B.E. Theory Project

IMT2019508
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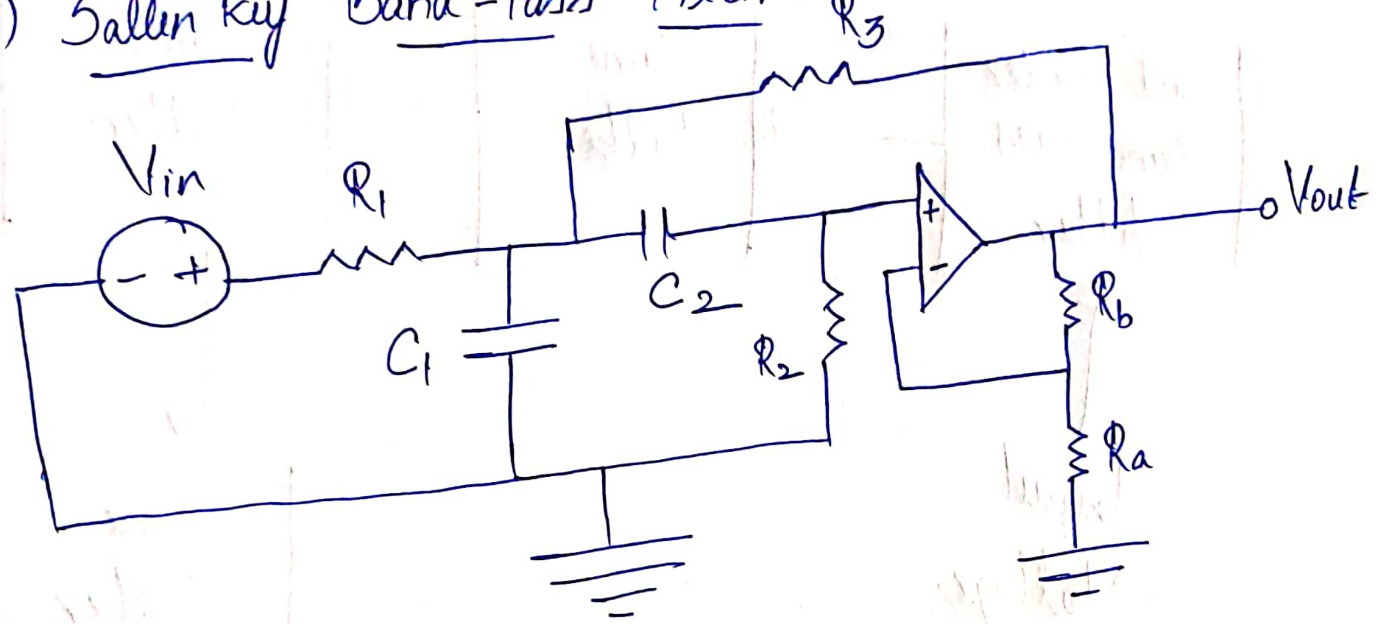
1.)

(a) Sallen key Band-Pass Filter:



Component Values:

$R_1 = 1406.451\ \Omega$

$C_1 = 1\ \mu F$

$C_2 = 1\ \mu F$

$R_3 = 703.22\ \Omega$.

$R_b = 100\ \Omega$

$R_a = 100\ \Omega$.

