EE 355 Analog Electronics
Test 1

Name Solutions
September 19, 2018

RULES

This is a closed book, closed notes test. You are, however, allowed one half of one piece of paper (front side only, hand-written) for notes and definitions. You must turn in your equations when you hand your test in.

You are permitted to use a calculator.

You have 50 minutes to complete the test. Please read through the entire test before starting, and read through the directions carefully. To receive partial credit, you must show your work.

I you have any questions, please raise your hand, and I will come to you to answer them. Do not hesitate to ask questions.

Circle/box all of your answers.

Parameters to be used, unless otherwise specified for a specific problem.

Opamp Parameters
$V_{sat} = \pm 5V$

Problem	Value	Score
1	30	
2	20	
3	20	
4	30	
Total	100	

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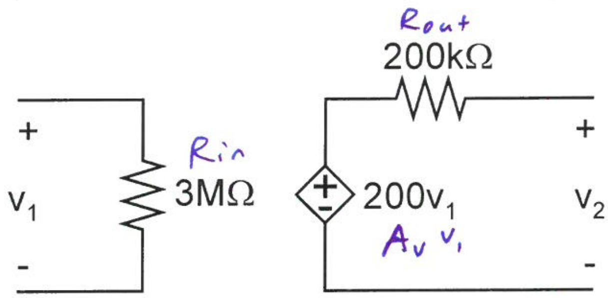
PROBLEM 1 (30 Points)

The following two-port amplifier model is to be used for all parts of this problem.



A. Determine the following characteristics of the amplifier. Write your answers on the lines that have been provided. (8 Points)

R_{in} = *3 MΩ*

R_{out} = *200 kΩ*

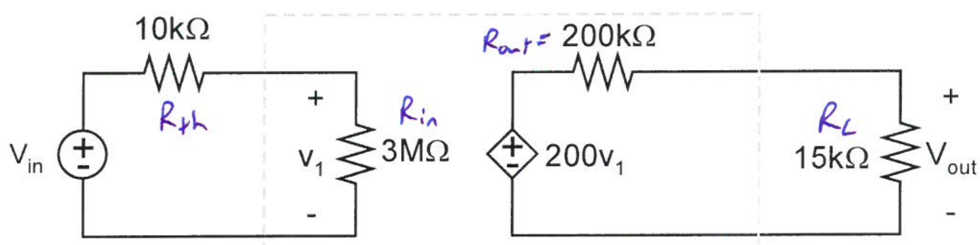
G_m = *−1 mS*

$A_{v,unloaded}$ = *200*

$$A_v = -G_m R_{out}$$

$$G_m = -\frac{A_v}{R_{out}} = -\frac{200}{200k\Omega} = -1mS$$

B. This amplifier is now connected to a preceding circuit (represented by a Thevenin equivalent) and drives a load resistance. Determine the voltage gain going from V_{in} to V_{out}. (10 Points)



$$\frac{V_{out}}{V_{in}} = \frac{V_1}{V_{in}} \cdot \frac{V_{out}}{V_1} = \left(\frac{R_{in}}{R_{in}+R_{th}}\right)\left((200)\frac{R_L}{R_L+R_{out}}\right) =$$

($200 \uparrow A_v$)

$$= \left(\frac{3M\Omega}{3M\Omega+10k\Omega}\right)\left((200)\frac{15k\Omega}{15k\Omega+200k\Omega}\right) = \boxed{13.91}$$

