Assignment - 02

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10.1.

The given circuit resembles an inverting amplifier of the OP amp. We know, $V_o = -\frac{R_f}{R_1} V_1$ for inverting amplifier.

Here, $R_f = 250\ k\Omega = 2.5 \times 10^5\ \Omega$

$R_1 = 20\ k\Omega = 2 \times 10^4\ \Omega$

$V_1 = 1.5\ V.$

So, $V_o = -\frac{R_f}{R_1} \times V_1 = \frac{2.5 \times 10^5}{2 \times 10^4} \times 1.5\ V$

$\therefore V_o = -18.75\ V$

Ans: $-18.75\ V$

10.2.

The given circuit resembles an inverting amplifier.

We know, $V_o = -\frac{R_f}{R_1} V_1$ for inverting amplifier.

Given, $R_f = \cancel{250\ k\Omega}\ 200\ k\Omega = 2 \times 10^5\ \Omega$

$R_1 = 20\ k\Omega = 2 \times 10^4\ \Omega$

V_1 has a range from 0.1 to 0.5 V.

For, $V_1 = 0.1\ V$,

$V_o = -\frac{R_f}{R_1} V_1 = \frac{2 \times 10^5}{2 \times 10^4} \times 0.1 = -1\ V$

For, $V_1 = 0.5\ V$,

$V_o = -\frac{R_f}{R_1} V_1 = \frac{2 \times 10^5}{2 \times 10^4} \times 0.5 = -5\ V$

Ans: The range of out put voltage is from -1V to -5V.

10.5.

The circuit in the figure is a non-inverting amplifier.
The output voltage is

$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_1$$

Given, $R_f = 360\ k\Omega = 3.6 \times 10^5\ \Omega$

$R_1 = 12\ k\Omega = 1.2 \times 10^4\ \Omega$

$V_1 = -0.3\ V.$

$$\therefore V_o = \left(1 + \frac{R_F}{R_1}\right) V_1$$

$$= \left(1 + \frac{3.6 \times 10^5}{1.2 \times 10^4}\right) \times (-0.3)$$

$$= (1 + 30) \times (-0.3)$$

$$= -9.3V$$

Ans: -9.3 V

10.6.

The given circuit resembles a non-inverting amplifier.
The output formula is $V_o = \left(1 + \frac{R_f}{R_1}\right) V_1$

Given, $R_f = 3.6 \times 10^5 \Omega$

$R_1 = 1.2 \times 10^4 \Omega$

$V_o = 2.4 \text{ V}$

Now, $V_o = \left(1 + \frac{R_f}{R_1}\right) V_1$

$$\Rightarrow V_1 = \frac{V_o}{1 + \frac{R_f}{R_1}}$$

$$\cancel{= \frac{2.4}{1 + \frac{360 \times 10^5}{1.2 \times 10^4}}}$$

$$= \frac{2.4}{1 + \frac{3.6 \times 10^5}{1.2 \times 10^4}}$$

$$= \frac{2.4}{31} = 0.07742 \text{ V}$$

$$= 77.42 \text{ mV}$$

Ans: 77.42 mV

10.7.

The network resembles a non-inverting amplifier.

The output voltage is given by

$$V_o = \left(1 + \frac{R_F}{R_1}\right) V_1$$

Given, $R_f = 2 \times 10^5 \, \Omega$

$R_1 = 10 \times 10^3 + R_v$

$V_1 = 0.5 \, V$

Setting R_v to minimum value or 0Ω,

$$R_1 = 10 \times 10^3 + 0 = 10^4 \, \Omega$$

$$\therefore V_o = \left(1 + \frac{2 \times 10^5}{10^4}\right) \times 0.5 = 10.5 \, V$$

Setting R_v to maximum value or $10 \, k\Omega$,

$$R_1 = 10 \times 10^3 + 10 \times 10^3 = 20 \times 10^3$$

$$\therefore V_o = \left(1 + \frac{2 \times 10^5}{20 \times 10^3}\right) \times 0.5 = 5.5 \, V$$

Ans: The output voltage will be in range 5.5 V to 10.5 V.

10.8.

The given circuit resembles a summing amplifier
The formula for output voltage is

$$V_o = -\left(\frac{R_f}{R_1}V_1 + \frac{R_f}{R_2}V_2 + \frac{R_f}{R_3}V_3\right)$$

Given, $R_f = 330 \times 10^3 \Omega$

$R_1 = 33 \times 10^3 \Omega$

$R_2 = 22 \times 10^3 \Omega$

$R_3 = 12 \times 10^3 \Omega$

$V_1 = 0.2 \text{ V}$

$V_2 = -0.5 \text{ V}$

$V_3 = 0.8 \text{ V}$

$$V_o = -\left(\frac{330 \times 10^3}{33 \times 10^3} \times 0.2 + \frac{330 \times 10^3}{22 \times 10^3} \times (-0.5) + \frac{330 \times 10^3}{12 \times 10^3} \times 0.8\right)$$

$$= -(2 - 7.5 + 22)$$

$$\therefore V_o = -16.5 \text{ V}$$

Ans: The output will be -16.5 V.