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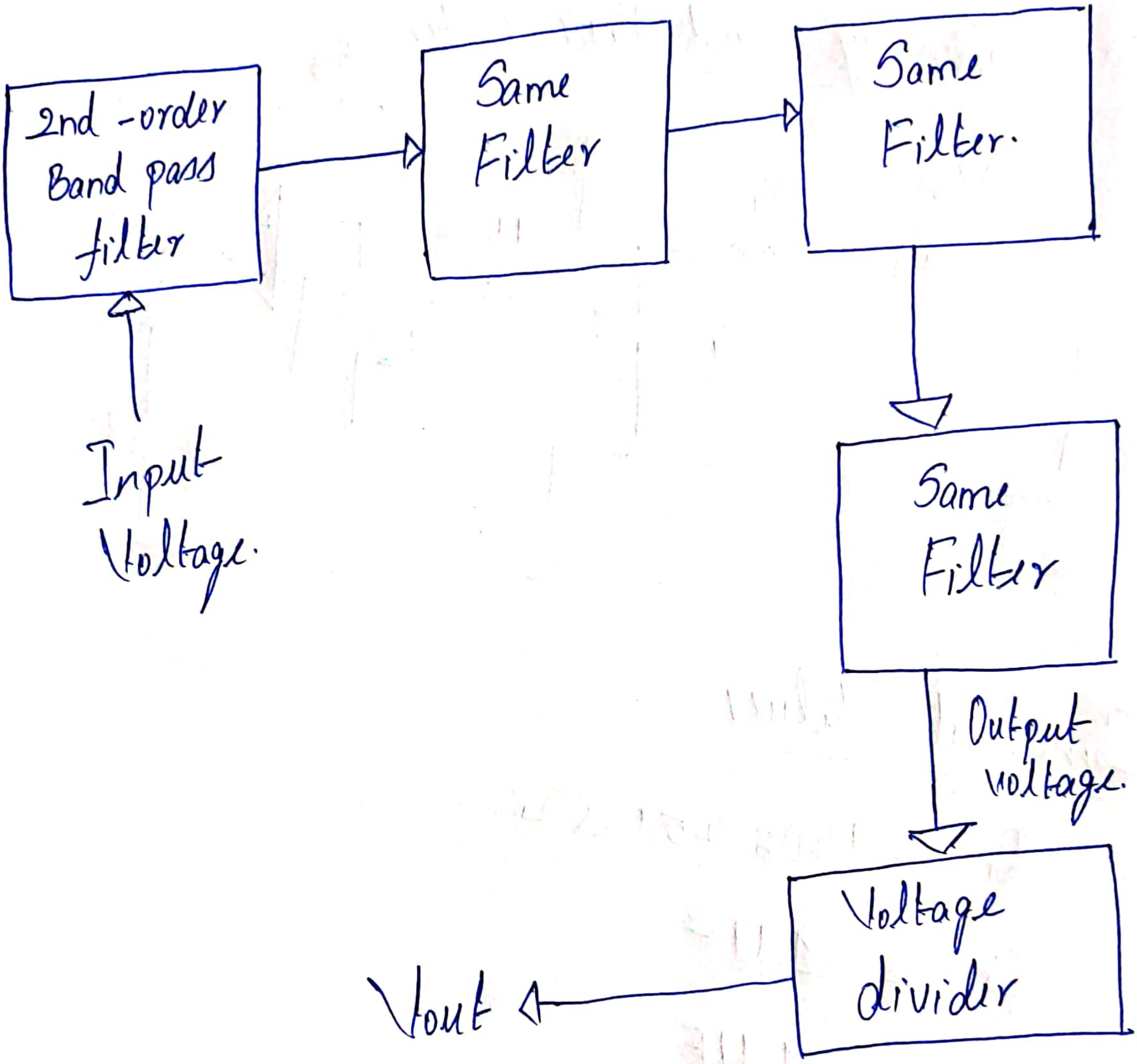
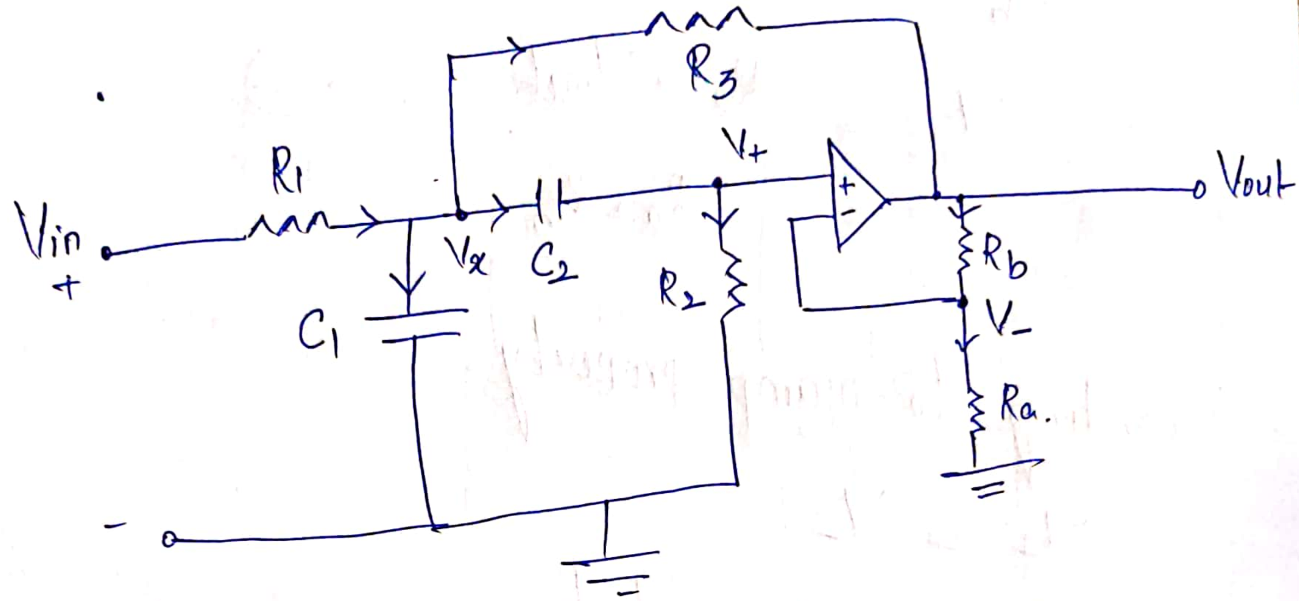
(b) Block diagram showing cascaded stages:



c) <u>Transfer Function of the filter:</u>



Now converting the circuit to frequency domain,

$$Z_C = 1/sC.$$

Now Applying KCL at V_x,

$$\frac{V_{in} - V_x}{R_1} = \frac{V_x - 0}{(1/sC_1)} + \frac{V_x - V_+}{1/sC_2} + \frac{V_x - V_{out}}{R_3}. \longrightarrow (1)$$