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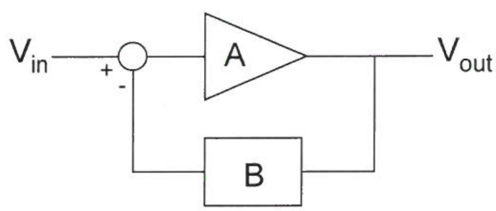
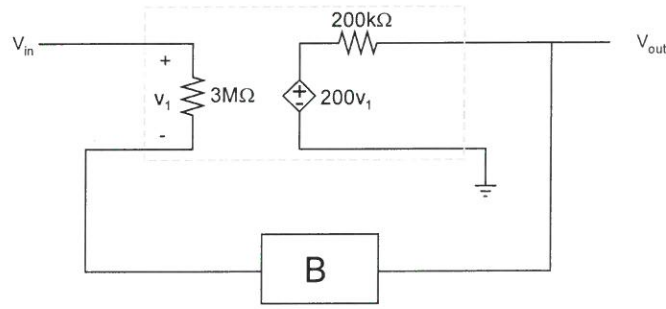
C. The original amplifier from the problem statement (i.e. the two-port model) is now placed in a negative feedback loop, as shown below. The triangle represents the two-port model (with characteristics from Part A), where A is $A_{v,unloaded}$ from Part A. Determine the following characteristics of the closed-loop system, and write your answers on the lines that have been provided. (12 Points)

B = 0.1

Simplified Version



Detailed Version



Loop Gain = 20

$A_{v,closed-loop}$ = 9.52

$R_{in,closed-loop}$ = 63 MΩ

$R_{out,closed-loop}$ = 9.52 kΩ

$$\text{Loop Gain} = AB = (A_{v,unloaded})(B) = (200)(0.1) = 20$$

$$\text{Closed-Loop Gain} = \frac{A}{1+AB} = \frac{200}{1+(200)(0.1)} = 9.52$$

Sanity Check → Closed-Loop Gain $\approx \frac{1}{B} = \frac{1}{0.1} = 10$ ✓ close

$$R_{in,\,closed\text{-}loop} = (R_{in})(1+AB) = (3M\Omega)(1+(200)(0.1)) = 63\,M\Omega$$

$$R_{out,\,closed\text{-}loop} = \frac{R_{out}}{1+AB} = \frac{200\,k\Omega}{1+(200)(0.1)} = 9.52\,k\Omega$$

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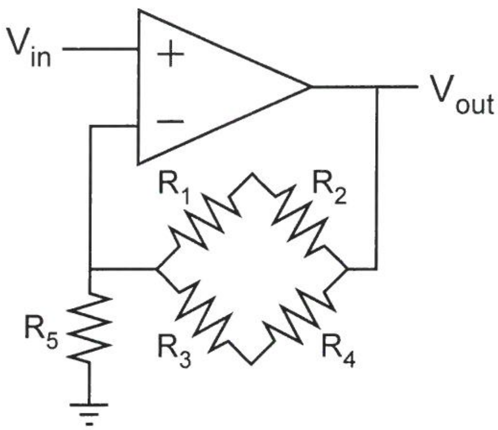
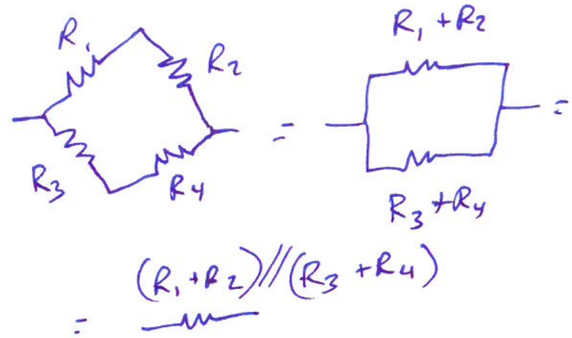
PROBLEM 2　　　　　　(20 Points)

Calculate the voltage-mode gain (V_{out}/V_{in}) for the following circuit.



