ENGR4300
Spring 2006
Test 2 version A

Name Soln

Section___________________________

Question 1 (25 points)___________

Question 2 (15 points) ___________

Question 3 (20 points)___________

Question 4 (20 points)___________

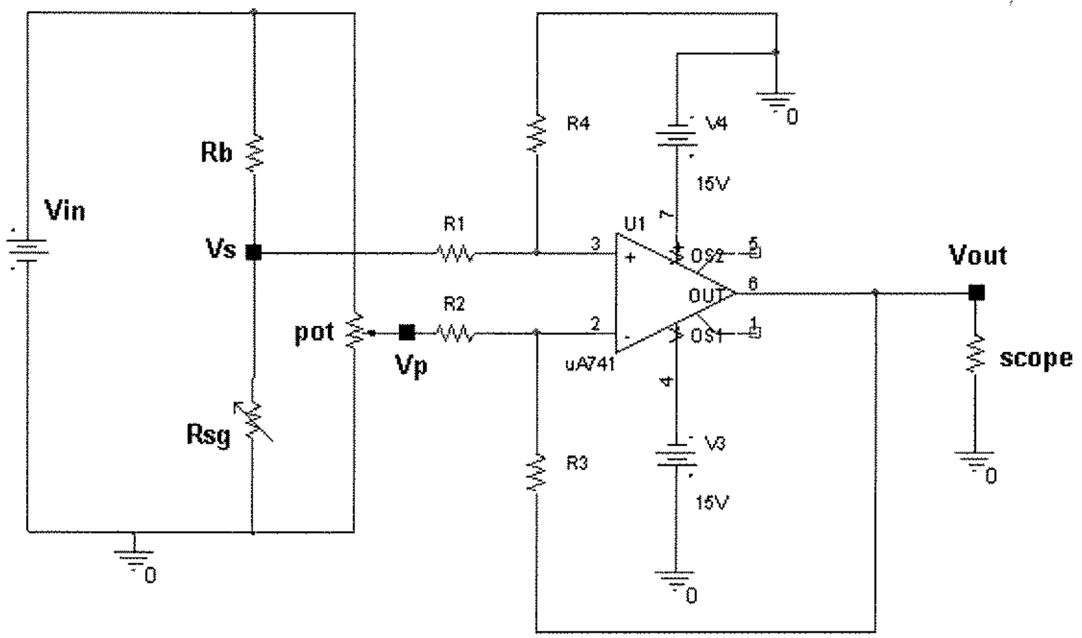
Question 5 (20 points)___________

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.

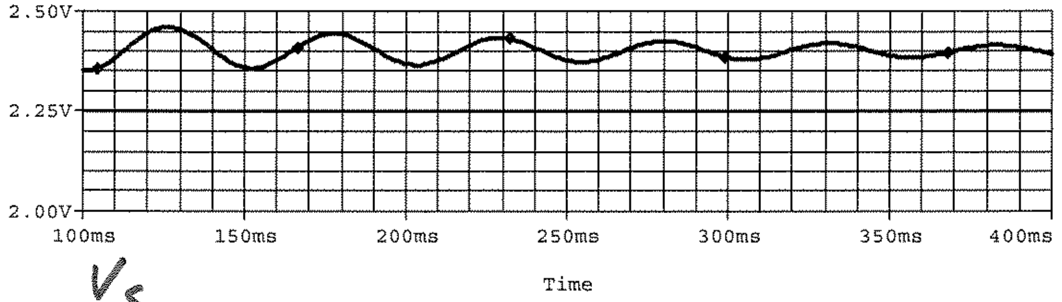
Soln

Question 1 – Bridges and Damped Sinusoids (25 points)

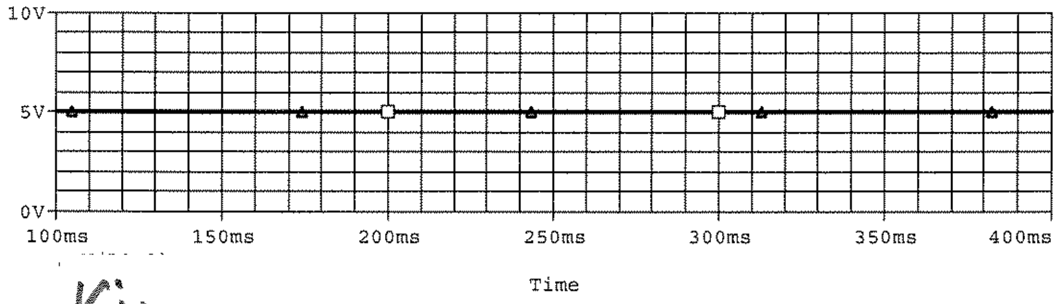


Above is figure of an amplified strain gauge bridge similar to the one you are using for project 2. The circuit has the following values: Vin = 5V, Rb=1K ohms, R1 = 2K ohms, R2 = 2K ohms, R3=10k ohms, R4=10k ohms, and the pot is a 2k pot.

