03/26/07

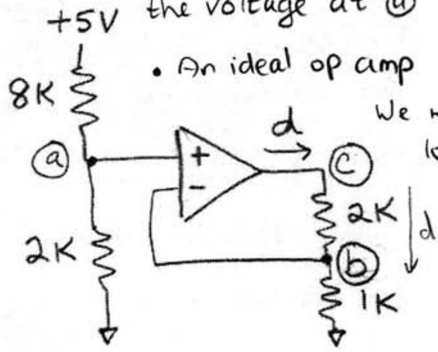
Op Amp Problems

________________ student name   Sagi Perel — TA

For each of the circuits below, using op amps (not comparators) compute the voltages and currents indicated by letters. Show your work.

(1)

- Since we assume an ideal op amp - no current flows from ⓐ to the (+) leg. So the voltage at ⓐ is a simple voltage divider: $V_a = \frac{5v \cdot 2K}{8K + 2K} = 1v$.



- An ideal op amp in this configuration - would cause $V_{(+)} = V_{(-)}$, so $V_b = V_a = 1v$. We know that d flows from ⓒ through ⓑ to ground - so looking @ the 1K: $(V_b - 0) = d \cdot 1K \Rightarrow d = 1mA$
- Looking @ the 2K: $V_c - V_b = d \cdot 2K \Rightarrow V_c = 3v$

$V_c = 1v + 1mA \cdot 2K$

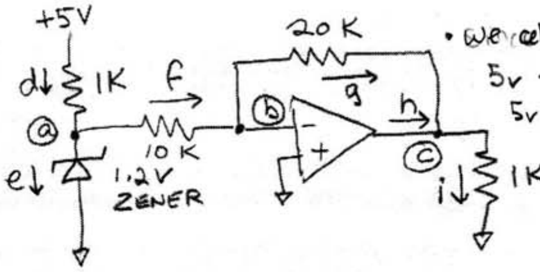
$V_c = 3v$

- Here we start from a known voltages: $V_{(+)} = V_{(-)} = V_b = 0$ and $V_a = 1.2v$ because of the zener diode.

(2)

- Now we know the voltage drop over the 10K: $V_a - V_b = f \cdot 10K$

$1.2v - 0v = f \cdot 10K \Rightarrow f = 0.12mA$



- We also know the voltage drop over the 1K (left one):

$5v - V_a = d \cdot 1K$

$5v - 1.2v = d \cdot 1K \Rightarrow d = 3.8mA$

- We know: $d = e + f \Rightarrow e = 3.68mA$
- Since no current flows into the (-) terminal then $g = f = 0.12mA$

- By knowing V_b, g - we can find V_c (voltage drop over the 20K):

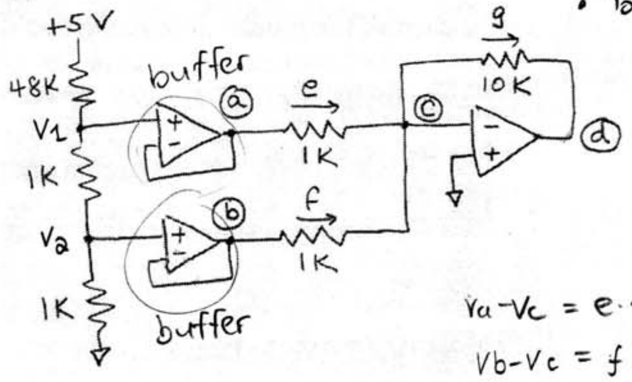
$V_b - V_c = g \cdot 20K \Rightarrow V_c = V_b - g \cdot 20K = 0 - 0.12mA \cdot 20K = -2.4v$

- To find i: look at the right 1K resistor: $V_c - 0 = i\,(1K)$

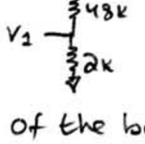
$-2.4v = i\,(1K) \Rightarrow i = -2.4mA$

- We know: $g + h = i$ so $h = i - g = (-2.4mA) - 0.12mA = -2.52mA$

(3)



- To find V_1:



$V_1 = 5v \cdot \frac{2K}{50K} = 0.2v$

Similarly, $V_2 = 5v \cdot \frac{1K}{49K} = 0.1v$

- Because of the buffers: $V_a = V_1 = 0.2v$

$V_b = V_2 = 0.1v$

- $V_{(-)} = V_{(+)} = V_c = 0v$
- From voltage drops over the resistors & ohm's law

