ECSE-2050 **Introduction to Electronics**
Summer 2020 **Name** ____________________

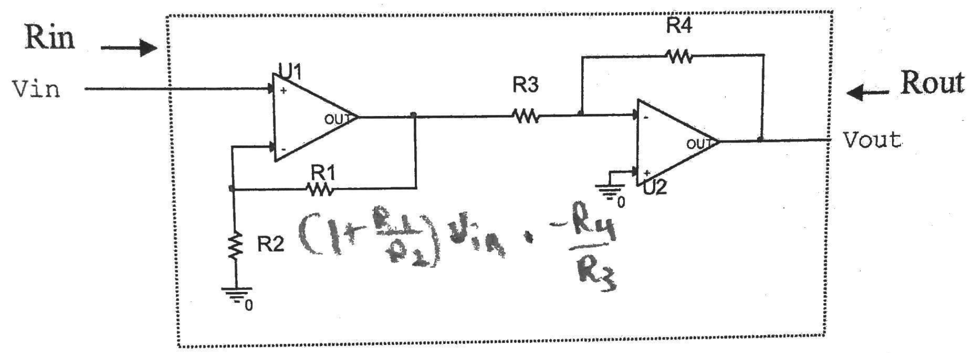
Homework 3

Reading: Chapter 2.5-2.8

1) Amplifier models

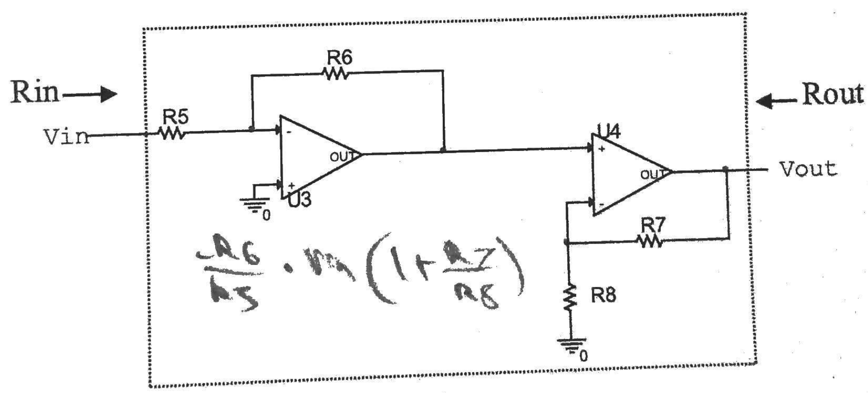
For each of the following circuits,

i.)Determine the input resistance, Rin, seen by the source
ii.)The output resistance, Rout, seen at the load.
iii.)The overall gain of the circuit, $A_{circuit}$ = Vout/Vin.
iv.)Redraw the circuit, using the equivalent dependent source model, with



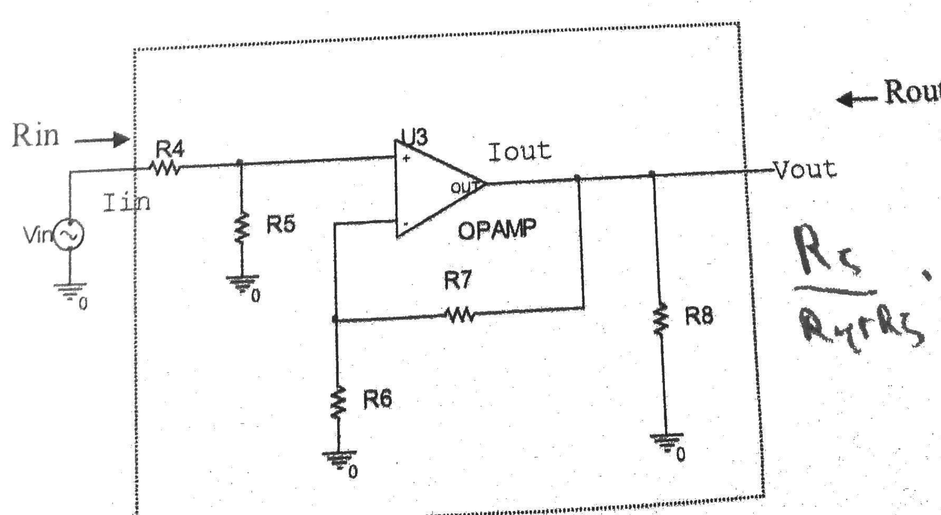
$\left(1+\frac{R_1}{R_2}\right) v_{in} \cdot -\frac{R_4}{R_3}$

a)



