Lecture 5

Op Amp – Part 3

Inverting Adder

Consider v_1 first, and deactivate other (v_2, v_3, v_4) sources.

It is nothing but a non-inverting amplifier.

So, $v_{o1} = -\frac{R_f}{R_1}v_1$

Similarly, if we active one source and deactivate others, we will get:

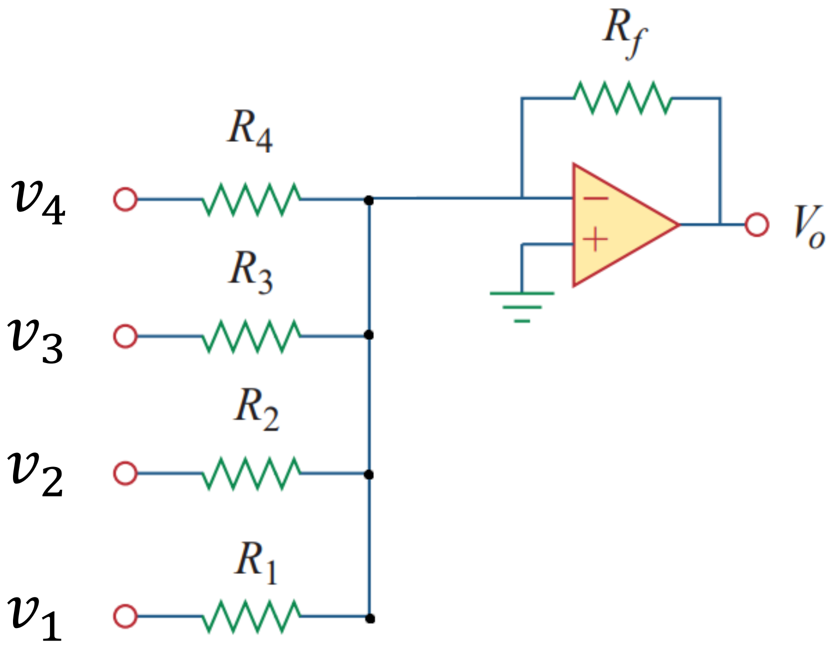
$v_{o2} = -\frac{R_f}{R_2}v_2$, $v_{o3} = -\frac{R_f}{R_3}v_3$, $v_{o4} = -\frac{R_f}{R_4}v_4$

Now, using **superposition principle**,

v_o=v_{o1}+v_{o2}+v_{o3}+v_{o4}

So, $v_o = -\frac{R_f}{R_1}v_1 - \frac{R_f}{R_2}v_2 - \frac{R_f}{R_3}v_3 - \frac{R_f}{R_4}v_4$

Or, $v_o = -(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3 + \frac{R_f}{R_4}v_4)$



We can use this circuit to add any 'n' number of inputs!

Example

Implement the following function using op-amps:

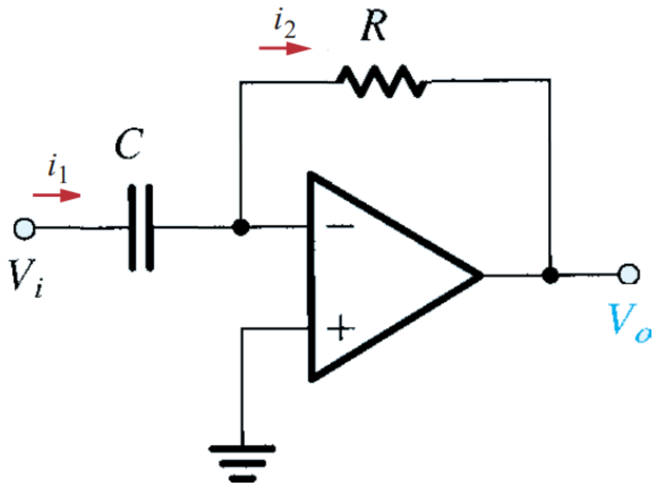
$$v_0 = -(v_1 + 0 \cdot 5v_2 + \boldsymbol{v_3})$$

Solution:

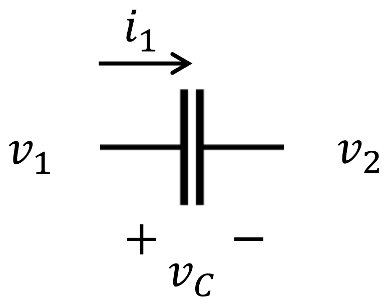
Here, $R_f/R_1 = 1$, $R_f/R_2 = 0.5$, $R_f/R_3 = 1$

