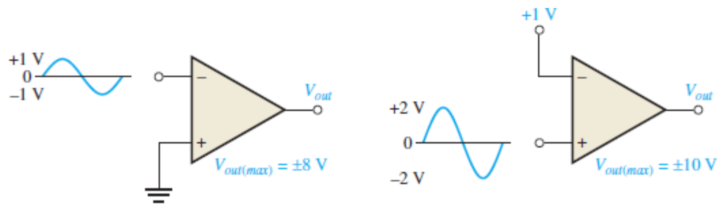
Op Amp Sheet 3

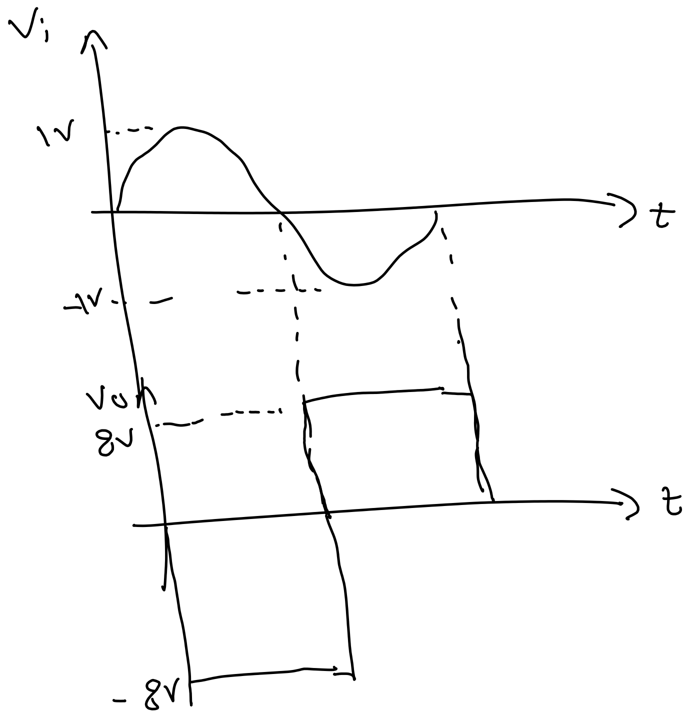
Tuesday, December 27, 2022 7:22 PM

1. Draw the output voltage waveform for each circuit shown with respect to the input. Show voltage levels.

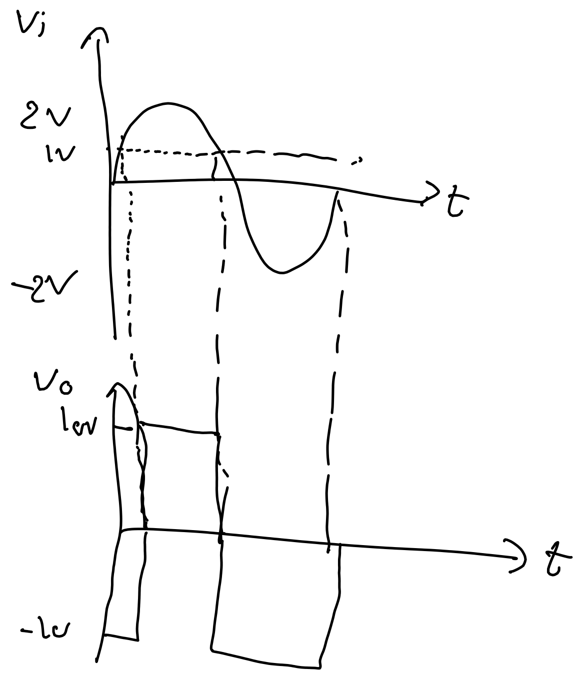


(a) (b)

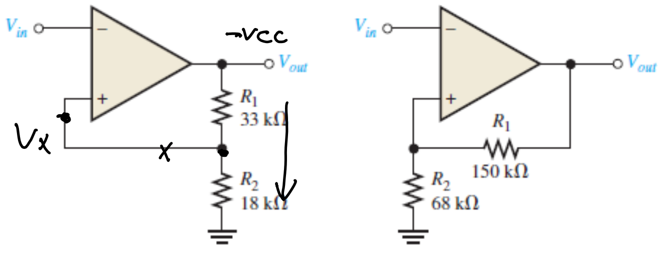
a)



b)