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10.9.

The given circuit resembles a summing circuit.

The output voltage is given as

$$V_o = -\left(\frac{R_f}{R_1} \times V_1 + \frac{R_f}{R_2} \times V_2 + \frac{R_f}{R_3} \times V_3\right)$$

Given, $R_f = 68 \times 10^3\ \Omega$

$R_1 = 33 \times 10^3\ \Omega$ $V_1 = 0.2\ V$

$R_2 = 22 \times 10^3\ \Omega$ $V_2 = -0.5\ V$

$R_3 = 12 \times 10^3\ \Omega$ $V_3 = 0.8\ V$

$$\therefore V_o = -\left(\frac{68 \times 10^3}{33 \times 10^3} \times 0.2 + \frac{68 \times 10^3}{22 \times 10^3} \times (-0.5) + \frac{68 \times 10^3}{12 \times 10^3} \times 0.8\right)$$

$$= -\left(\frac{68}{165} - \frac{17}{11} + \frac{68}{15}\right)$$

$$= -17/5 = -3.4$$

Ans: The output voltage is ~~$-17/5\ V$.~~ $-3.4\ V$.

10.11.

In the given OP amp, the input terminals have the same voltage. The output is short-circuited.

$$\therefore V_o = V_1$$

$$\Rightarrow V_o = 0.5\ V \quad [\because V_1 = 0.5\ V]$$

Ans: The output voltage is 0.5 V

10.12.

For the first OP-amp the two terminals have same voltage, So, $V_o = V_i$

$$\therefore V_o = 1.5\ V$$

For the second OP-amp, it resembles an inverting amplifier. The formula is

$$V_o = -\left(R_f / R_1\right) \times V_1$$

Given, $R_f = 100 \times 10^3\ \Omega$

$R_1 = 20 \times 10^3\ \Omega \qquad V_1 = 1.5\ V$

$$\therefore V_o = -\left(\frac{100 \times 10^3}{20 \times 10^3}\right) \times (1.5)$$

$$\therefore V_o = -7.5\ V$$

Ans: The output voltage is ~~7.5 V~~ -7.5 V.

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10.13.

For the first OPamp, it resembles a unity follower.

The output voltage is $V_o = V_1$

Given, $V_1 = 0.2\,V$

$\therefore V_o = 0.2\,V$

For the second OP amp, the configuration resembles an inverting amplifier. The output is

$$V_2 = -\frac{R_f}{R_1} \times V_1$$

Given, $R_f = 200 \times 10^3\,\Omega$

$R_1 = 20 \times 10^3\,\Omega$ $\quad V_1 = 0.2\,V$

$$\therefore V_2 = -\frac{200 \times 10^3}{20 \times 10^3} \times 0.2$$

$$\therefore V_2 = -2\,V$$

~~So,~~ Ans: The output voltage is $-2\,V$.

For the third OP-amp, $V_3 = \left(1 + \frac{R_f}{R_1}\right) \times V_1$ [Non-inverting Amplifier]

$$= \left(1 + \frac{200 \times 10^3}{10 \times 10^3}\right) \times (0.2)$$

$$\therefore V_3 = 4.2\,V$$

Ans: 4.2 V

10.14.

The first OP amp resembles ~~as~~ an inverting amplifier. The output voltage is given as,

$$V_{o_1} = \left(1 + \frac{R_f}{R_1}\right) V_1$$

Given, $R_f = 400 \times 10^3 \, \Omega$

$R_1 = 20 \times 10^3 \, \Omega$

$V_1 = 0.1 \, V$

$$\text{So, } V_{o_1} = \left(1 + \frac{400 \times 10^3}{20 \times 10^3}\right)(0.1)$$

$$= 2.1 \, V$$

The second OP-amp resembles a unity follower. The output voltage is

$$V_{o_2} = V_1$$

Given, $V_1 = 0.1 \, V$

So, $V_{o_2} = 0.1 \, V$

For the third OP-amp, it resembles a summing amplifier. The output formula is

$$V_o = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2\right)$$

Given, $R_f = 100 \times 10^3 \, \Omega$

$R_1 = 20 \times 10^3 \, \Omega$

$R_2 = 10 \times 10^3 \, \Omega$

$V_1 = 2.1 \, V$

$V_2 = 0.1 \, V$

$$\therefore V_o = -\left(\frac{100\times10^3}{20\times10^3}\times 2.1 + \frac{100\times10^3}{10\times10^3}\times 0.1\right)$$

$$= -11.5\text{ V}$$

Ans: The output voltage is -11.5 V.