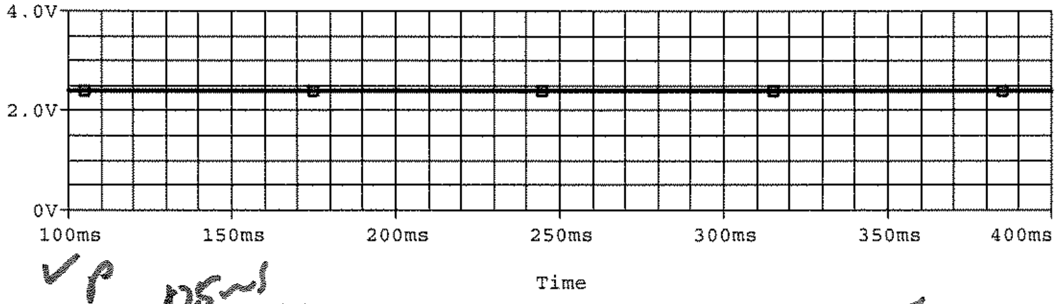
a) Assuming the bridge is ideal and that it has been properly balanced, which of these four plots is correct for each of the following four voltages on the figure: Vin, Vs, Vp, and Vout. (Indicate the signal in the box below the plot). (8 points)

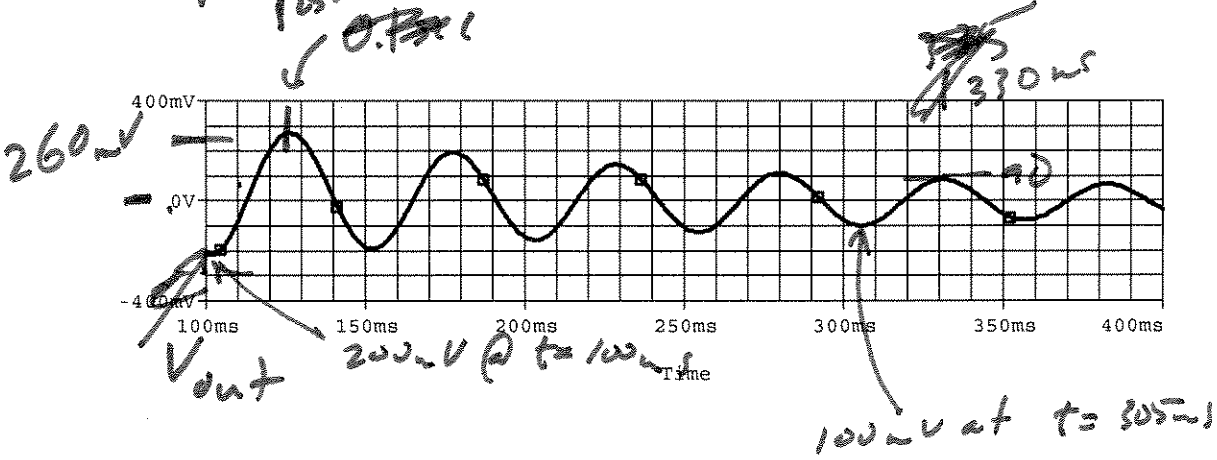


Vs



Vin





b) What is the resonant frequency of the output signal in Hertz? (3 points)

$T = (305ms - 100ms)/4 \Rightarrow 19.5Hz$

or

ut c
ok at
he data
points and.

c) What is the damping constant of the output signal? (4 points)

Positive Peaks,
260mV at 125ms, 90mV at 330 ms,

$-\alpha = \frac{\ln(v(t_2)/v(t_1))}{t_2 - t_1}$

$\alpha \approx 5.2/sec$

Neg. peaks 200mV at t=100ms, 100mV @ t=305ms

$\alpha = \frac{\ln(v(t_1)/v(t_2))}{(t_2 - t_1)} = 3.4/sec$

d) Write an equation for Vout in terms of Vs and Vp. Do not substitute numerical values for the resistors. (2 points)

$$V_{out} = \frac{R4}{R1}(V_s - V_p) \text{ or } V_{out} = \frac{R3}{R2}(V_s - V_p)$$

e) If R_{pot} is the total resistance of the potentiometer, R_{top}, is the resistance between the center of the pot and the source voltage, R_{bottom} is the resistance between the center of the pot and ground, R_{sg} is the resistance of the strain gauge, and Rb is as shown in the figure, which of the following are true statements? Assume the bridge is balanced and in its rest position. (4 points) (Circle T or F for each statement.)