2. Determine the hysteresis voltage for each comparator shown. The maximum output levels are ±11 V.



(a) (b)

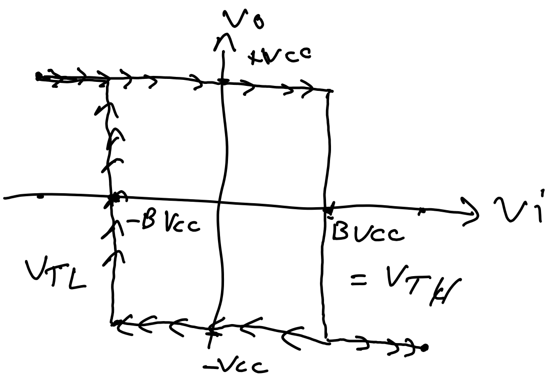
at $v_{in} < V_x$

$$V_x = V_{cc}\underbrace{\frac{R_2}{R_1+R_2}}_{\beta} = \beta V_{cc}$$

at $v_{in} > V_x$

$$V_o = -V_{cc}$$

$$V_x = -V_{cc}\frac{R_2}{R_1+R_2} = -\beta V_{cc}$$



$$V_H = 2\beta V_{cc}$$

a) $$V_H = 2\beta V_{max}$$

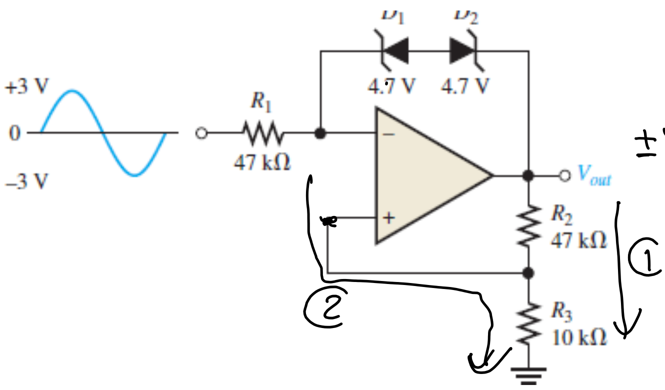
$$= 2\frac{R_2}{R_1+R_2} 11$$

$$= 2\frac{18}{33+18} 11 = 7.76\,V$$

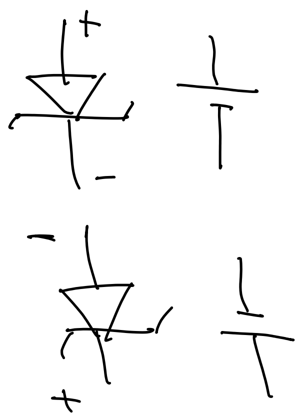
b) $V_H = 2\beta V_{max}$

$= 2 \dfrac{68}{68+150} 11 = 6.86V$

3. Determine the output voltage waveform in the following figure.



$\pm V_{max}$



at $V_o = +V_{max}$

$V_{ZS} = 4.7 + 0.7 = 5.4V$

at $V_o = -V_{max}$

$V_{ZS} = -4.7 - 0.7 = -5.4V$

$V_{ZS} = \pm 5.4V$

for Loop 1

$V_o = V_{R2} + V_{R3} \rightarrow 1$

for Loop 2

$V_o = V_{ZS} + V_{R3} \rightarrow 2$

eq 1 − eq 2

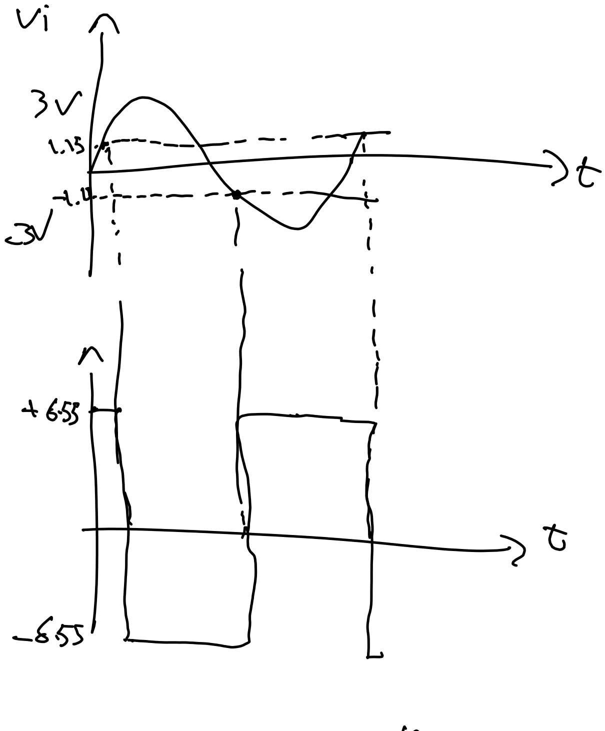
$0 = V_{R2} - V_{ZS}$

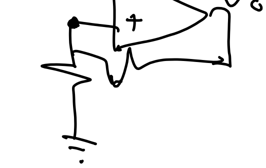
$V_{R2} = V_{ZS} = \pm 5.4 V$