$-\frac{R_6}{R_5} \cdot v_{in} \left(1+\frac{R_7}{R_8}\right)$

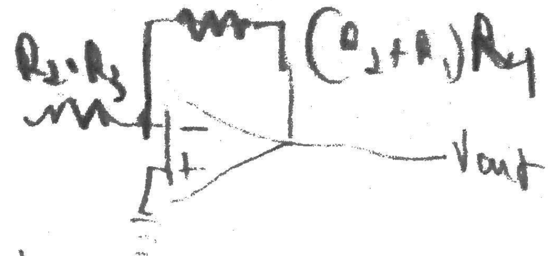
b)



$\frac{R_5}{R_4+R_5} \cdot \left(1+\frac{R_7}{R_6}\right)$

1 A:

i: simplify to



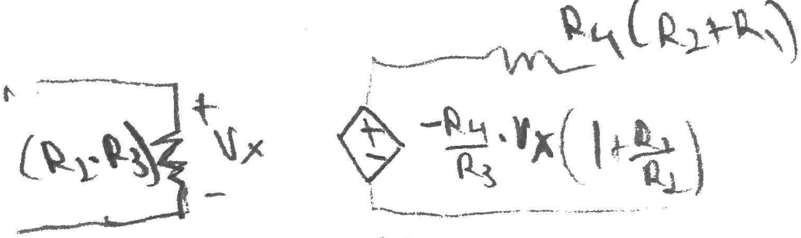
$R_{in} = R_2 \cdot R_3$

ii: $\frac{V_{out}}{I_{out}} = \frac{-\frac{R_4}{R_3}\left(1+\frac{R_1}{R_2}\right)\cdot V_{in}}{I_{out}}$ $\quad I_{out} = I_{R_1} = \frac{V_{in}}{R_2 \cdot R_3}$

$R_{out} = R_4(R_2+R_1)$

iii: gain = $\left(1+\frac{R_1}{R_2}\right) \cdot -\frac{R_4}{R_3}$

iv:



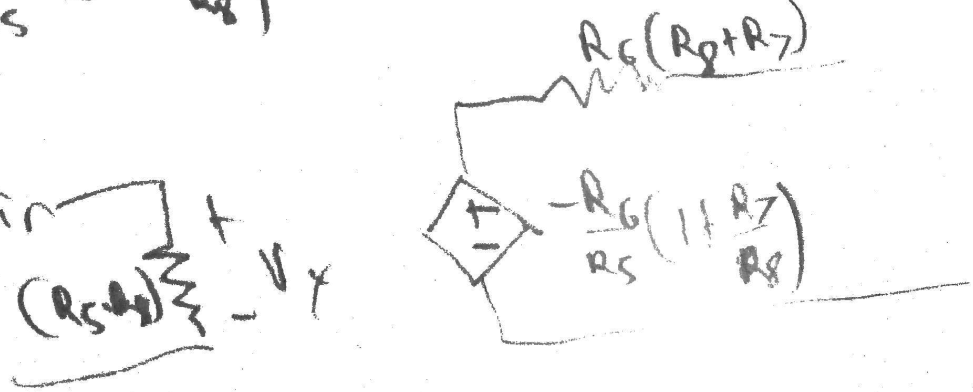
B: i: simplify to:

$R_{in} = R_5 \cdot R_8$

ii: $R_{out} = R_6(R_8+R_7)$

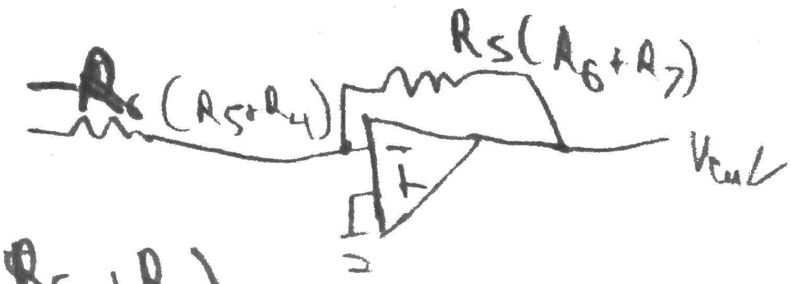
iii: $-\frac{R_6}{R_5}\left(1+\frac{R_7}{R_8}\right)$

iv:



c:

i: simplify to

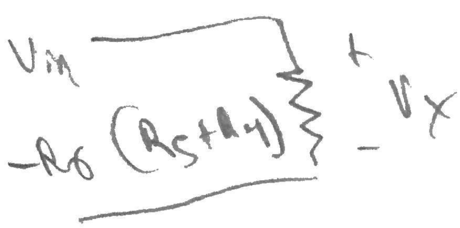


$R_{in} = -R_6(R_5+R_4)$

ii: $R_{out} = R_5(R_6+R_7)$

iii: gain $= \left(\frac{R_6+R_7}{R_6}\right)\left(\frac{R_5}{R_5+R_4}\right)$

iv:

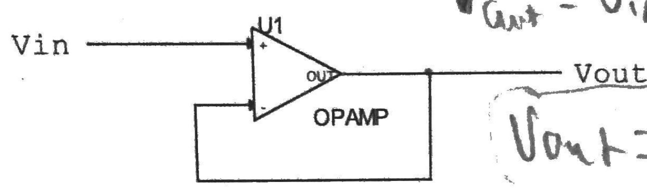


2) DC Bias characteristics

The bias characteristics for the following amplifiers are

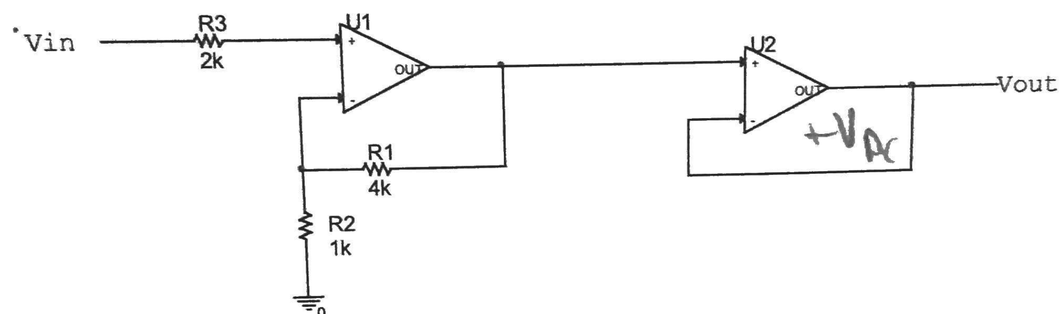
1) $V_{DCoffset} = 5mV$
2) $I^{-}_{bias} = 0.5\mu A$
3) $I^{+}_{bias} = 0.5\mu A$

$V_{out} = V_{in} + (1 + \frac{R_2}{R_1})V_{DC} + I R_2$

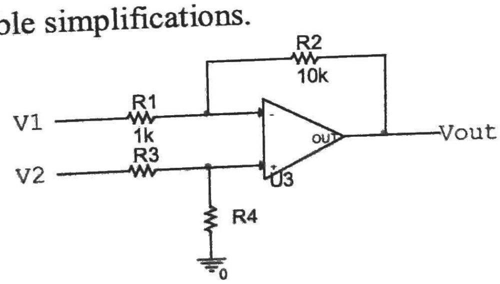


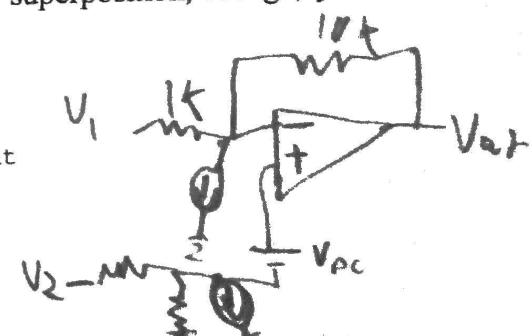
$V_{out} = V_{in} + 5mV$

a) Determine the output voltage due to DC biases.

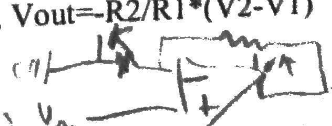


b) Determine the output voltage due to DC biases. Both op-amps will have DC bias sources. Include sketches of the circuits you use for superposition, though, you can make reasonable simplifications.





c) Choose R3 and R4 such that the difference amplifier has zero output voltage due to DC bias sources and is balanced, Vout=-R2/R1*(V2-V1)



$V_{out} = 55mV$

V_{dc} offset : V_A

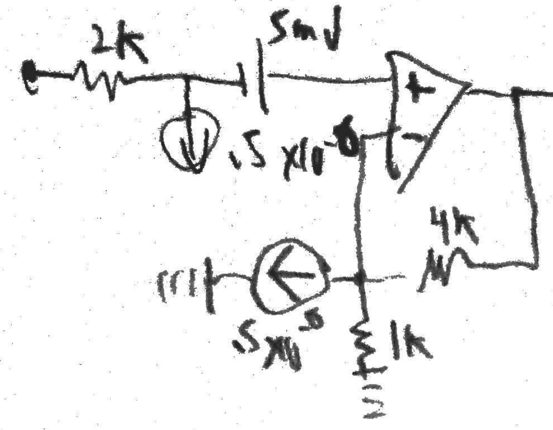
For V_1: $-10V_1$

$I^+ : -(\frac{1}{R_3} + \frac{1}{R_4})^{-1}(11)(.5\mu A) = -5.5mV$

For V_2 : $\frac{V_2(R_3)}{R_3 + R_4} \cdot (1 + 10)$

$(\frac{1}{R_3} + \frac{1}{R_4})^{-1}$

2b:

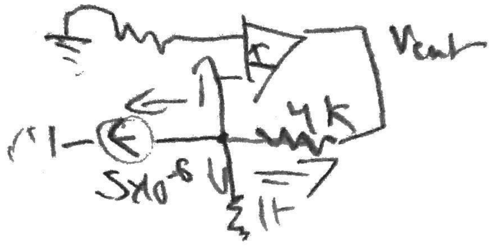


For V_{DC}: $V_n = V_{DC}(1+4)$

$= 25mV$

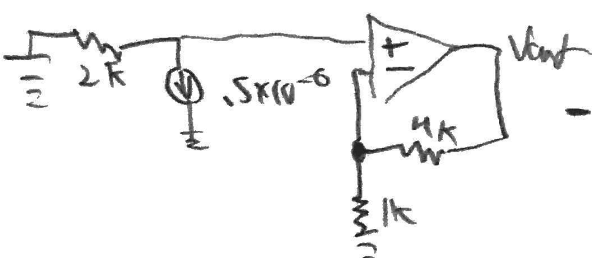
For V_1: $V_n = V_1(5)$

For I^-:



$.5\times10^{-6}(4k) = .002mV$

For I^+



$-.5\times10^{-6}(2k)(5) = -.005mV$

$V_{out} = 25mV + 5V_1 - 5mV + 2mV = 5V_1 + 22mV + 5mV$

$V_{out} = 5V_1 + 22mV + 5mV$

2C

I^-: $V_{out} = 0.5nA \cdot 10k = 5mV$

$V_{out} = 10(V_2 - V_1) = 10V_2 - 10V_1$

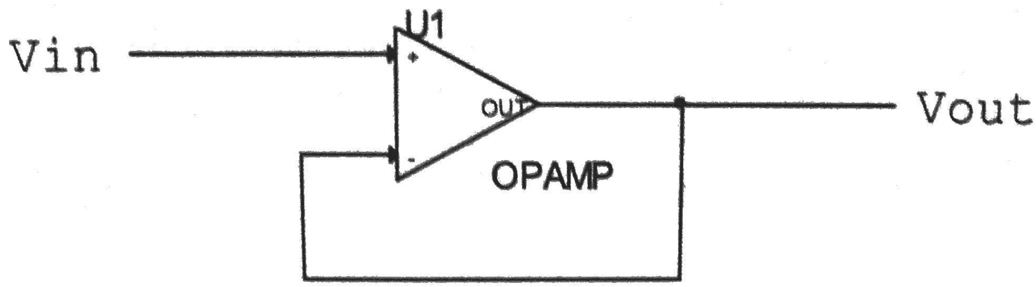
$= 11V_2 \frac{R_4}{R_3+R_4} - 10V_1 + 55mV - 5.5mV\left(\frac{1}{R_3} + \frac{1}{R_4}\right)^{-1} + 5mV$

$\frac{R_4}{R_3+R_4} = \frac{10}{11}$ $\qquad$ $\frac{R_3 \cdot R_4}{R_3+R_4} = \frac{120}{11}$

$R_4 = 120$

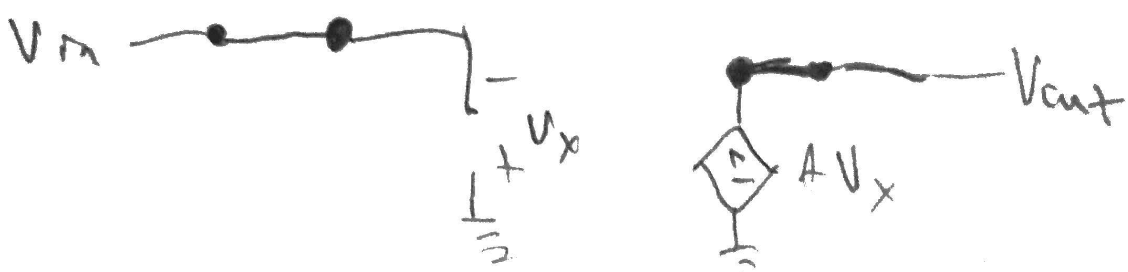
$R_3 = 12$

3) Finite op-amp gain



a) Sketch the equivalent circuit when considering the finite gain op-amp model (the dependent source model of the op-amp itself with finite gain $A_{op\text{-}amp}$).
b) Verify that your answer approaches the ideal result as $A_{op\text{-}amp} \rightarrow \infty$.
c) For Vin = 5V and an internal finite op-amp gain of 10^5, determine the output voltage. Would you consider the effect due to finite gain to be negligible?

A:



B: $V_{out} = A(V_{in} - V_{out})$ Gain $= \frac{V_{out}}{V_{in}} = \frac{A}{A+1}$

$A \to \infty : \frac{\infty}{\infty} = 1 \to$ needed for voltage follower

C: $V_{out} = \frac{10^5}{10^5+1} \cdot 5 \cong 4.999\ldots V$

negligible