ECSE-2050

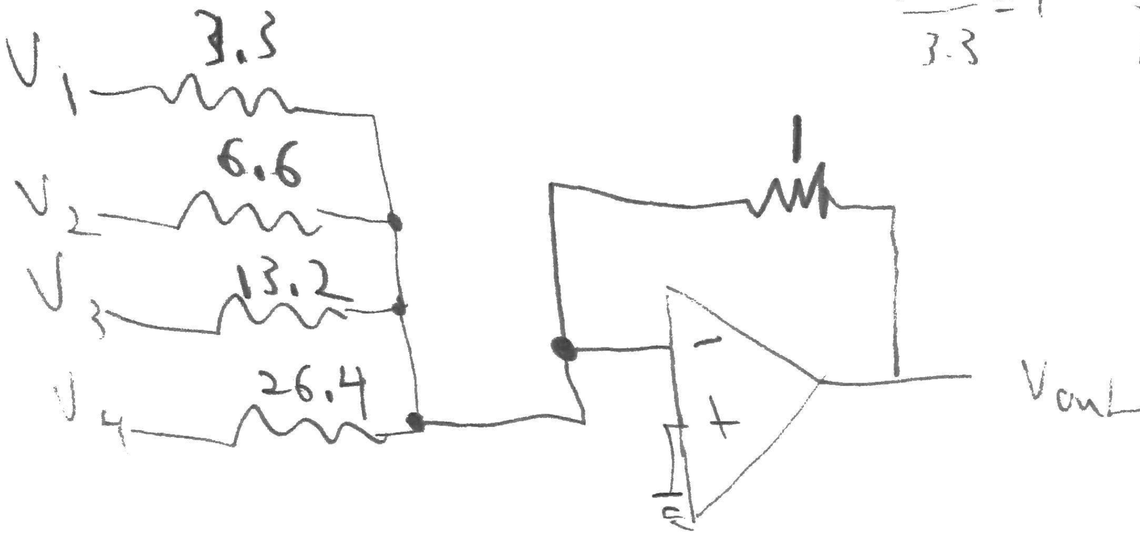
Introduction to Electronics
Summer 2020 **Name** ____________________

Homework 2

1) Design a 4-bit D/A converter, with an output range of 0 to -15V. The digital LO/HI voltages are 0V/3.3V.

each is 1V $-\frac{R_f}{R_1}(8V_1 + 4V_2 + 2V_3 + 1V_4) = -15$

$\frac{3.3}{3.3} = 1 \quad -\frac{R_f}{R_1} = -\frac{1}{3.3}$



2) Common mode and differential mode analysis. Assume the op-amps are ideal.