$$I_{R_2} = \frac{V_{R_2}}{R_2} = \frac{\pm 5.4}{47K} = \pm 114.89\ \mu A$$

$$V_o = V_{R_2} + V_{R_3}$$
$$= \pm 5.4 + \pm 114.89\ \mu A \times 10K$$
$$= \pm 6.53\ V$$

$$V_{TL} = -\beta V_{max} = -1.15\ V$$
$$V_{TH} = \beta V_{max} = 1.15\ V$$
$$\beta = \frac{R_3}{R_2 + R_3}$$

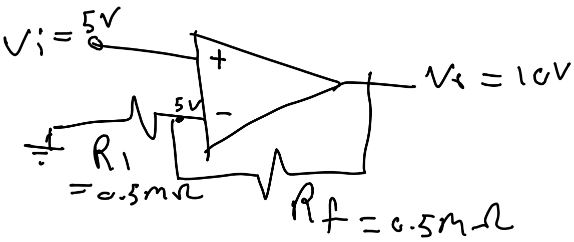




4. Design a non-inverting amplifier with the gain of 2. At the maximum output voltage of 10V the current in the voltage divider is to be 10 μA.

Gain = 2

$V_{o max} = 10V \rightarrow I = 10 \mu A$



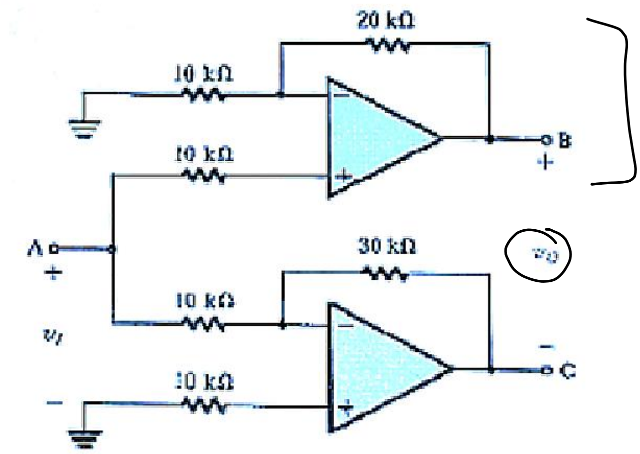
$$G = 1 + \frac{R_f}{R_1} = 2 \rightarrow \frac{R_f}{R_1} = 1 \rightarrow R_f = R_1$$

$$V_o = G V_i \rightarrow V_i = \frac{V_o}{G} = \frac{10}{2} = 5V$$

$$R_f = \frac{V_o - V_i}{I} = \frac{10-5}{10 \mu A} = 0.5 \; M\Omega$$

$$R_1 = R_f = 0.5 M\Omega$$

5. Calculate V_B, V_C and the voltage gain (V_{out}/V_{in}) for the circuit shown



$$V_B = V_A\left(1+\frac{20}{10}\right) = 3V_A$$

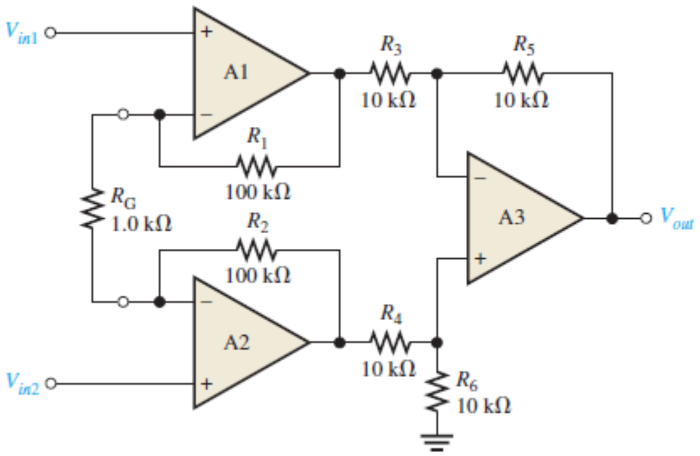
$$V_C = V_A \; - \frac{30}{10} = -3V_A$$

