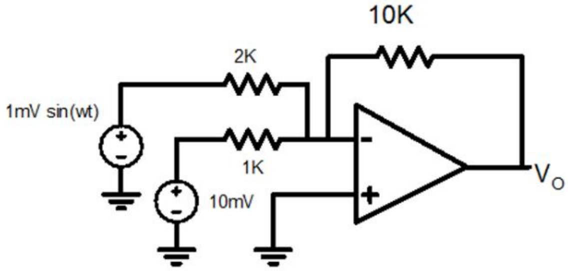
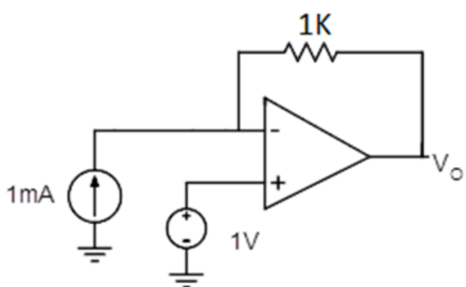
1. Determine the output of the ideal op-amp circuits shown below.

i.



$$v_o = -\left\{\frac{10K}{1K} \times 10mV + \frac{10K}{2K} \times 1mV \sin(\omega t)\right\}$$
$$= -\{0.1 + 5 \times 10^{-3} \sin(\omega t)\}$$

ii.



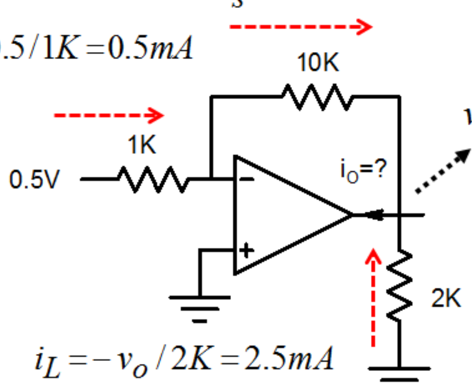
$$v_+ = v_- = 1V$$

$$\frac{1 - v_o}{1K} = 1mA \qquad v_o = 0V$$

iii.