If $R_f = 1\ \text{k}\Omega$, $R_2 = 2\ \text{k}\Omega$, $R_3 = 1\ \text{k}\Omega$

Op Amp as Differentiator



Review – Capacitor



$$i_1 = \mathrm{C}\frac{dv_C}{dt} = C\frac{d(v_1 - v_2)}{dt}$$

Since v_+ is connected to ground, $v_+ = 0V$

Since there is negative feedback, from virtual short, $v_- = v_+ = 0V$

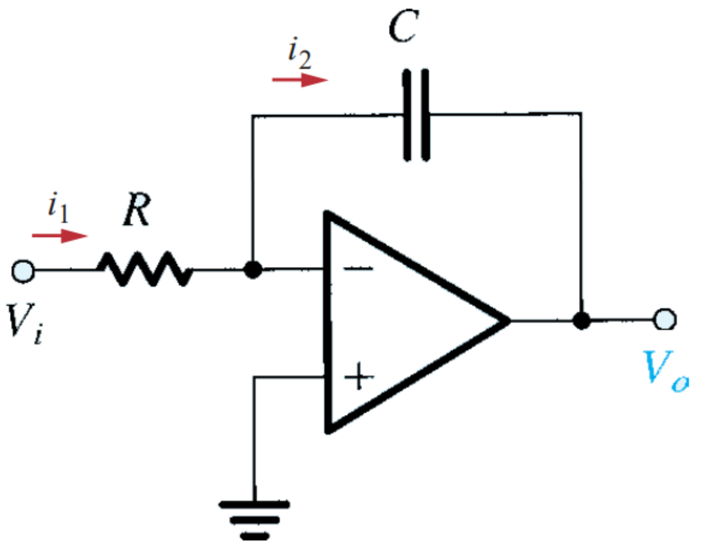
For the capacitor C, $\Rightarrow i_1 = \mathrm{C}\frac{dv_C}{dt} = C\frac{d(v_i - v_-)}{dt} = C\frac{dv_i}{dt}$

From Ohm's law for $R \Rightarrow i_2 = \frac{v_- - v_0}{R} = -\frac{v_o}{R}$

Since ideal op-amp, $i_- = i_+ = 0$, so $i_1 = i_2$

$$\Rightarrow -\frac{v_o}{R} = C\frac{dv_i}{dt} \Rightarrow v_o = -RC\frac{dv_i}{dt} \text{ [Ans.]}$$

Op Amp as Integrator



Since v_+ is connected to ground, $v_+ = 0V$

Since there is negative feedback, from virtual short, $v_- = v_+ = 0V$

From Ohm's law for $R \Rightarrow i_1 = \frac{v_i - v_-}{R} = \frac{v_i}{R}$

For the capacitor C, $\Rightarrow i_2 = \mathrm{C}\frac{dv_C}{dt} = C\frac{d(v_- - v_o)}{dt} = -C\frac{dv_o}{dt}$

Since ideal op-amp, $i_- = i_+ = 0$, so $i_1 = i_2$

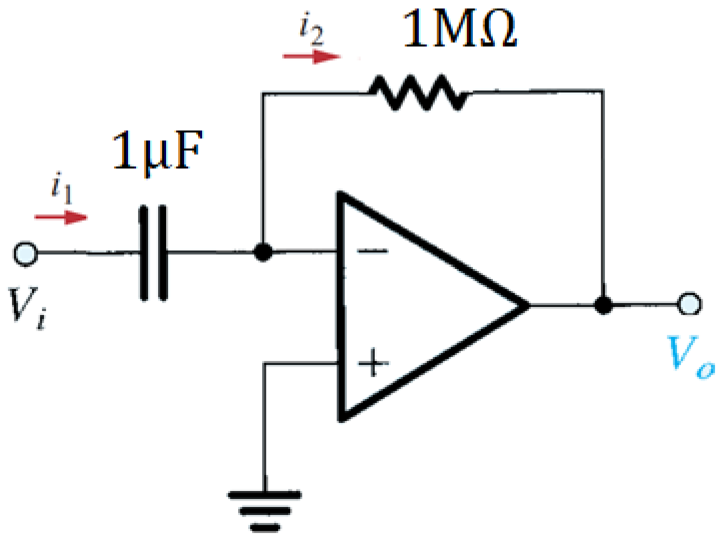
$$\Rightarrow \frac{v_i}{R} = -C\frac{dv_o}{dt}$$

$$= -RC\frac{dv_o}{dt}$$

$$\Rightarrow v_o = -\frac{1}{RC}\int v_i \, dt$$

Example

Observe the following Figure. If v_i = 5sin6t, Find the value of $\boldsymbol{v_0}$.