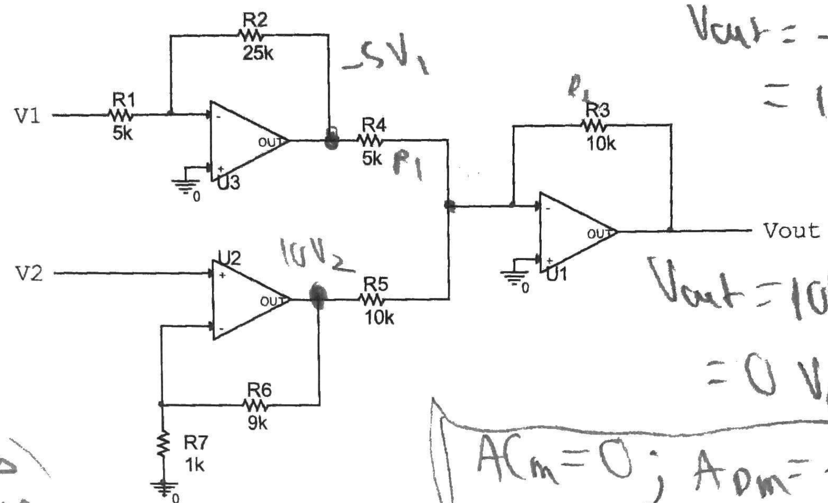
$V_{cm} = \frac{V_1+V_2}{2}$

$V_{dm} = V_2 - V_1$

$V_1 = V_{cm} - \frac{V_{DM}}{2}$

$V_2 = V_{cm} + \frac{V_{DM}}{2}$

$CMRR = 20\log\left(\frac{A_{DM}}{A_{CM}}\right)$

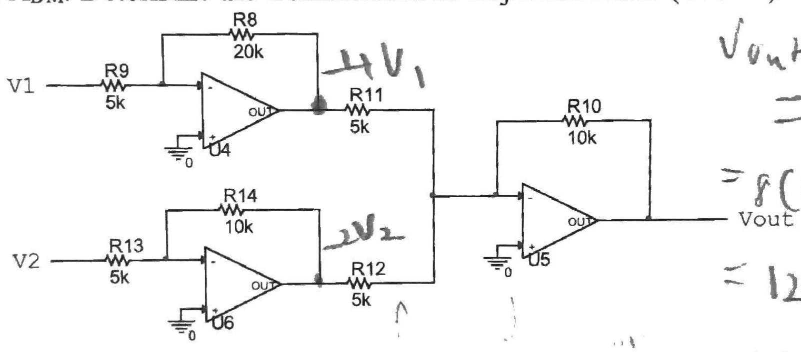


$V_{out} = -2(-5V_1) - (10V_2)$
$= 10V_1 - 10V_2$

$V_{out} = 10(V_{cm} - \frac{V_{DM}}{2}) - 10(V_{cm} + \frac{V_{DM}}{2})$
$= 0\,V_{cm} - 10V_{DM}$

$\boxed{A_{CM} = 0;\ A_{DM} = -10,\ CMRR = \infty}$

a)For the above circuit determine the common mode gain, A_{CM}, and the differential gain, A_{DM}. Determine the Common Mode Rejection Ratio (CMRR).



$V_{out} = -2(-4V_1) - 2(-2V_2)$
$= 8V_1 + 4V_2$
$= 8(V_{cm} - \frac{V_{DM}}{2}) + 4(V_{cm} + \frac{V_{DM}}{2})$
$= 12V_{cm} - 2V_{DM}$

b)For the above circuit determine the common mode gain, A_{CM}, and the differential gain, A_{DM}. Determine the Common Mode Rejection Ratio (CMRR).

c)For V2 = 4V, V1 = 2V, determine V_{CM}, V_{DM} and Vout.

d)For V2 = 101V, V1 = 99V, determine V_{CM}, V_{DM} and Vout.

e)Based on your parts c and d results, how would you characterize the above circuit as a difference amplifier (recalling that measuring differences is the important part of a difference amplifier).

$A_{CM} = 12;\ A_{DM} = -2$

$CMRR = 20\log\left(-\frac{2}{12}\right) = -15.56$

c: $V_{out} = 8(2) + 4(4) = 32V$

$V_{cm} = 4 - \frac{V_{DM}}{2}$

$32 = 12\left(4 - \frac{V_{DM}}{2}\right) - 2V_{DM}$

$\frac{-16}{-8} = V_{DM} = 2\ V$

$V_{cm} = \frac{32 - 2(2)}{12} = 2.33V$

D: $8(99) + 4(101) = \boxed{V_{out} = 1196\,V}$

$$99 = V_{cm} - \frac{V_{Dm}}{2}$$
$$101 = V_{cm} + \frac{V_{Dm}}{2}$$

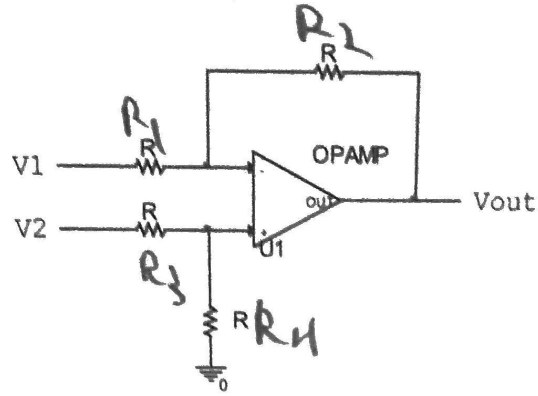
$$\boxed{\begin{aligned} V_{cm} &= 100 \\ V_{Dm} &= 2 \end{aligned}}$$

E: $-4 + 1200 = 1196$: from D

$-4 + 36 = 32$: from C

it works as intended

3) Difference amplifier



a) When considering gold band resistors (5% tolerance), **approximately** determine the worst case common mode rejection ratio for the above circuit.

$$V_{cm} = \frac{V_1 + V_2}{2}$$

R_1 and R_2 are Related from $R_3 + R_4$

$$A_{cm} = \frac{R_4}{R_3+R_4} \cdot \frac{R_1+R_2}{R_1} - \frac{R_2}{R_1}$$

$CMRR = -20\log\left(\frac{A_{cm}}{A_{DM}}\right)$

meaning A_{cm} and A_{DM} need to be as far apart as possible

$$A_{DM} = \frac{1}{2}\left(\frac{R_4}{R_3+R_4} \cdot \frac{R_1+R_2}{R_1} + \frac{R_2}{R_1}\right)$$