$$V_o = V_B - V_C$$

$$V_o = 3V_A - (-3V_A)$$

$$V_o = 6V_i \rightarrow \frac{V_o}{V_i} = 6$$

6. For the instrumentation amplifier configuration shown in figure.
   - **a)** Find the voltage gains of op-amps A_1 and A_2.
   - **b)** Find the overall voltage gain of the instrumentation amplifier
   - **c)** The following voltages are applied to the instrumentation amplifier: V_{in1} = 5mV, V_{in2} = 10mV, V_{cm} = 225mV. Determine the final output voltage.
   - **d)** What value of R_G must be used to change the gain of the instrumentation amplifier to 1000?



Gain for A_1, A_2 $\quad R_1 = R_2 = R$

$$G = 1 + \frac{2R}{R_G} = 201$$

$$\text{overall Gain} = \left(1+\frac{2R}{R_a}\right)\frac{R_6}{R_4} = 201$$

$$V_{out} = \left(1+\frac{2R}{R_G}\right)\frac{R_6}{R_4} * (V_{in2} - V_{in1})$$

$$= 201\ ((10 + 2/25) - (5 + 2/75))$$

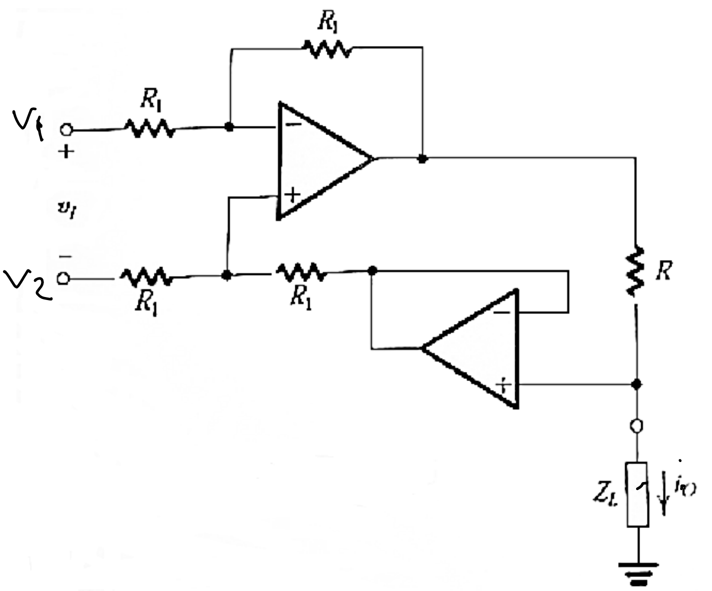
$V_{out} = 1005\ mV$

$$\text{overall Gain} = \left(1 + \frac{2R}{R_G}\right)\frac{\cancel{R_6}}{\cancel{R_4}}$$

$$1000 = \left(1 + \frac{2*100}{R_G}\right)$$

$R_G = 4.99\ k\Omega$

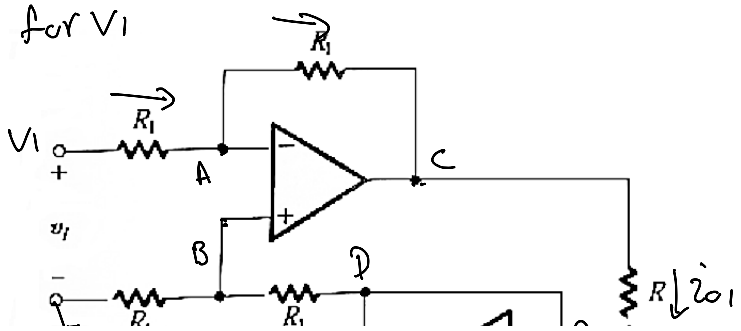
7. For instrumentation amplifier shown, derive an expression for i_o