10.15.

The first OP amp is a summing amplifier.

The output is

$$V_o = -\left(\frac{R_f}{R_1}\times V_1 + \frac{R_f}{R_2}\times V_2\right)$$

Given,

$R_f = 600\times10^3\ \Omega$

$R_1 = 15\times10^3\ \Omega$

$R_2 = 30\times10^3\ \Omega$

$V_1 = 0.025$ V

$V_2 = -0.020$ V

$$V_{o_1} = -\left(\frac{600\times10^3}{15\times10^3}\times 0.025 + \frac{600\times10^3}{30\times10^3}\times(-0.02)\right)$$

$$= -600\text{ mV}$$

Second OP amp resembles a unity follower.

So, $V_{o_2} = V_2 = -20$ mV

The third OP-amp is also a summing amplifier.

Given,

$R_f = 300\times10^3\ \Omega$

$R_1 = 30\times10^3\ \Omega$

$R_2 = 15\times10^3\ \Omega$

$V_{o_1} = -0.6$ V

$V_{o_2} = 0.02$ V

$$\therefore V_o = -\left(\frac{300\times10^3}{30\times10^3}\times(-0.6)+\frac{300\times10^3}{15\times10^3}\times(-0.02)\right)$$

$$\therefore V_o = -6.4\,V$$

Ans: The output valtage is $-6.4\,V$.

10.23:

The logarithmic value of CMRR is

$$CMRR = 20\log_{10}\frac{A_d}{A_c}$$

Here, $A_d = \frac{V_o}{V_d}$ and $A_c = \frac{V_o}{V_c}$

Given, $V_o = 0.12\ V$

$V_d = 0.001\,V$

$$\therefore A_d = \frac{0.12}{0.001} = 120\ V$$

And, $A_c = V_o/V_c$ where, $V_o = 20\times10^{-6}\ V$

$V_c = 0.001\ V$

$$\therefore A_c = \frac{20\times10^{-6}}{0.001} = 0.02\ V$$

$$\text{So, } CMRR = 20\log_{10}\frac{120}{0.02}$$

$$= 75.56\,dB$$

Ans: The value for CMRR is $75.56\,dB$.

10.24

(a) We know, $V_o = A_d V_d \left(1 + \frac{1}{CMRR} \times \frac{V_c}{V_d}\right)$

Here, $V_d = V_{i_1} - V_{i_2}$

$= 200 \times 10^{-6} - 140 \times 10^{-6}$

$= 60 \times 10^{-6} V$

And, $V_c = \frac{V_{i_1} + V_{i_2}}{2} = \frac{200 \times 10^{-6} + 140 \times 10^{-6}}{2}$

$= 170 \times 10^{-6} V$

Given, $CMRR = 200$

$A_d = 6000$

$\therefore V_o = 6000 (60 \times 10^{-6}) \left(1 + \frac{1}{200} \times \frac{170 \times 10^{-6}}{60 \times 10^{-6}}\right)$

$\therefore V_o = 365.1 \times 10^{-3} V$

(b)

Again, putting $CMRR = 10^5$

$V_o = 6000 \times (60 \times 10^{-6}) \times \left(1 + \frac{1}{10^5} \times \frac{170 \times 10^{-6}}{60 \times 10^{-6}}\right)$

$\therefore V_o = 360.01 \times 10^{-3} V$

Ans: ~~for (a) V₀ = 365.1x~~

for (a), output voltage is 365.1 mV

for (b), output voltage is 360.01 mV

11.1

The given circuit resembles an inverting amplifier.

$$V_o = -\frac{R_f}{R_1} \times V_1$$

Given, $R_f = 180 \times 10^3 \,\Omega$

$R_1 = 3600\,\Omega = 3.6 \times 10^3\,\Omega$

$V_1 = 3.5 \times 10^{-3}$ V rms

$$\therefore V_o = -\frac{180 \times 10^3}{3.6 \times 10^3} \times 3.5 \times 10^{-3}$$

$$= -175 \text{ mV rms}$$

Ans: The output voltage will be -175 mV rms.

11.2

The output voltage V_o for the given non-inverting amplifier is

$$V_o = \left(1 + \frac{R_f}{R_1}\right) V_1$$

Given, $R_f = 750 \times 10^3\,\Omega$

$R_1 = 36 \times 10^3\,\Omega$ $\quad V_1 = 150 \times 10^{-3}$ V

$$\therefore V_o = \left(1 + \frac{750 \times 10^3}{36 \times 10^3}\right) \times (150 \times 10^{-3}) = 3.275 \text{ V rms}$$

Ans: The output voltage will be 3.275 V rms.