~~Acc~~ or Applying KCL at 'V_-',

$$\frac{V_{out} - V_-}{R_b} = \frac{V_-}{R_a}$$

$$\Rightarrow \frac{V_{out}}{R_b} = V_-\left(\frac{1}{R_a} + \frac{1}{R_b}\right)$$

$$\Rightarrow V_- = \frac{R_a \times V_{out}}{R_a + R_b} \longrightarrow (2).$$

According to opamp property.

$$V_+ = V_-$$

$$\Rightarrow V_+ = \frac{R_a \times V_{out}}{R_a + R_b}.$$

Applying KCL at V_+,

$$\frac{V_x - V_+}{1/SC_2} = \frac{V_+ - 0}{R_2}$$

$$\Rightarrow SC_2 V_x = \frac{V_+}{R_2} + SC_2 V_+$$

$$\Rightarrow SC_2 V_x = V_+\left(\frac{1}{R_2} + SC_2\right).$$

$$\Rightarrow V_x = \left(\frac{R_a \times V_{out}}{R_b + R_a}\right)\left(\frac{1}{SC_2 R_2} + 1\right) \longrightarrow (3).$$

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Now in 1,

$$\frac{V_{in} - V_x}{R_1} = SC_1 V_x + \cancel{SC_2 V_x}\, \frac{V_+}{R_2} + \frac{V_x - V_{out}}{R_3}.$$

$$\Rightarrow \frac{V_{in} - \left(\frac{R_a \times V_{out}}{R_b + R_a}\right)\left(\frac{1 + SC_2R_2}{SC_2R_2}\right)}{R_1}$$

$$= \cancel{S}C_1 \left(\frac{R_a \times V_{out}}{R_b + R_a}\right)\left(\frac{1 + SC_2R_2}{\cancel{S}C_2R_2}\right)$$

$$+ \left(\frac{R_a \times V_{out}}{R_b + R_a}\right) \cdot \frac{1}{R_2}$$

$$+ \frac{\left(\frac{R_a \times V_{out}}{R_b + R_a}\right)\left(\frac{1 + SC_2R_2}{SC_2R_2}\right) - V_{out}}{R_3}.$$

$$\Rightarrow \frac{SC_2R_2R_bV_{in} + SC_2R_2R_aV_{in} - R_aV_{out} - R_aV_{out}SC_2R_2}{R_1(R_b+R_a)(SC_2R_2)}$$

$$= \frac{(R_aV_{out} + R_aV_{out}SC_2R_2)C_1}{(R_b+R_a)C_2R_2} + \frac{R_aV_{out}}{R_2(R_b+R_a)}$$

$$+ \frac{R_aV_{out} + R_aV_{out}SC_2R_2 - R_bV_{out}SC_2R_2 - R_aV_{out}SC_2R_2}{R_3(R_b+R_a)(SC_2R_2)}$$

$$\Rightarrow \frac{C_1R_aV_{out} + C_1R_aV_{out}SC_2R_2 + C_2R_aV_{out}}{C_2R_2(R_b+R_a)}$$

$$+ \frac{R_aV_{out} - R_bV_{out}SC_2R_2}{SC_2R_2R_3(R_b+R_a)}.$$

$$\Rightarrow \left(\frac{R_a+R_b}{R_a}\right)\frac{s V_{in}}{R_1 C_1} = \frac{V_{out}\left[R_1R_3R_2C_1C_2s^2 + R_3R_2C_2s + R_1R_3C_1s - \frac{R_b}{R_a}R_1R_2C_2s + R_1 + R_3\right]}{R_1R_2R_3C_1C_2}$$

$$\Rightarrow \frac{V_{out}}{V_{in}} = \frac{\left(\frac{R_a+R_b}{R_a}\right) s R_2 R_3 C_2}{R_1R_2R_3C_1C_2s^2 + s\left(R_3R_2C_2 + R_1R_3C_2 - C_2\frac{R_bR_1R_2}{R_a}\right) + R_1 + R_3} \longrightarrow (5)$$

Multiplying and dividing (5) by $R_1 R_2 R_3 C_1 C_2$.

$$\frac{V_{out}}{V_{in}} = H(s)$$

$$= \frac{\left(\frac{R_a+R_b}{R_a}\right)\frac{s}{R_1 C_1}}{s^2+\left(\frac{1}{R_1 C_1}+\frac{1}{R_2 C_1}+\frac{1}{R_2 C_2}-\frac{R_b}{R_a R_3 C_1}\right)s+\frac{R_1+R_3}{R_1 R_3 R_2 C_1 C_2}}$$