$R_1 = 10k\Omega$
$R_2 = 10k\Omega$
$R_3 = 10k\Omega$
$R_4 = 2k\Omega$
$R_5 = 5k\Omega$

Simplify the resistor network

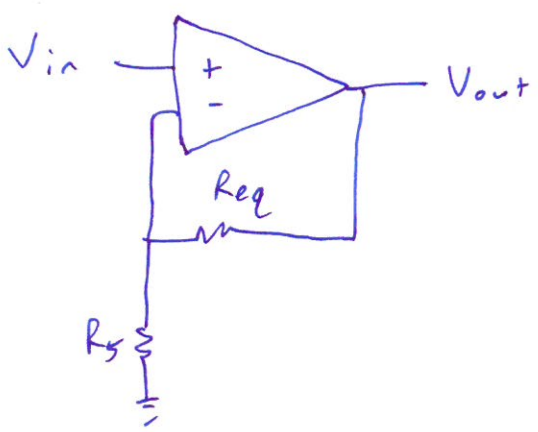


Let $R_{eq} = (R_1 + R_2) // (R_3 + R_4) =$

$= (10\,k\Omega + 10\,k\Omega) // (10\,k\Omega + 2\,k\Omega) =$

$= 7.5\,k\Omega$

Re-Draw



→ Non inverting Amplifier

Negative Feedback exists!

$\therefore V_+ = V_- = V_{in}$

$V_- = V_{out} \dfrac{R_5}{R_5 + R_{eq}} = V_{in}$

$$\frac{V_{out}}{V_{in}} = \left(1 + \frac{R_{eq}}{R_5}\right) = 1 + \frac{7.5\,k\Omega}{5\,k\Omega} = \boxed{2.5}$$

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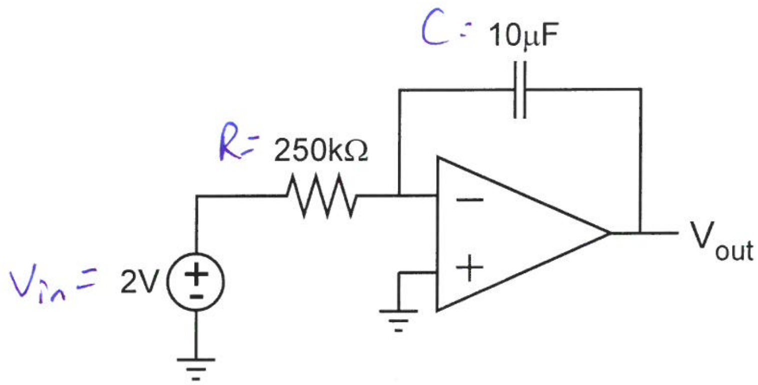
PROBLEM 3 (20 Points)

For the following circuit, determine the output voltage at time t = 0.5 sec. Assume that there are no initial conditions on the capacitor (i.e. the voltage across the capacitor at time t = 0 sec is 0V).



This is an integrator circuit

Negative feedback exists

$\therefore V_- = V_+ = 0V$

KCL @ V_-

$$\frac{V_{in}}{R} + C\frac{dV_{out}}{dt} = 0$$

$$\frac{dV_{out}}{dt} = \frac{-V_{in}}{RC}$$

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

$$V_{out} = -\frac{1}{RC}\int_0^t V_{in}\, dt = -\frac{1}{RC}(V_{in})(t) + V_{init}$$

($V_{init} \uparrow 0$)

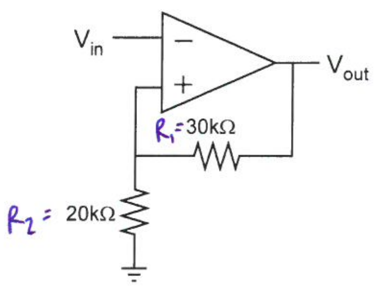
$$\therefore V_{out} = -\frac{1}{(250k\Omega)(10\mu F)}(2V)(0.5s) = \boxed{-0.4V}$$

PROBLEM 4 (30 Points)

Use the circuit shown below for this problem.

A. Sketch the transfer function (i.e. input-to-output voltage relationship) in as much detail as possible on the axes that have been provided. Label all interesting items on the sketch.

B. Sketch the time-domain output of this circuit in response to the input waveform. Please draw the output on the same plot as the input. Provide as much detail as possible, and label all interesting items.