11.3

The first OPamp is in non-inverting mode and the next two are in inverting amplifier mode.

For non-inverting amplifier,

$$A_{v_1} = \left(1+\frac{R_f}{R_1}\right) V_1$$

and for inverting amplifier,

$$A_{v_2} = \left(-\frac{R_f}{R_1}\right) \times V_1$$

So, the output voltage is

$$V_o = A_{v_1} \times A_{v_2} \times A_{v_3} \times V_i$$

$$= \left(1+\frac{510\times10^3}{18\times10^3}\right)\left(\frac{-680\times10^3}{22\times10^3}\right)\left(\frac{-750\times10^3}{33\times10^3}\right)\left(20\times10^{-6}\right)$$

$$= 412\, mV$$

Ans: The output voltage is 412 mV

11·6

The output valtage V_o of the summing amplifier is

$$V_o = -\left(\frac{R_f}{R_1} \times V_1 + \frac{R_F}{R_2} \times V_2\right)$$

Given, $R_f = 4.7 \times 10^5 \Omega$ $\quad V_1 = 40 \times 10^{-3} V$

$R_1 = 4.7 \times 10^4 \Omega$ $\quad V_2 = 20 \times 10^{-3} V$

$R_2 = 1.2 \times 10^4 \Omega$

$$\therefore V_o = -\left(\frac{4.7 \times 10^5}{4.7 \times 10^4} \times 40 \times 10^{-3} + \frac{4.7 \times 10^5}{1.2 \times 10^4} \times 20 \times 10^{-3}\right)$$

$$= -1.18 V$$

Ans: The autput valtage is -1.18 V.

11·7

The given circuit resembles a subtractor amplifier.

The autput valtage is

$$V_o = \frac{R_3}{R_1 + R_3} \times \frac{R_2 + R_4}{R_2} V_1 - \frac{R_4}{R_2} V_2$$

$$= \frac{10 \times 10^3}{10 \times 10^3 + 10 \times 10^3} \times \frac{150 \times 10^3 + 300 \times 10^3}{150 \times 10^3} \times 1$$

$$- \frac{300 \times 10^3}{150 \times 10^3} \times 2$$

$$= 0.5 \times 3 \times 1 - 2 \times 2$$

$$= -2.5 V$$

Ans: The autput valtage is -2.5 V

~~10.8~~ 11·8

The given circuit resembles a subtractor amplifier.

The output voltage is

$$V_o = -\left(\frac{R_f}{R_3}\left(-\frac{R_f}{R_1} \times V_1\right) + \frac{R_f}{R_2} V_2\right)$$

Given, $R_f = 3.3 \times 10^5 \Omega$

$R_3 = 3.3 \times 10^4 \Omega$ $\quad V_1 = 12 \times 10^{-3}\ V$

$R_2 = 4.7 \times 10^4 \Omega$ $\quad V_2 = 18 \times 10^{-3}\ V$

$R_1 = 4.7 \times 10^4 \Omega$

$$\therefore V_o = -\left[\frac{-3.3 \times 10^5}{3.3 \times 10^4} \times (12 \times 10^{-3})\left(\frac{4.7 \times 10^5}{4.7 \times 10^4}\right) + \frac{4.7 \times 10^5}{4.7 \times 10^4}(18 \times 10^{-3})\right]$$

$$= -[-1.2 + 0.18]$$

$$= 1.02\ V$$

Ans:

So, the output voltage is 1.02 V.

11.13

The output current can be written as

$$V_o = -\frac{R_F}{R_1} \times V_1 \quad \text{[For inverting amplifier]}$$

$$\Rightarrow I_o = \frac{R_F}{R_1} \times V_1 \left(\frac{1}{R_o}\right) \quad [\because V_o = I_o R_o]$$

Given, $R_F = 100 \times 10^3 \, \Omega$ $\quad V_1 = 10 \times 10^{-3} \, V$

$R_1 = 200 \times 10^3 \, \Omega$

$R_o = 10 \, \Omega$

$$\therefore I_o = \frac{100 \times 10^3}{200 \times 10^3} \times \frac{1}{10} \times 10 \times 10^{-3}$$

$$= 0.5 \, mA$$

Ans: The output current is 0.5 mA

11.14

The output voltage for the amplifier is

$$V_o = \left(1 + \frac{2R}{R_P}\right)(V_2 - V_1)$$

Given, $R = 5000 \, \Omega$ $\quad V_2 = 1 \, V$

$R_P = 1000 \, \Omega$ $\quad V_1 = 3 \, V$

$$\therefore V_o = \left(1 + \frac{2 \times 5000}{1000}\right)(1 - 3)$$

$$= -22 \, V$$

Ans: The output voltage is $-22V$.