$\frac{Rb}{Rb+R_{sg}} = \frac{R_{top}}{R_{pot}}$ [✓ T] F

$\frac{Rb}{R_{sg}} = \frac{R_{top}}{R_{bottom}}$ [✓ T] F

$R_{top} + R_{bottom} = R_{pot}$ [✓ T] F

$\frac{R_{top}}{Rb} = \frac{R_{pot} - R_{top}}{R_{sg}}$ [✓ T] F

f) Starting with the equation from part d, derive an equation for Vout in terms of Vin for this circuit. Use the resistor naming conventions we used in part e (R_{pot}, R_{top}, R_{bottom}, R_{sg}, and Rb) and the other resistors in the circuit (R1, R2, R3, and R4). You will not need all of these resistors in the answer. You cannot assume the bridge is balanced. You cannot substitute numerical values for the resistors. You cannot express your answer in terms of Vs and Vp. (4 points) version A, Prob 1 soln.

Answers:

a) Vs, Vin, Vp, Vout

b) T=(305m-100m)/4=51.25m f=1/51.25m f = 19.5 Hz

c) v0,t0 = 200mv,0.1s v1,t1 = 100mv,0.305s

*100m = 200m eEE(-α*0.205) α=3.4/s* ⇒ OR 5.2/sec for positive peak

d) $Vout = \frac{R4}{R1}(Vs - Vp)$ *(R4 could also be R3, R1 could also be R2)*

e) T T T T

f)

$$Vout = \frac{R4}{R1}(Vs - Vp) \quad Vs = \frac{R_{sg}}{R_{sg} + Rb}Vin \quad Vp = \frac{R_{bottom}}{R_{pot}}Vin$$

$$Vout = \frac{R4}{R1}\left(\frac{R_{sg}}{R_{sg} + Rb}Vin - \frac{R_{bottom}}{R_{pot}}Vin\right)$$

$$Vout = \frac{R4}{R1}\left(\frac{R_{sg}}{R_{sg} + Rb} - \frac{R_{bottom}}{R_{pot}}\right)Vin$$

(R4 could be R3, R1 could be R4, Rpot could be Rtop+Rbottom)
(The above amount of simplification is sufficient.)

Alternate answers:

~~*a) Vout, Vs, Vin, Vp*~~

~~*b) T=(510m-100m)/9=45.56m f=1/410m f = 22.0 Hz*~~

~~*c) v0,t0 = 300mv,0.1s v1,t1 = 200mv,0.560s*~~

~~*200m = 300m eEE(-α*0.46) α=0.9/s*~~

~~*d) e) f) same*~~

~~Please note: I don't agree with this answer.~~

For part c, it does matter which peaks they are.

For positive peaks
260mV @ 125ms, 90mV at 330ms

$$\alpha = \frac{\ln[v(t_1)/v(t_2)]}{t_2 - t_1} \cong 5.2/\text{sec}$$

~~≅ 3.[illegible]/sec~~

Prob 2 Soln.

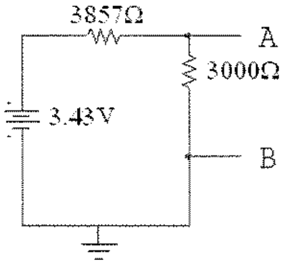
Answers A:

a) $Vth = V_{AB} = V1*(R4)/(R2+R4+R3)=6V*(2k)/(500+2k+1k) = 3.43V$

```
b)               +-----(R4)---------+
A ---- (R5) ---+                    +----------B
                 +---(R2)---(R3)--+
```

*R23 = 500+1000 = 1500 R234 = (1500*2000)/(1500+2000)=857 ohms*
Rth = 3000+857 = 3857 ohms

c)



d) 3.43 = I (3857+3000) I=0.5mA

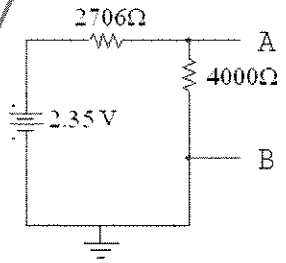
Answers B:

a) $Vth = V_{AB} = V1*(R4)/(R2+R4+R3)=8V*(1k)/(400+1k+2k) = 2.35V$

```
b)        +-----(R4)---------+
A -------+                   +----(R5)------B
          +---(R2)---(R3)--+
```