$i_s = 0.5mA$

$i_s = 0.5/1K = 0.5mA$

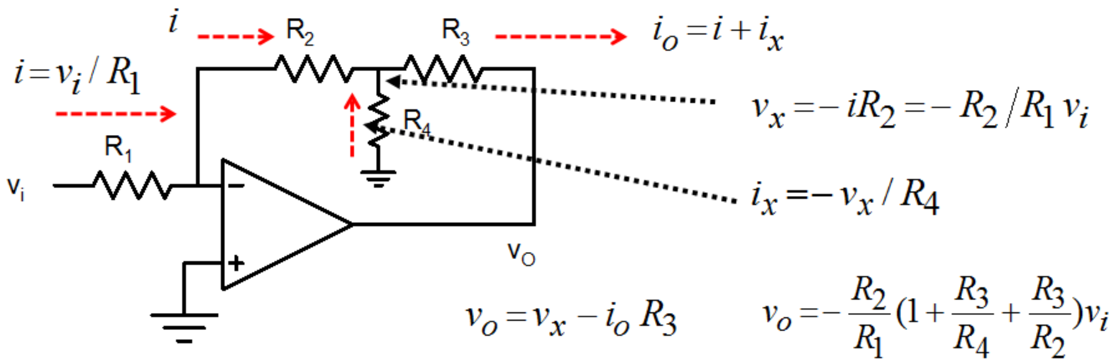


$v_o = -i_s \times 10K = -5V$

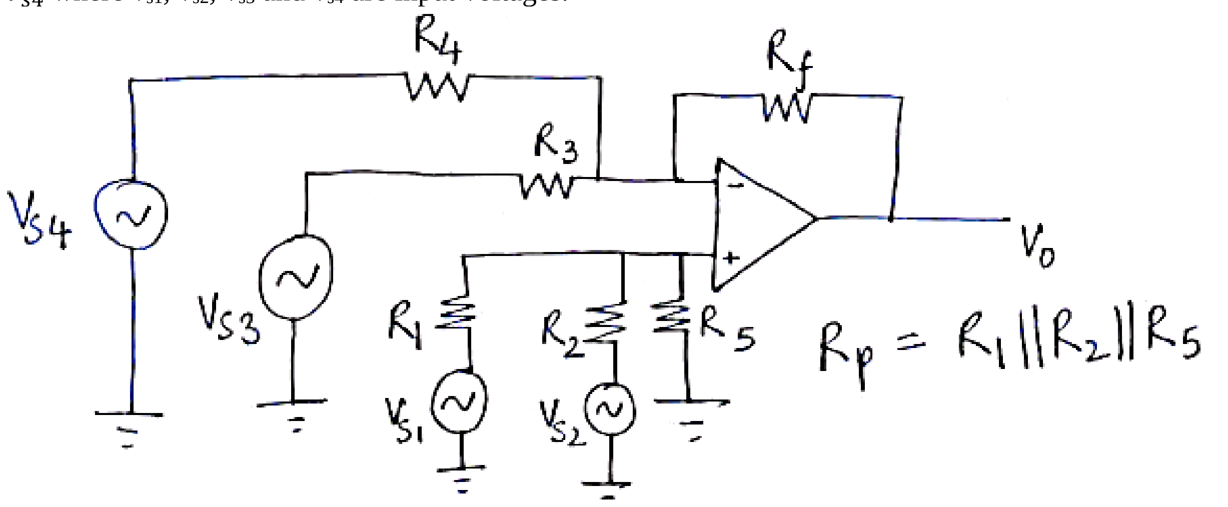
$i_o = i_S + i_L = 3mA$

$i_L = -v_o / 2K = 2.5mA$

iv.



2. Design an op-amp circuit that would generate the following output voltage $V_O = 2v_{s1} + 4v_{s2} - 8v_{s3} - 10v_{s4}$ where v_{s1}, v_{s2}, v_{s3} and v_{s4} are input voltages.



$$v_o = -\left(\frac{R_f}{R_3}\right)v_{S3} - \left(\frac{R_f}{R_4}\right)v_{S4} + \left(1+\frac{R_f}{R_3\|R_4}\right)\times\frac{R_p}{R_1}v_{S1}$$

$$+\left(1+\frac{R_f}{R_3\|R_4}\right)\times\frac{R_p}{R_2}v_{S2}$$

$$V_0 = 2v_{S1} + 4v_{S2} - 8v_{S3} - 10v_{S4}$$

Let $R_f = 10K$

$$\therefore \frac{R_f}{R_3} = 8$$

$$\frac{10K}{R_3} = 8 \Rightarrow R_3 = 1.25k\Omega$$

$$\frac{R_f}{R_4} = 10$$

$$\therefore \frac{10K}{R_4} = 10 \Rightarrow R_4 = 1k\Omega$$

$$\frac{R_f}{R_3\|R_4}\times\frac{R_p}{R_1} = 2 \Rightarrow \frac{10K}{(1.25\|1k)}\times\frac{R_p}{R_1} = 2$$

$$\Rightarrow \frac{R_p}{R_1} = 0.105$$

$$\frac{R_f}{R_3\|R_4}\times\frac{R_p}{R_2} = 4 \Rightarrow \frac{10K}{(1.25k\|1k)}\times\frac{R_p}{R_2} = 4$$