$$A_{cm} \rightarrow 1 - \frac{1.05}{.95} = -0.105$$

$$A_{DM} \rightarrow \frac{1}{2}\left(1 + \frac{1.05}{.95}\right) = 1.05$$

$CMRR = 20\log\left(\frac{-0.105}{1.05}\right)$

$= -20\,dB$

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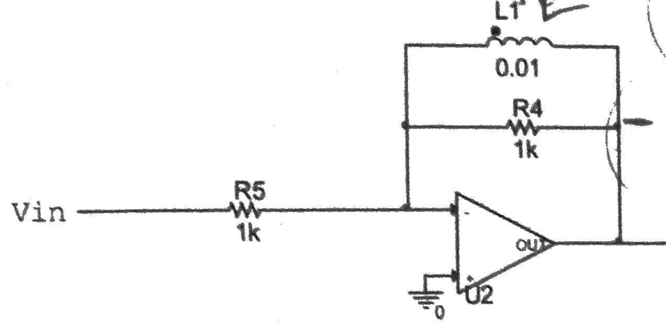
4) Differentiators/Integrators



$$\left(\frac{100}{s} + \frac{1}{1000}\right)^{-1}$$

$$\frac{1000s}{10^5+s} \Big/ (1000) \cdot V_{in}$$

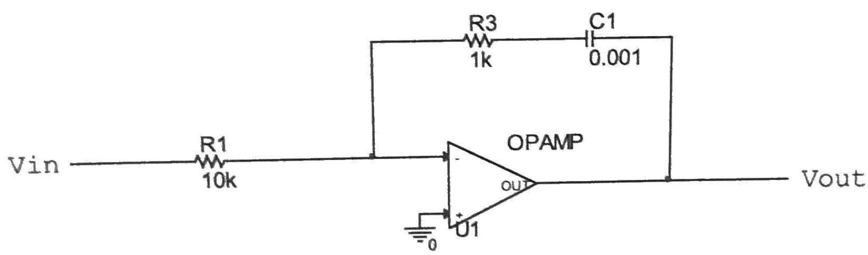
$$\frac{-s}{10^5+s}$$

Assume the op-amp has infinite power (unlimited supply voltage)

a) As frequency approaches zero (but is still greater than zero), what is the approximate (simplified) transfer function? What type of amplifier circuit corresponds to that transfer function?

b) As frequency approaches infinity (large, but finite), what is the approximate (simplified) transfer function? What type of amplifier circuit corresponds to that transfer function?

c) For the above circuit, sketch the Bode magnitude plot for H(s) = Vout(s)/Vin(s). Include dB values in regions where the gain is constant. Indicate the slope of the plot where the gain is not constant. Identify any poles and zeros on the plot. (a log-log plot is provided on the next page.)



d) As frequency approaches zero (but is still greater than zero), what is the approximate (simplified) transfer function? What type of amplifier circuit corresponds to that transfer function?

e) As frequency approaches infinity (large, but finite), what is the approximate (simplified) transfer function? What type of amplifier circuit corresponds to that transfer function?

f) For the above circuit, sketch the Bode magnitude plot for H(s) = Vout(s)/Vin(s). Include dB values in regions where the gain is constant. Indicate the slope of the plot where the gain is not constant. Identify any poles and zeros on the plot. (a log-log plot is provided on the next page.)

g) If Vin(t) = 10cos(1E9t)+5V, determine the output voltage as a function of time, Vout(t).

4 A: $\frac{-5}{10^5+s} = H(s)$ $s \to 0$ $\boxed{H(0) = -5 \cdot V_{in}}$. Voltage Follower

B: $\boxed{H(\infty) = \frac{-\infty}{\infty} \cdot V_{in} = \frac{-5}{5}}$ Inverting amplifier