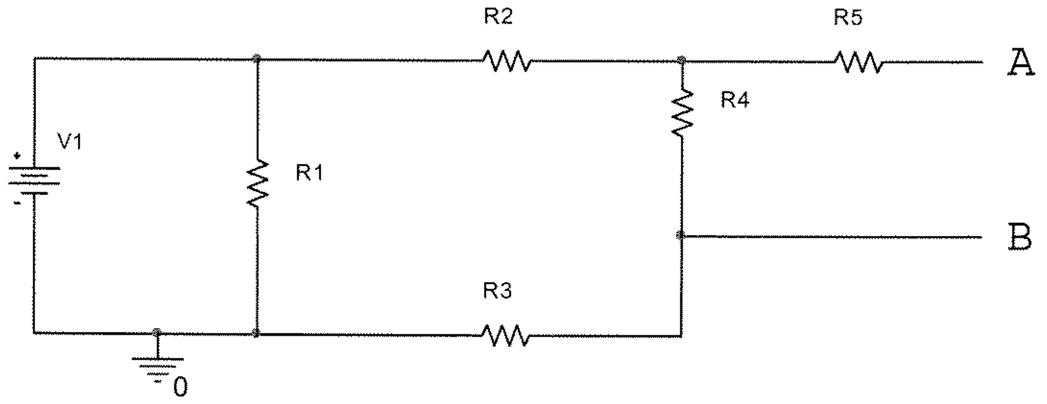
*R23 = 400+2000 = 2400 R234 = (2400*1000)/(2400+1000)=706 ohms*
Rth = 706+2000 = 2706 ohms

c)



d) 2.35 = I (2706+4000) I=0.35mA

Question 2 – Thevenin Equivalents (15 points)



V1=6V, R1=2k ohms, R2=500 ohms, R3=1k ohms, R4=2k ohms, R5=3k ohms

a) Find the Thevenin equivalent voltage with respect to A and B for the circuit shown above. (5 points)

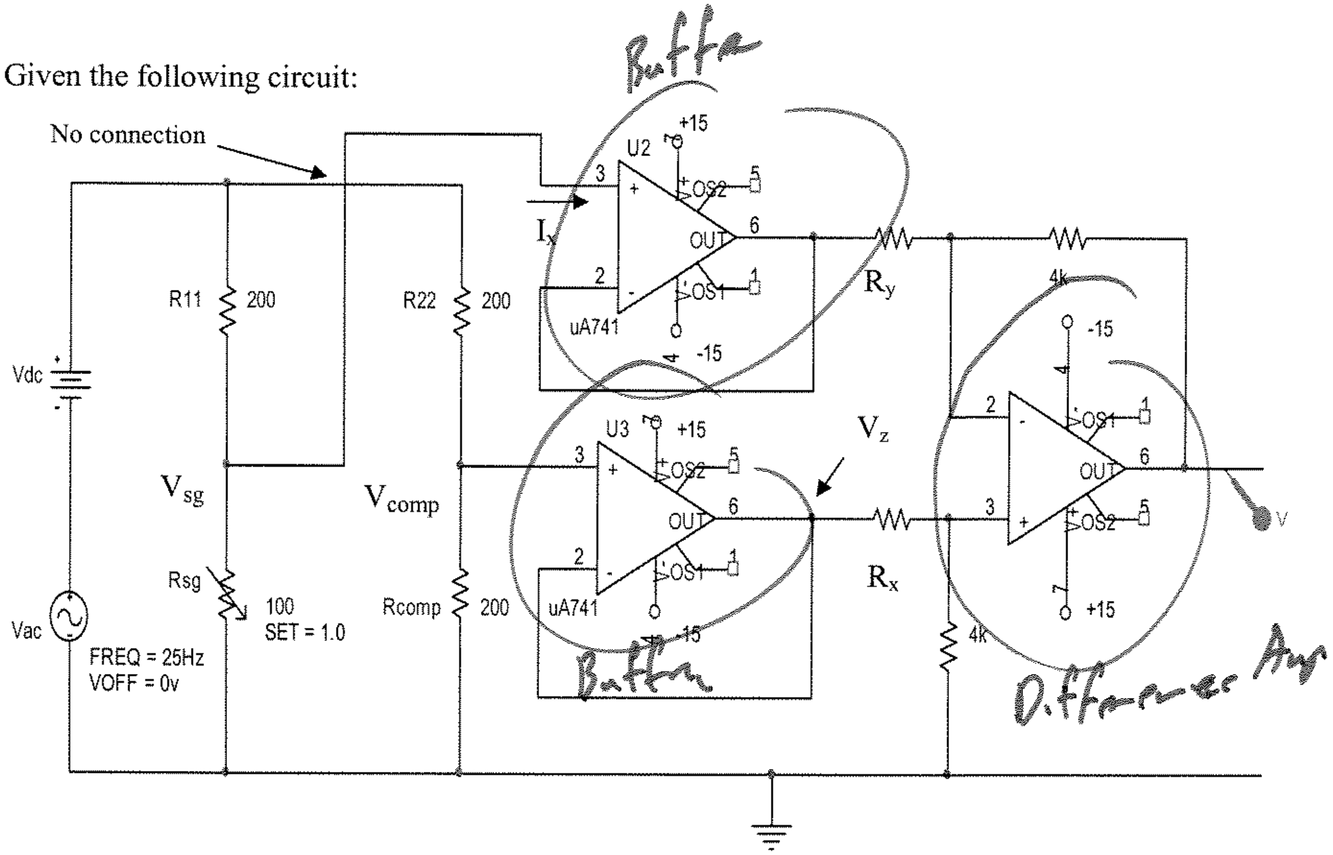
b) Find the Thevenin equivalent resistance with respect to A and B for the circuit shown above. (5 points)

c) Draw the Thevenin equivalent circuit with a load resistor of 3K between points A and B. (3 points)

d) What is the current through the 3K load resistor in the circuit you drew in part c? (2 points)