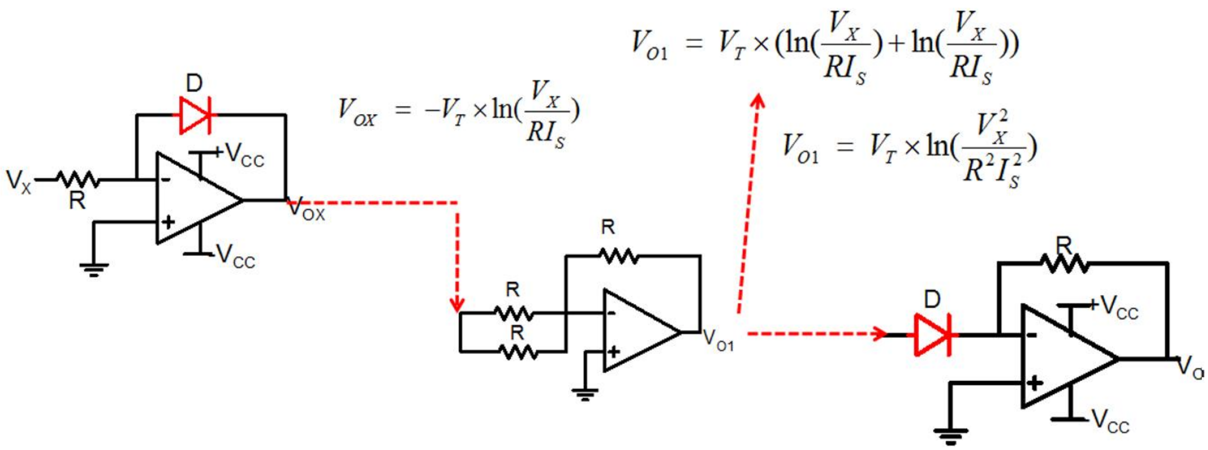
$$\Rightarrow \frac{R_p}{R_2} = 0.211$$

$$\frac{R_1}{R_p}\times\frac{R_p}{R_2} = \frac{1}{0.105}\times 0.211 \Rightarrow \frac{R_1}{R_2} = 2$$

Let $R_2 = 1k\Omega \Rightarrow R_1 = 2k\Omega \Rightarrow R_p = 0.211k\Omega$

$$\therefore R_5 = 0.308k\Omega$$

3. Design an op-amp circuit that can produce $V_O = K \times V_{IN}^2$ where V_{in} is the input voltage.



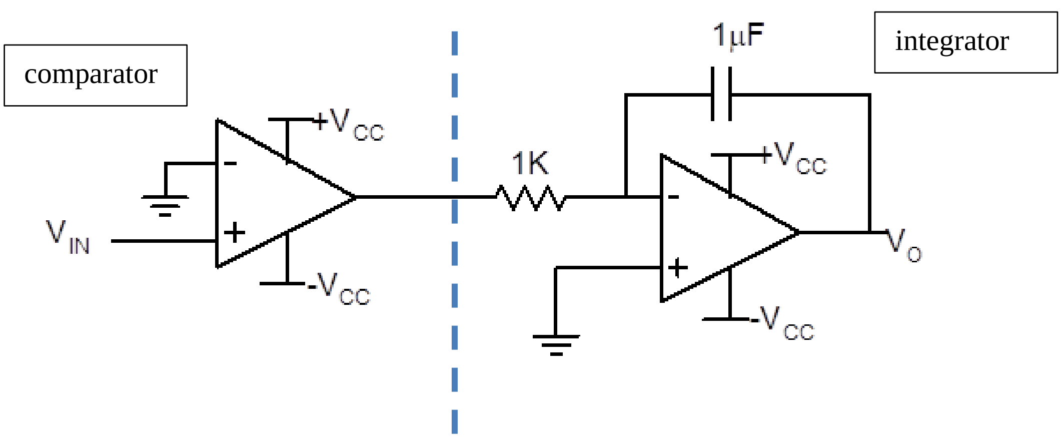
$$V_{OX} = -V_T \times \ln(\frac{V_X}{RI_S})$$

$$V_{O1} = V_T \times (\ln(\frac{V_X}{RI_S}) + \ln(\frac{V_X}{RI_S}))$$

$$V_{O1} = V_T \times \ln(\frac{V_X^2}{R^2 I_S^2})$$

$$V_O \cong -RI_S \times e^{\frac{V_{O1}}{V_T}} = -\frac{V_X^2}{RI_S}$$

4. Sketch the output voltage of the circuit shown below for $V_{in} = 1V sin(2\pi f t); f = 1KHz$ and supply voltages of $\pm 5V$



for the comparator,

$V_{01} = +5V$ if $V_{IN} > 0$

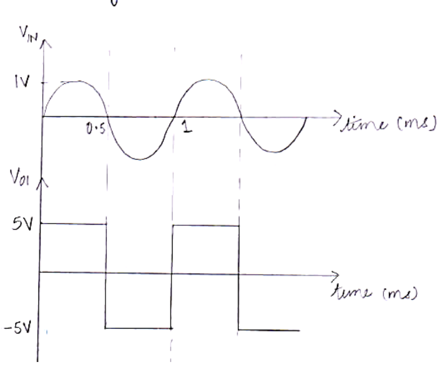
$= -5V$ if $V_{IN} < 0$

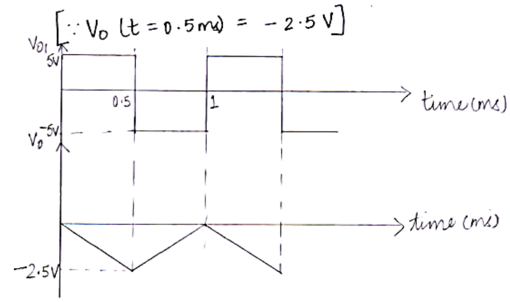
For the integrator, $V_0(t) = \frac{-1}{RC}\int V_{01}\,dt = -10^3 \int V_{01}\,dt$