Solution:

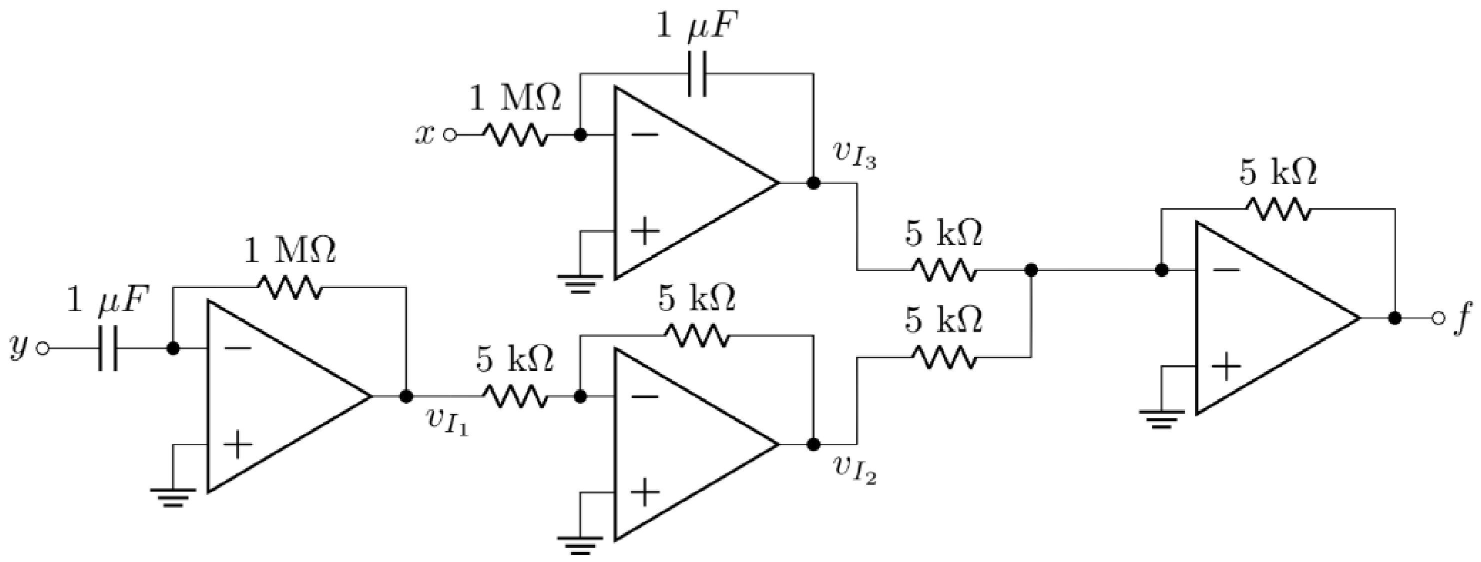
This is a **differentiator**.

$$So, v_o = -RC\frac{dv_i}{dt} = -1 \times 10^6 \times 1 \times 10^{-6} \times \frac{d(5\text{sin6t})}{dt}$$

$$\Rightarrow v_o = -1 \times (5 \times 6cos6t) = -30cos6t \text{ [Ans.]}$$

Example

Analyze the circuit below to **find** an expression of f in terms of inputs x and y.



Solution:

$$\mathrm{v_{I1}} = -\frac{\mathrm{dy}}{\mathrm{dt}}\,;\mathrm{v_{I3}} = -\frac{1}{\mathrm{RC}}\int \mathrm{x\,dt}\,;\mathrm{v_{I2}} = -\mathrm{v_{I1}} = \frac{\mathrm{dy}}{\mathrm{dt}}\,;\ \mathrm{f} = -(\mathrm{v_{I2}} + \mathrm{v_{I3}})$$