Problem 3

Given the following circuit:



Note: Rsg is variable resistor to model a strain gauge. The SET=1.0 simple means that the nominal resistance is the full 100Ω. Use 100Ω for you analysis.

a) What is the voltage V_{sg} in the circuit above if the amplitude Vac=6 and Vdc = 0v?

2pts V_{sg} is an AC voltage with a magnatude of 3V an 0 dc

allowed answers 3V, 3Vac, magnatude of 3V

b) What is the voltage V_{comp} in the circuit above if the amplitude Vac=6 and Vdc = 0v?

2pts 3Vac

c) With Vdc = 6v and the amplitude of Vac = 0v, what is I_x?

2pts 0 mA

d) What is the voltage V_z if Vdc = 6v and the amplitude of Vac = 0v?

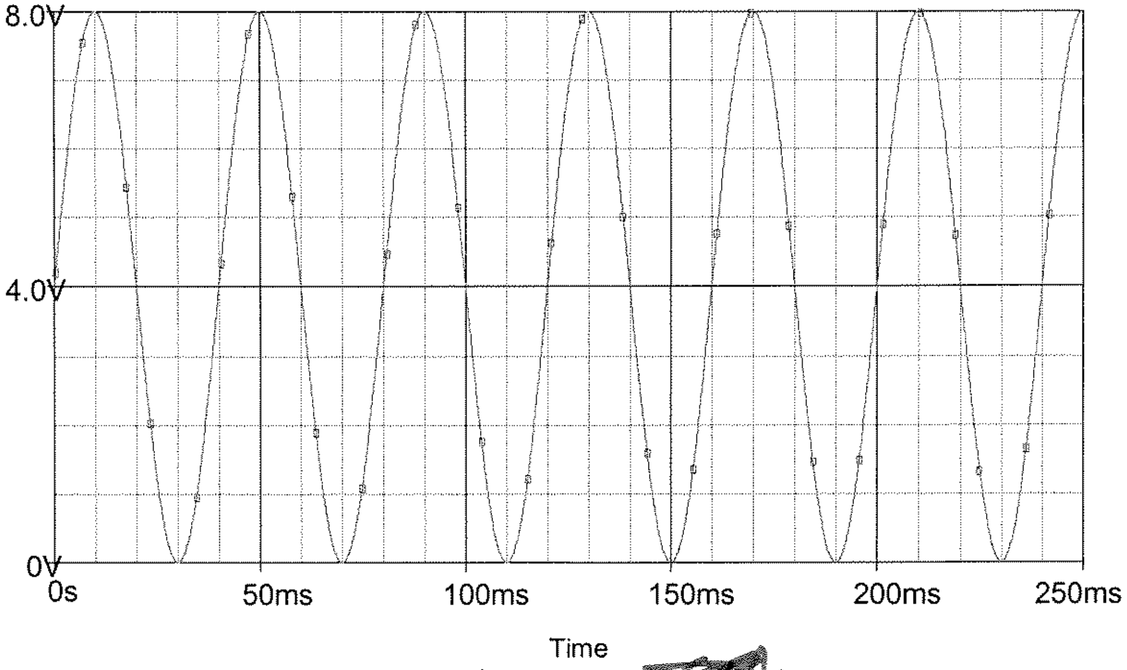
2pts 3Vdc

e) Circle and label the op amp configurations on the schematic above, choosing from the following types:

1. Follower/Buffer
2. Inverting Amp
3. Non-inverting Amp
4. Differentiator
5. Integrator
6. Adding (Mixing) Amp
7. Difference (Differential) Amp

$\frac{6 \text{ pts}}{2 \text{ each}}$

f) What values of R_x and R_y would you use to produce the following plot with Vdc = 6v and the amplitude of Vac = 6v, if the probe's output appeared as follows?