D: $\left(1000 + \frac{1000}{s}\right) \div 10^4 = \frac{-(s+1)}{10s} = H(s)$

$s \to 0$ $\frac{-1}{s \to 0}$ Inverting amplifier $H(0) = -\infty$

E: $H(s) \to H(\infty) = \frac{-\infty}{\infty}$ Inverting Amp

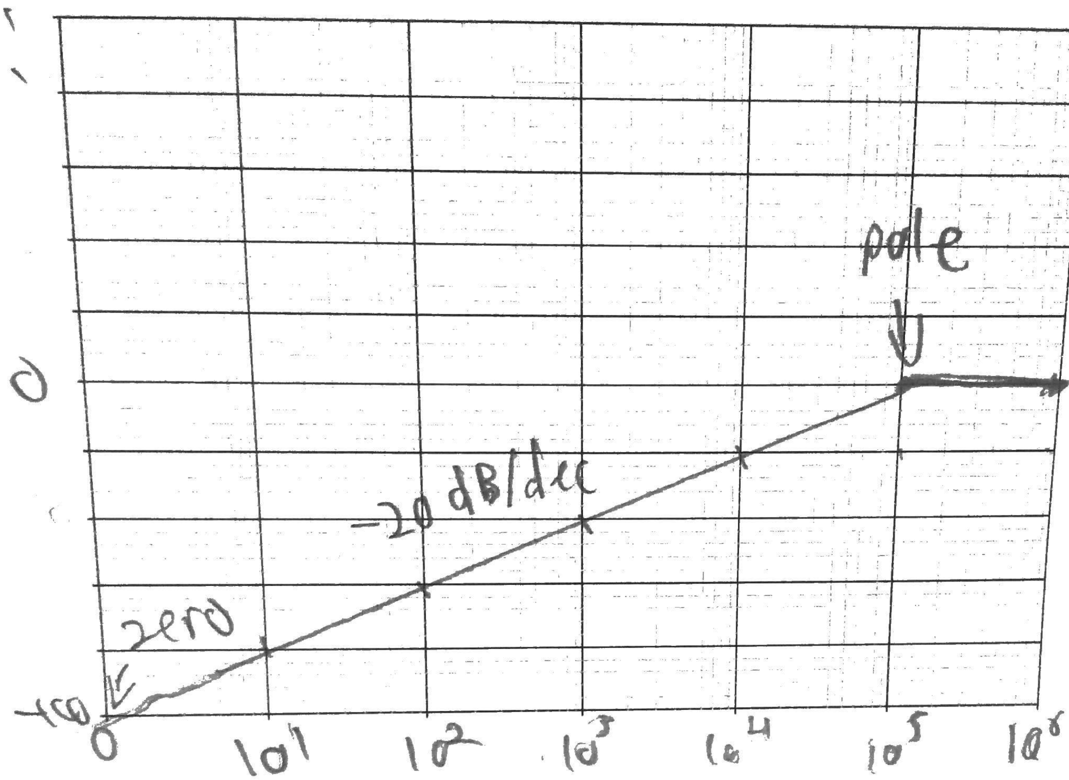
G:

$\left(-\frac{1000 - \frac{1}{j10^9(0.001)}}{10k}\right) = A = -1 + j\frac{1}{10^{10}}$

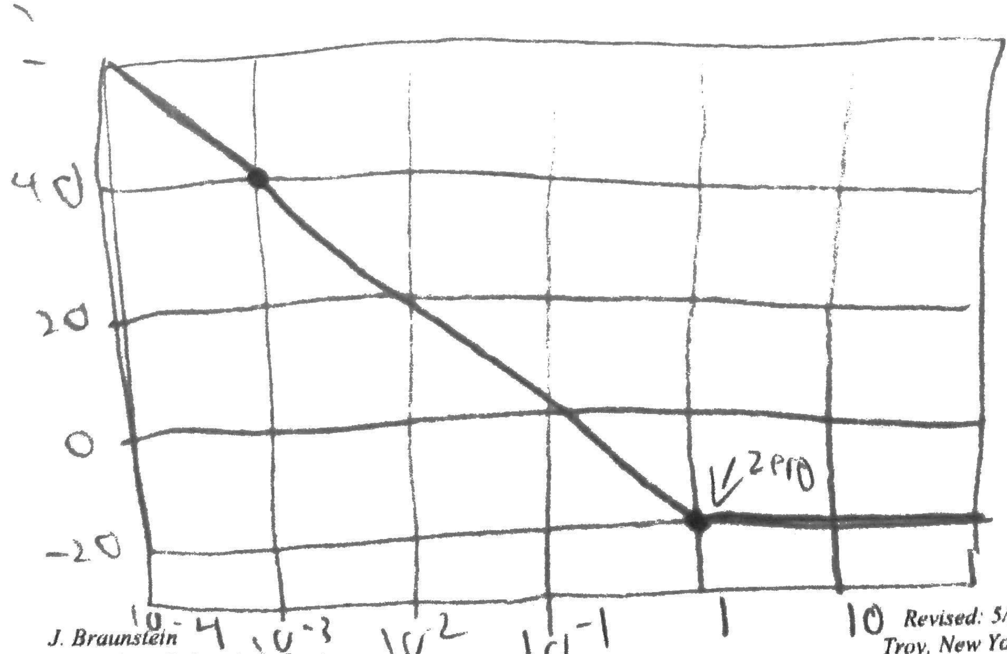
$\sqrt{-1^2 + \left(\frac{1}{10^{10}}\right)^2} = 1 \to$ inverting $\to -1$

Thus $V_{out} = (10\cos(10^4 t) - 5V)$

C:


pole
0
-20 dB/dec
zero
-100
0
10^1
10^2
10^3
10^4
10^5
10^6

F:


40
20
0
-20
zero
10^-4
10^-3
10^2
10^-1
1
10

pole at 0