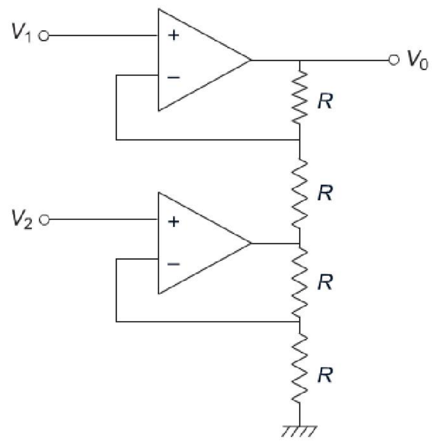
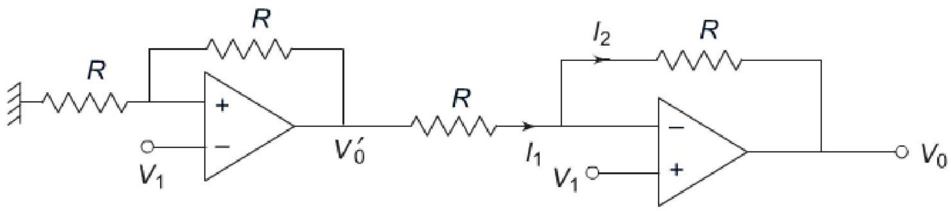
Solved Problems on Op-Amp

Q1:

Show that $V_0 = 2(V_1 - V_2)$.



The circuit can be drawn as given below.



$$\frac{V_0'}{V_2} = \text{Gain} = \frac{R_1 + R_2}{R_1} = \frac{2R}{R} = 2$$

$$V_0' = 2V_2$$

$$\frac{V_0' - V_1}{R} = \frac{V_1 - V_0}{R} = 2V_1 = -V_0' - V_0$$

$$\Rightarrow \qquad 2V_1 = (V_0' + V_0)$$

$$2V_1 = 2V_2 + V_0$$

$$\Rightarrow \qquad V_0 = 2(V_1 - V_2)$$

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Q2:

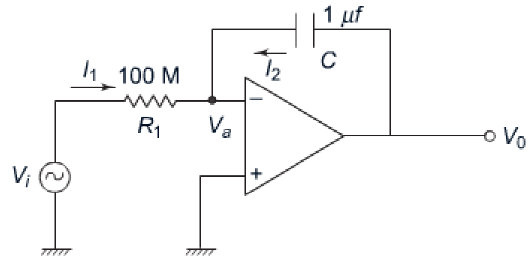
For an op-amp integrator with $R = 100\ M\Omega$ and $C = 1\ \mu F$, an input of $2 \sin 1000\ t$ is applied. Determine the value of v_0.

Given — *Required;* V_0.

$v_i = 2 \sin 1000\ t$ — $v_o = 20\ \mu v$

$R = 100\ M\Omega$

$C = 1\ \mu F$



$$I_1 + I_2 = 0$$

$$I_1 = -I_2$$

$$I_2 = \frac{V_0 - V_a}{Z_f}$$

$$I_2 = \frac{cdV_0}{dt}$$

$$I_1 = -I_2$$

V_i = Input voltage

$$\frac{v_i}{R} = -\frac{cdV_0}{dt}$$

V_o = Output voltage

$$I_1 = \frac{v_i - v_a}{R},\ V_0 = 0$$

V_a = Voltage at the inverting terminal

$$I_1 = \frac{v_i}{R}$$

= 0 V $\because$ Non-inverting terminal is grounded.

$$\frac{v_i}{R} = -c\frac{dV_0}{dt}$$

$$\Rightarrow \quad -\frac{v_i}{RC} = \frac{dv_0}{dt} = \int \frac{dV_0}{dt} - \int \frac{V_i}{RC} dt$$

$$\Rightarrow \quad v_0 = -\frac{1}{RC}\int_0^1 V_t dt$$

$$v_0 = -\frac{1}{RC}\int_0^1 V_i dt$$

$$= \frac{-1}{(100 \times 10^6)(10^{-6})}\int_0^1 2 \sin 1000t\ dt$$

$$= \frac{-1}{100}\int 2 \sin 1000t\ dt$$

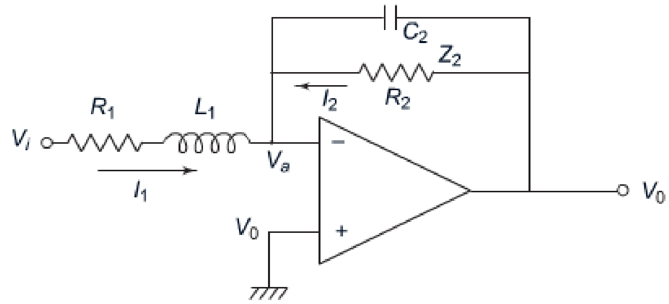
$$= \frac{-1}{50}\int \sin 1000\ t\ dt$$

$$= \frac{-1}{(50)(1000)} \cos 1000\ t$$

$$|v_0| = \frac{1}{50000} = 20\ \mu V$$

Q3: (assignment Q 2)

An op-amp has R_1 and L_1 in series on the input side, connected to the inverting terminal and R_2, C_2 connected in parallel in the feedback path. The non-inverting terminal is grounded. Derive the transfer function.