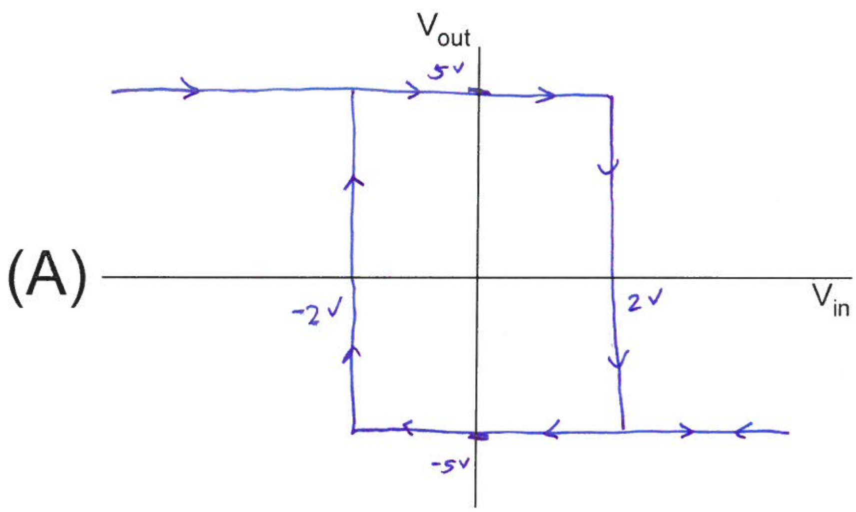
→ Inverting Schmitt Trigger

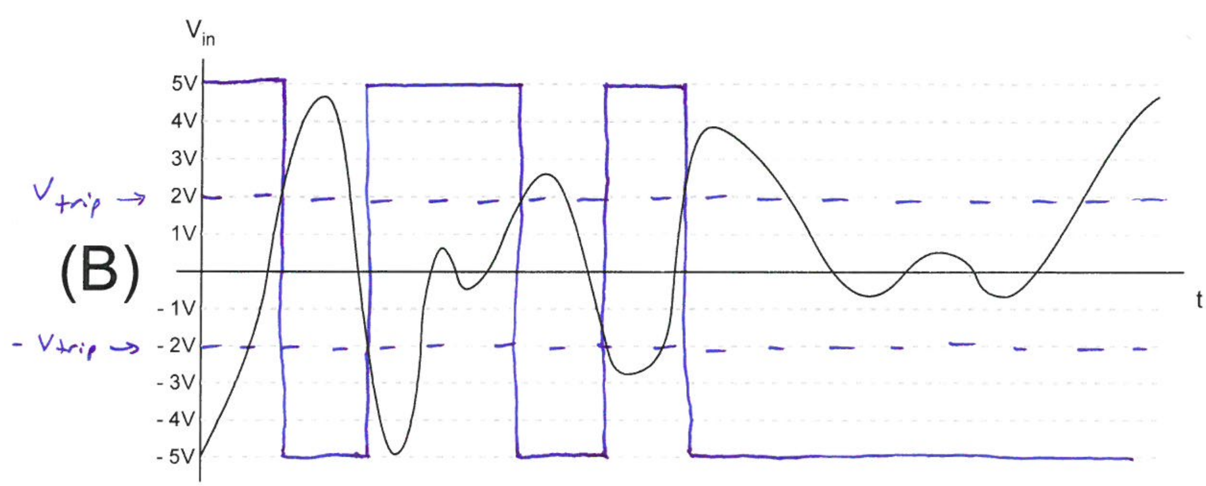
$V_{out} = \pm V_{sat} = \pm 5V$ (from first page)

$V_+ = \pm V_{sat} \frac{R_2}{R_1 + R_2} = (\pm 5V)\left(\frac{20k\Omega}{30k\Omega + 20k\Omega}\right) = \pm 2V$

If $V_{out} = +V_{sat} \Rightarrow V_{in,trip} = +2V$

If $V_{out} = -V_{sat} \Rightarrow V_{in,trip} = -2V$





Name Solutions

Problem 4 Extra Work Page