$R_x = R_y =$ ~~[illegible]~~ 0.~~[illegible]~~Ω

1pt $V_{SG} = \left(\frac{1}{3}\right) 6 V_{ac} + \left(\frac{1}{3}\right) 6 V_{DC} = 2V_{ac} + 2V_{DC}$

1pt $V_Z = V_{comp} = \left(\frac{1}{2}\right)(6V_{ac}) + \left(\frac{1}{2}\right)(6V_{DC}) = 3V_{ac} + 3V_{DC}$

$V = \frac{4k}{R_y}(V_Z - V_{SG}) = \frac{4k}{R_y}(1V_{ac} + 1V_{DC}) = 4V_{ac} + 4V_{DC}$

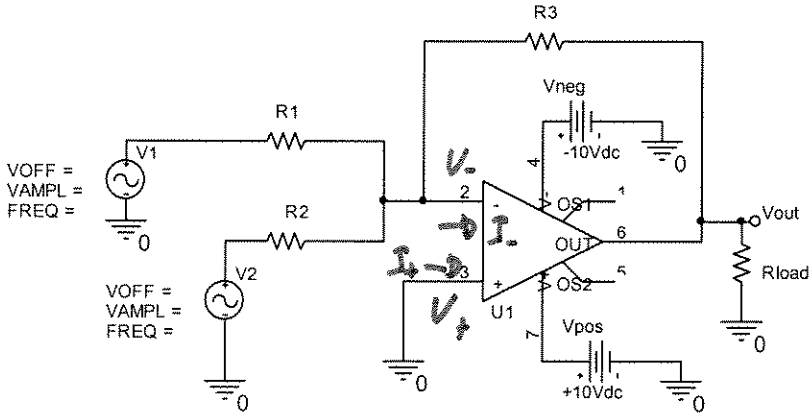
$R_y = 1k$

$\frac{4k}{R_y} = 4$

$R_x = R_y = 1k$

4pt

Question 4 Op-Amp circuits (20 points) Assume the op-amp is ideal.



a) Above is a Capture schematic of an op-amp circuit that you should recognize. What type of circuit is it?

adder (2pts)

b) We assume that the op-amp is ideal. What are the two "golden rules" that we then use to analyze the circuit? In some sections of the course this was referred to as the "virtual short model." So an alternative wording of this question is: what are the characteristics of the virtual short op-amp model? (The answer is the same for either wording.)

$V_+ = V_-$, $I_- = 0$, $I_+ = 0$ (2pts)

c) If V1 = 0.8V, V2 = 0.5V, R1 = 5kΩ, R2 = 5kΩ, and R3 = 20kΩ, what is the value of Vout in Volts? Show your work.

$$V_{out} = -\frac{R_3}{R_1}V_1 - \frac{R_3}{R_2}V_2 = \left(-\frac{20}{5}\right)(0.8) + \left(-\frac{20}{5}\right)(0.5)$$

$$= \underline{-5.2\,V}$$

(3pt)

d) Repeat the last question but with R2 replaced with a 2kΩ resistor.

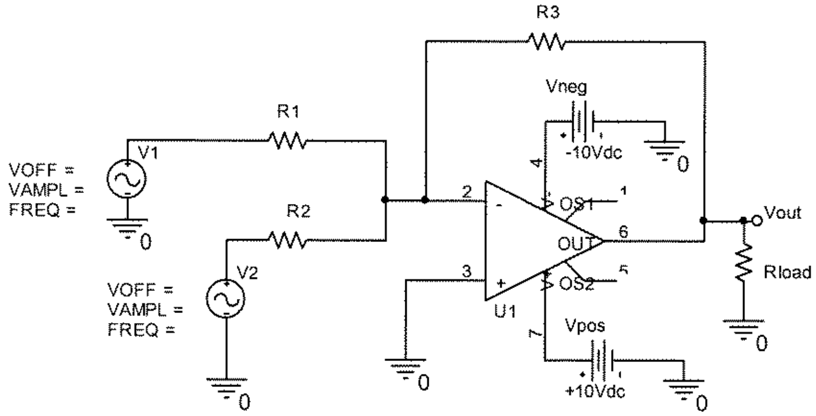
$$V_{out} = \left(-\frac{20}{5}\right)(0.8) - \left(\frac{20}{2}\right)(0.5)$$

$$-3.2 \quad - 5$$

$$= \underline{\underline{-8.2\,V}}$$

(3pts)

This is the same circuit as on the previous page.



e) Write an expression for Vout in terms of V1, V2, R1, R2 and R~~f~~. 3

$$V_{out} = -\frac{R3}{R1} \cdot V1 - \frac{R3}{R2} \cdot V2$$

2pt

f) Assume that Vout on this op-amp will saturate if it gets to within 1.5V of either power supply. If V1= -1.0V, R1 = 5kΩ, R2 = 2kΩ, and R3 = 20kΩ: what is the range of voltage for V2 that will keep the op-amp out of saturation? Give your answer in volts with 2 significant digits. (Note that the resistors have the same values as those used in part 4 of this problem, but V1 and V2 may be different.)