Hint:

$$I_1 + I_2 = 0 \Rightarrow I_1 = -I_2$$

$$Z_1 = R_1 + j\omega L_1 \qquad I_1 = \frac{v_i}{Z_1} = \frac{v_i}{R_1 + jwL_1}$$

$$Z_2 =- \frac{R_2 . \dfrac{1}{j\omega c_2}}{R_2 + \dfrac{1}{j\omega c_2}} \qquad I_2 = \frac{v_0}{Z_2} = \frac{v_0}{\dfrac{R_2}{fwR_2 c_2 + 1}}$$

$$Z_2 = \frac{\dfrac{R_2 / j\omega c_2}{jR_2 c_2 \omega + 1}}{j\omega c_2} \qquad I_2 = v_0 \, \frac{(iwR_2 c_2 + 1)}{R_2}$$

$$I_1 = -I_2$$

And A_v = Vo/Vi

Q4: (Assignment Q 3)

Q3: In figure 3, find out the expression for current in R2.

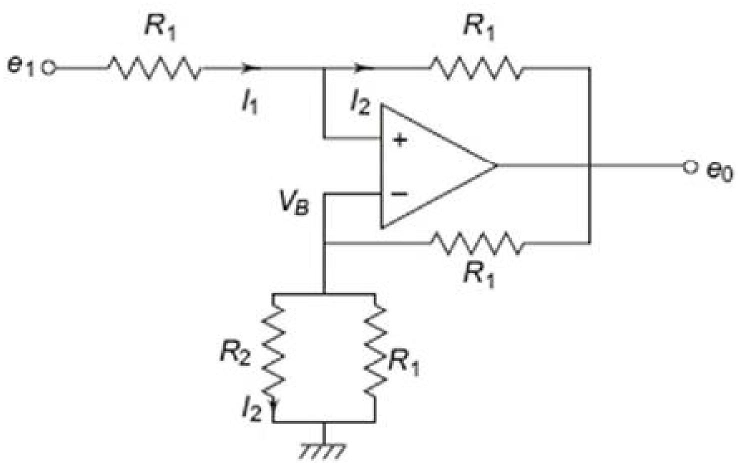


Figure 3.

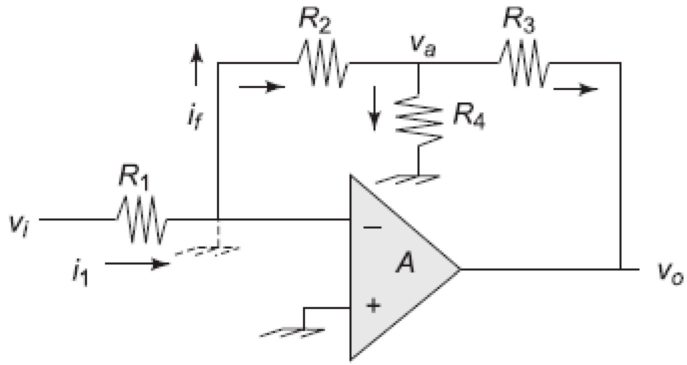
Hint:

$$V_B = \frac{R_1 R_2}{R_1 + R_2} \cdot e_0/R_1 + \frac{R_1 R_2}{R_1 + R_2} \Rightarrow \frac{\dfrac{e_0 R_1 R_2}{R_1 + R_2}}{R_1\left(1 + \dfrac{R_2}{R_1 + R_2}\right)}$$

$$V_B = e_0 \frac{R_2}{R_1 + 2R_2}$$

Then apply KCL to get e_1 and VB. Then current through R2 can be calculated.

Q 5: find the value of Closed loop gain in the amplifier shown below



Ans:

$$\frac{v_i}{R_1} = -\frac{v_a}{R_2}$$

$$v_a = -\frac{R_2}{R_1}v_i$$

$$\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}\right)v_a = \frac{v_o}{R_3}+\frac{0}{R_2}$$

$$v_o = \left(1+\frac{R_3}{R_2}+\frac{R_3}{R_4}\right)v_a$$

$$= -\left(1+\frac{R_3}{R_2}+\frac{R_3}{R_4}\right)\frac{R_2}{R_1}v_i$$

$$\frac{v_O}{v_i} = -\frac{R_F}{R_1} = -\frac{R_2+R_3+\dfrac{R_2R_3}{R_4}}{R_1}$$

If $R_1 = R_2 = R_3 = 1$ K, $R_4 = 10\ \Omega$,
then $R_F = 2$ K + 1 M/10 = 2 K + 100 K
= 102 K, voltage-gain

$$= A_v = \frac{v_o}{v_i} = -\frac{102\text{ K}}{1\text{ K}} = -102$$