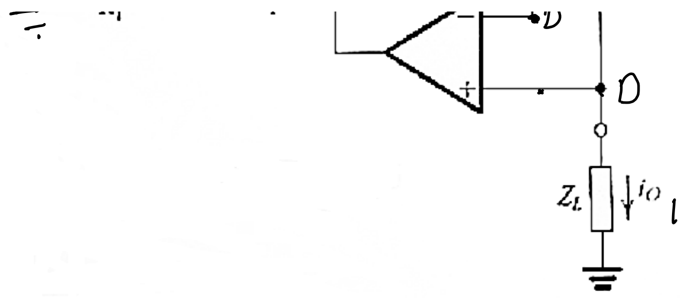


$V_i = V_1 - V_2$

using super Position

for V1





$$V_D = \hat{i}_{o1} Z_L$$

$$V_B = V_D \frac{R_1}{R_1 + R_1} = \frac{V_D}{2} = \frac{\hat{i}_{o1} Z_L}{2}$$

$$V_A = V_B$$

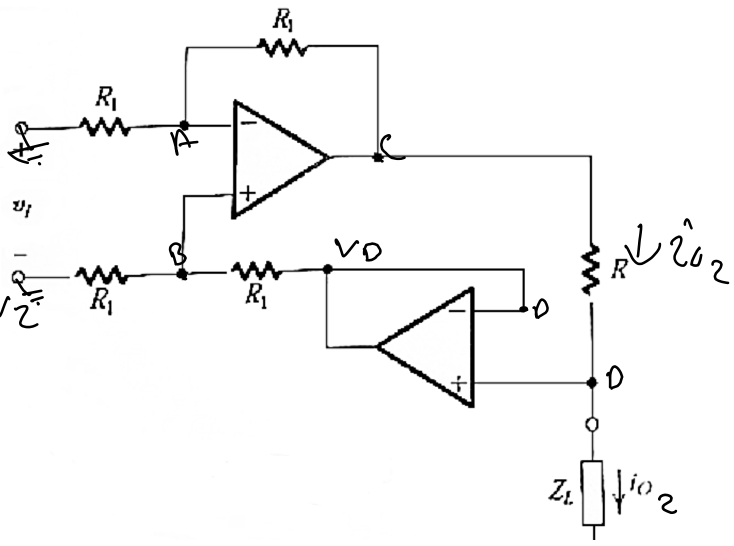
$$V_C = \hat{i}_{o1}(R + Z_L)$$

$$\frac{V_1 - V_A}{\cancel{R_1}} = \frac{V_A - V_C}{\cancel{R_1}}$$

$$V_1 - \frac{i_{o1} Z_L}{2} = \frac{\hat{i}_{o1} Z_L}{2} - \hat{i}_{o1}(R + Z_L)$$

$$V_1 = \cancel{\hat{i}_{o1} Z_1} - \hat{i}_{o1} R - \cancel{\hat{i}_{o1} Z_L}$$

$$V_1 = -\hat{i}_{o1} R \rightarrow \hat{i}_{o1} = \frac{-V_1}{R}$$



$$V_B = \frac{V_2}{2} + \frac{V_D}{2}$$

$$V_D = i_{o2} Z_L$$

$$V_B = \frac{V_2}{2} + \frac{i_{o2} Z_L}{2}$$

$$V_C = i_{o2} (R + Z_L)$$

$$V_A = \frac{V_C}{2} = \frac{i_{o2}(R + Z_L)}{2}$$

$$V_A = V_B \longrightarrow \frac{i_{o2}(R + Z_L)}{\cancel{2}} = \frac{V_2}{\cancel{2}} + \frac{i_{o2} Z_L}{\cancel{2}}$$

$$V_2 = i_{o2} R + \cancel{i_{o2} Z_L} - \cancel{i_{o2} Z_L}$$

$$V_2 = i_{o2} R \longrightarrow i_{o2} = \frac{V_2}{R}$$

$$i_o = i_{o1} + i_{o2}$$

$$= -\frac{V_1}{R} + \frac{V_2}{R}$$

$$= -\left(\frac{V_1 - V_2}{R} \right)$$

$$i_o = -\frac{V_i}{R}$$