8pt

V_{out} max = 8.5V   2pt

if $V_{out} = (-4)V1 + (-10)(V2)$

if $V1 = -1V$

$V_{out} = 4 - 10 \cdot V2$

$V_2(max) = 1.25V$

$V_2(min) = -0.45V$

⇓

2pt for correct answer

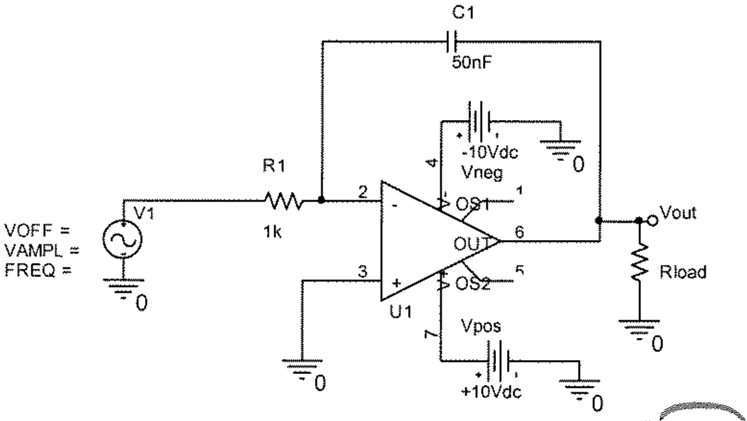
$V_{out}(max) = 8.5 = 4 - 10(V2(min))$

$V_2(min) = -4.5/10 = -0.45V$ 2pt

$V_{out}(min) = -8.5 = 4 - 10(V_2(max))$ 2pt

$V_2(max) = \frac{12.5}{10} = 1.25$

Question 5 Op-Amp Integrators and Differentiators (20 points)



(~~2pt~~) a) Above is a Capture schematic of an op-amp circuit that you should recognize. What type of circuit is it? 1pt

Integrator 1pt ~~2pt~~

~~2pt~~ 7pt b) For this part, plot the output signal for this circuit if the input is as shown below. Use the lower plot for your output. Assume that the output is at 0 volts at t=0.

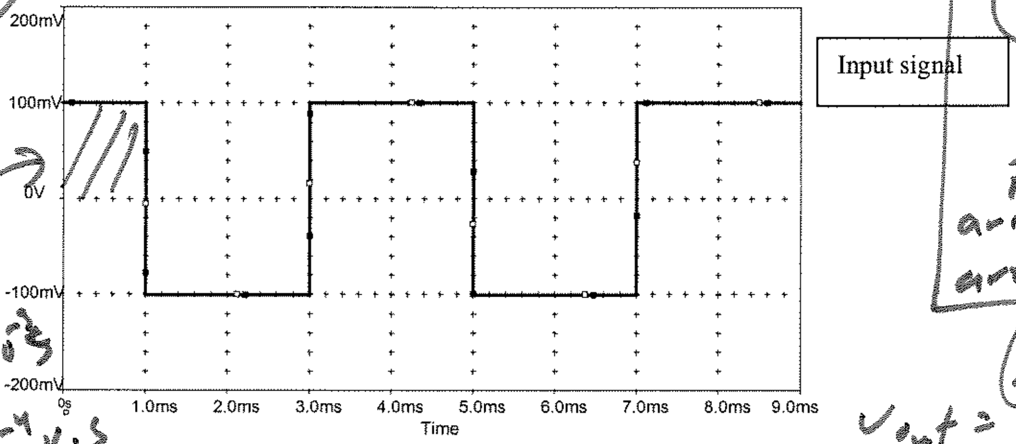
~~2pt~~ 7pt

- at final 1pt

$\frac{1}{RC} = 2\times10^4$ 2pt

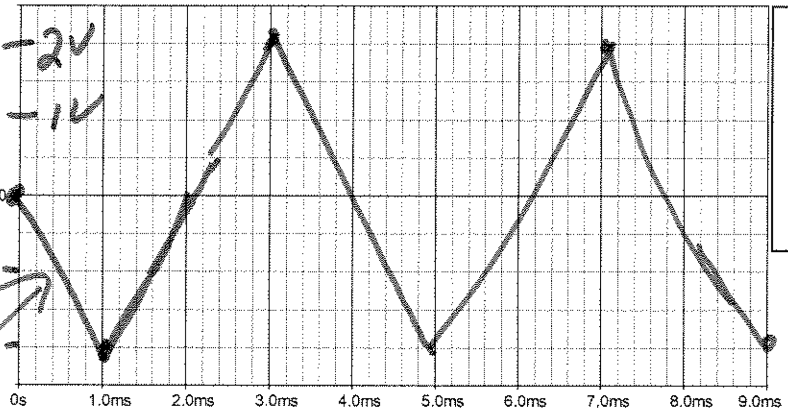
area till 1ms 2pt

area from 1 - 3ms 2pt



area
$100mV \cdot 10^{-3}$
$\int_0^{1ms} = 10^{-4} V \cdot s$

$V_{out} = \frac{-1}{RC} \int V_{in}\, dt$



Draw output signal
Label minimum and maximum voltages.
Label the vertical axis.
Assume Vout=0 at t=0.

