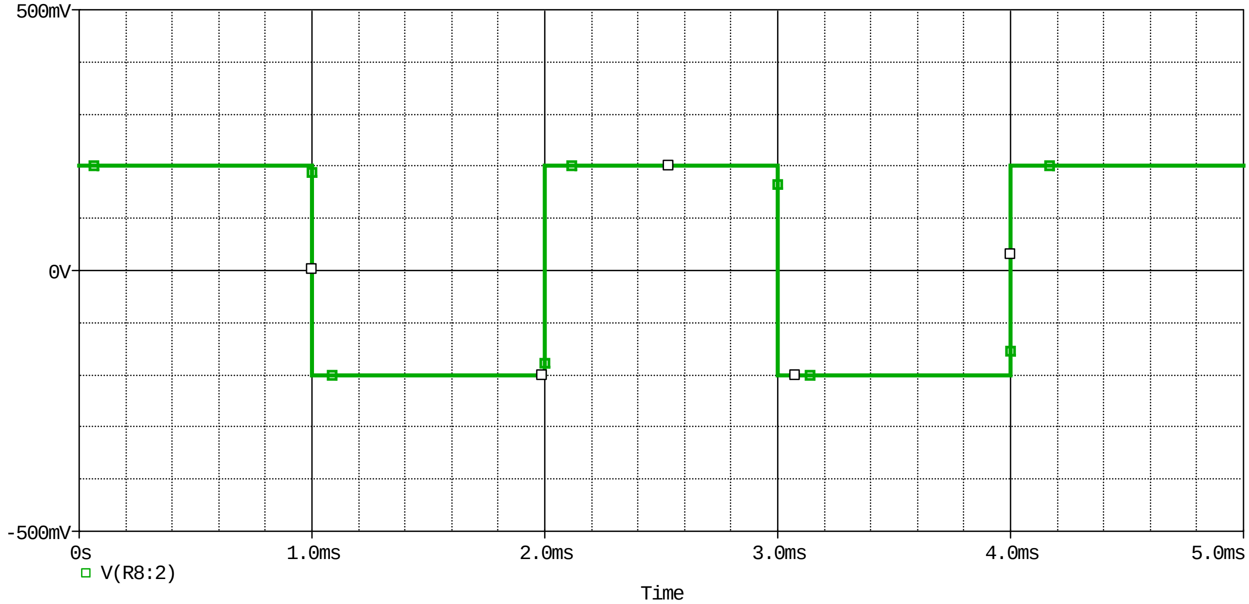
Replace C with open circuit.

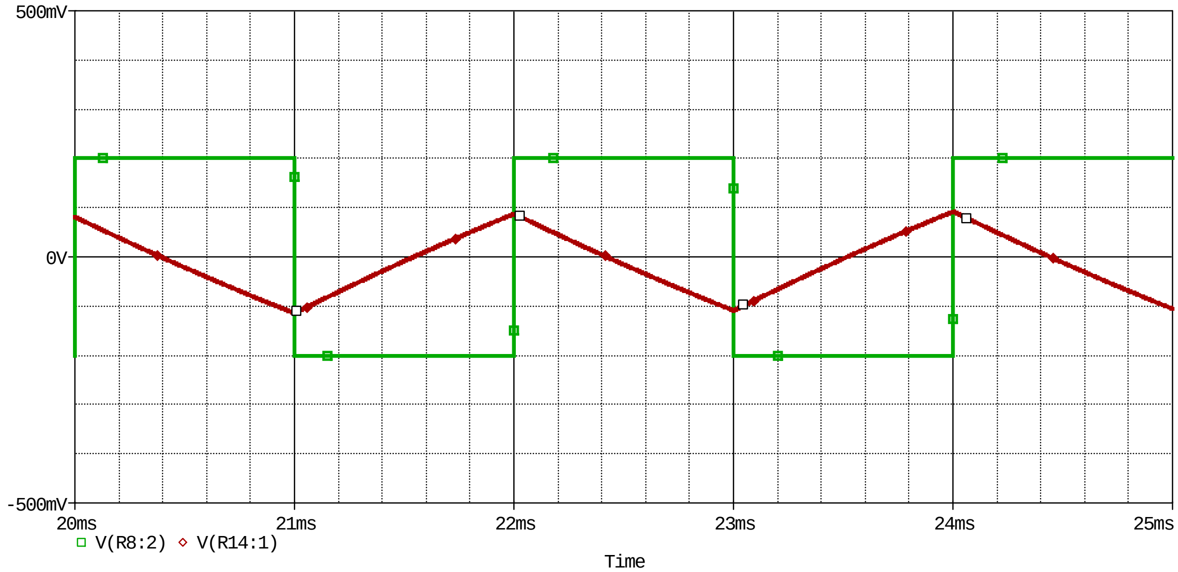


6) (4pt) Show that simplification of the transfer function from 2) for small ω gives the same results as the analysis of the redrawn circuit in 5).

$$\frac{V_{out}}{V_1} = -\frac{R_f}{R_{in}\left(1 + j\omega R_f C_f\right)} = -\frac{1000}{200 + j\omega} = -\frac{1000}{200} = -5$$ *which is the same ratio as for the inverting op amp.*

7) (2pt) Sketch the output of the original circuit in 1) to a square wave input on the axis below. Show the correct shape of the waveform but don't worry about the amplitude scaling.


500mV
0V
-500mV
0s
1.0ms
2.0ms
3.0ms
4.0ms
5.0ms
V(R8:2)
Time


500mV
0V
-500mV
20ms
21ms
22ms
23ms
24ms
25ms
V(R8:2) V(R14:1)
Time