for $V_{IN} > 0$, $V_0 = -5 \times 10^3 \times t$

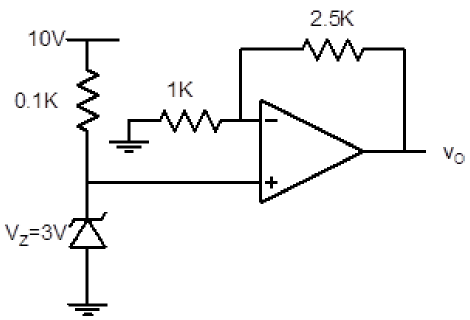
for $V_{IN} < 0$, $V_0 = -2.5 + 5 \times 10^3 (t - 0.5ms)$

$[\because V_0 (t = 0.5ms) = -2.5V]$





5. Determine the output for the ideal op-amp circuit shown below.



This is a non-inverting amplifier with V_Z as input.

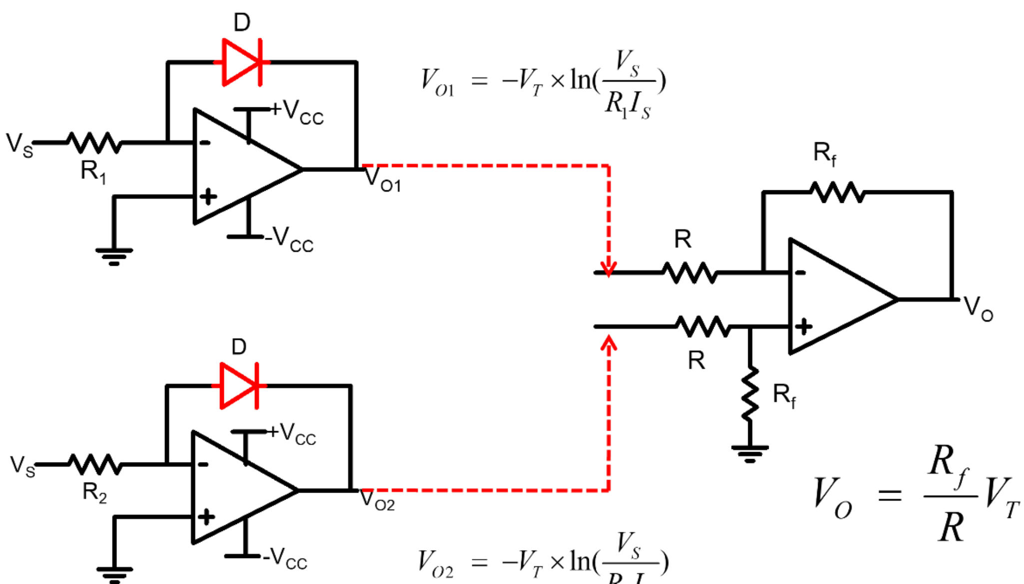
$$v_0 = V_Z\left(1 + \frac{R_2}{R_1}\right)$$

$$\therefore\ v_0 = 3\left(1 + \frac{2.5}{1}\right)\ \text{V}$$

$$\Rightarrow\ v_0 = 3(3.5)\ \text{V}$$

$$\Rightarrow\ v_0 = 10.5\ \text{V}$$

6. Design a temperature sensor using a couple of OP-Amps and resistors.



$$V_{O1} = -V_T \times \ln\left(\frac{V_S}{R_1 I_S}\right)$$

$$V_{O2} = -V_T \times \ln\left(\frac{V_S}{R_2 I_S}\right)$$

$$V_O = \frac{R_f}{R} V_T \times \ln\left(\frac{R_2}{R_1}\right)$$

Output voltage is directly proportional to temperature