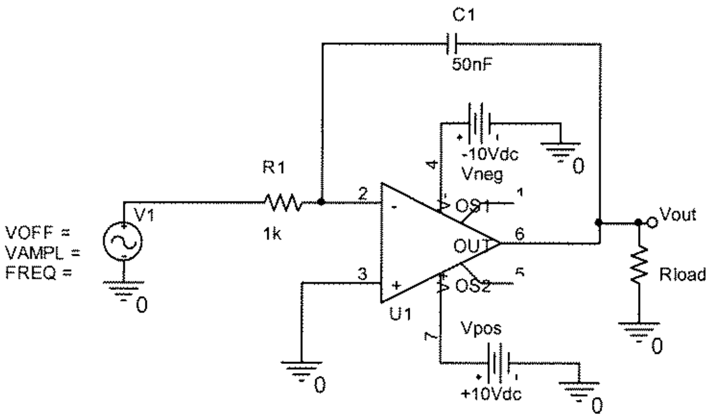
$\frac{1}{RC} = 2\times10^4$

2pt

1pt for neg

$\underbrace{2\times10^4 \int_0^{1ms} 0.1V\,dt}_{2V}$

2pt to get Vout min = -2
" " " " max = +2



(3pt) c) The circuit above is the same circuit as the one used for parts 1 and 2, but now assume that the input is sinusoidal and that we are interested in steady state response. What is H(jω), the transfer function for this circuit? H(jω) = **Vout/V1**. You must use the component values, don't leave the answer in terms of R1 or C1. Simplify your answer.

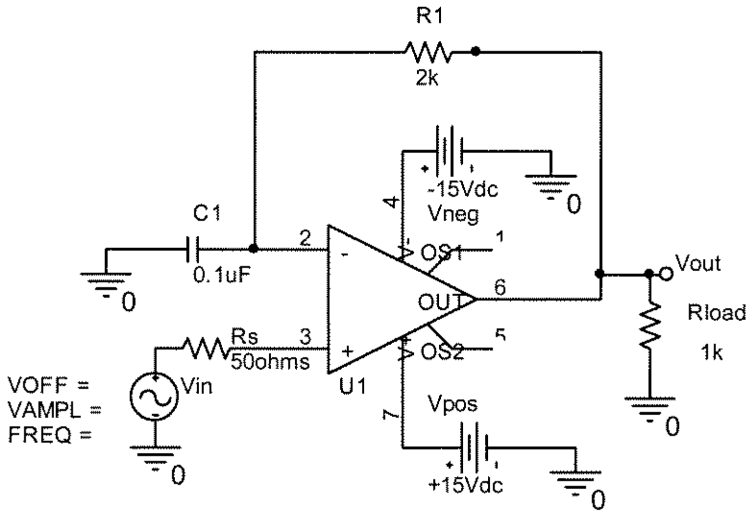
$$H(j\omega) = \frac{-1}{j\omega RC} = -\left(\frac{1}{j\omega}\right)(2\times10^4)$$

$$H(j\omega) = -\frac{2\times10^4}{j\omega}$$

$$\boxed{\text{OR} = \frac{(j)(2\times10^4)}{\omega}}$$

3pt

The circuit below is used for the next two parts.



(4pt)

d) For this circuit, the input is sinusoidal. What is H(jω), the transfer function for this circuit? H(jω) = **Vout/V1**. You must use the component values, don't leave the answer in terms of R1 or C1. Simplify your answer.

5pts (3pt)

$$H(j\omega) = \frac{Z_f}{Z_1} + 1 = \frac{R_1 + \frac{1}{j\omega C_1}}{1/j\omega C_1} = 1 + j\omega R_1 C_1$$

~~3pt~~

~~H(jω)~~ = 1 +

$R_1 = 2\times10^3$, $C' = 10^{-7}$ $R_1 C_1 = 2\times10^{-4}$

(5pt)

f) The circuit shown in part 4 was simulated with an AC sweep. At one frequency, the output was found to have a 45 degree phase shift relative to the input. Calculate that frequency in Hz, f45. Now determine the effective gain at this frequency, A45= |Vout|/|Vin| at f45. Show your work or method for partial credit.

f_{45} = 796 (Hz) or 800Hz (3pt)

$H(j\omega) : 1 + j\omega(2\times10^{-4})$ (2pt)

A_{45} = $\sqrt{2}$ = 1.4 (2pt)

45° angle when

$\angle H(j\omega) = 45°$

real part = imaginary part

OR arc tan = 45°

$\omega \cdot 2\times10^{-4} = 1$

$\omega = 5000$ rad/sec

$f = \frac{\omega}{2\pi} = 796$ Hz