$V_a - V_c = e \cdot 1K \Rightarrow e = 0.2mA$

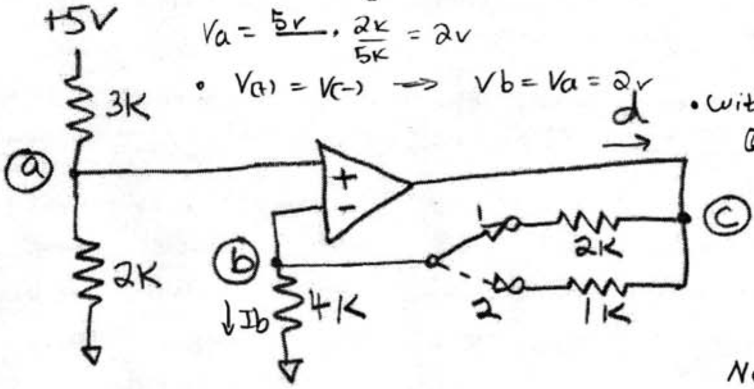
$V_b - V_c = f \cdot 1K \Rightarrow f = 0.1mA$

- $g = e + f = 0.3mA$
- Voltage drop over 10K: $V_c - V_d = g \cdot 10K$

$0 - V_d = 0.3mA \cdot 10K$

$V_d = -3v$

(4) Calculate voltages and currents with switch in each position.



- From voltage divider (since no current flows to the (+) terminal):

$V_a = \frac{5v}{5k} \cdot 2k = 2v$

- $V_{(+)} = V_{(-)} \Rightarrow V_b = V_a = 2v$

- With switch @ 1: current d flows through (c) over the 2k, through (b) to ground. So from voltage drop over (b):

$I_b = \frac{V_b - 0}{4k} = \frac{2v}{4k} = 0.5mA$

$d = I_b = 0.5mA$

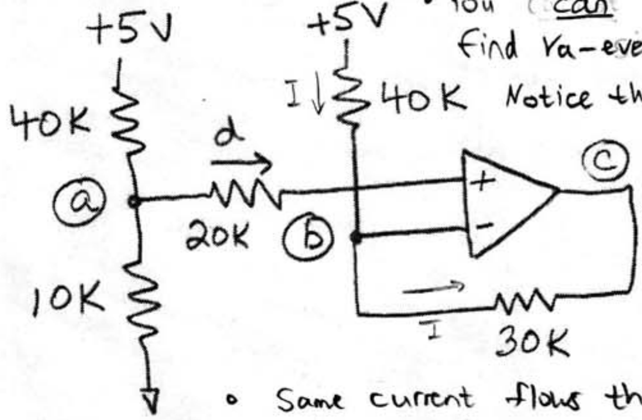
Now - from voltage drop over the 2k:

$V_c - V_b = d \cdot 2k$

$V_c = 0.5mA \times 2k + 2v = 3v$

- When the switch is in (2) state - then d remains the same (verify that!) and by doing a similar calculation: $V_c = 0.5mA \times 1k + 2v = 2.5v$

(5)



- You can use a simple voltage divider here to find Va - even though current splits there. Notice that d flows to the (+) terminal - so $d = 0 mA$.
- $V_a = 5v \cdot \frac{10k}{50k} = 1v$
- $V_{(+)} = V_{(-)} \Rightarrow V_b = V_a = 1v$

($V_{(+)} = V_{(a)}$ since $d = 0mA$)

- Same current flows through the 40k & 30k (nothing flows into the (+) terminal) - so from 40k we know:

$5v - V_b = I \cdot 40k$

$5v - 1v = I \cdot 40k$

$I = \frac{4v}{40k} = 0.1mA \Rightarrow$ from 30k: $V_b - V_c = I \cdot 30k$

$V_c = V_b - I \cdot 30k = 1v - 0.1mA \cdot 30k = -2v$

(6) An op amp actually has two separate gains, one for each of the inputs. In a perfect op amp A_1=A_2. Find the Common Mode Rejection Ratio (CMRR) for a real op amp in which A_1=600,000 and A_2=600,100. Express your answer in dB.

$20\log\left|\frac{1}{2}\cdot\frac{A_1+A_2}{A_1-A_2}\right| \hat{=} 76 dB$ (because it's v, and not P - use 20log and not 10log)

answers: (1) a=1V, b=1V, c=3V, d=1mA; (2) a=1.2V, b=0V, -2.4V, d=3.8mA, e=3.68mA, f=0.12mA, g=0.12mA, h= -2.52mA, i= -2.4mA; (3) a=0.2V, b=0.1V, c=0V, d= -3V, e=0.2mA, f=0.1mA, g=0.3mA; (4) a=2V, b=2V, c=(3V or 2.5V), d=0.5mA; (5) a=1V, b=1V, c= -2V, d=0mA; (6) 76 dB (voltage ratio=6000.5).