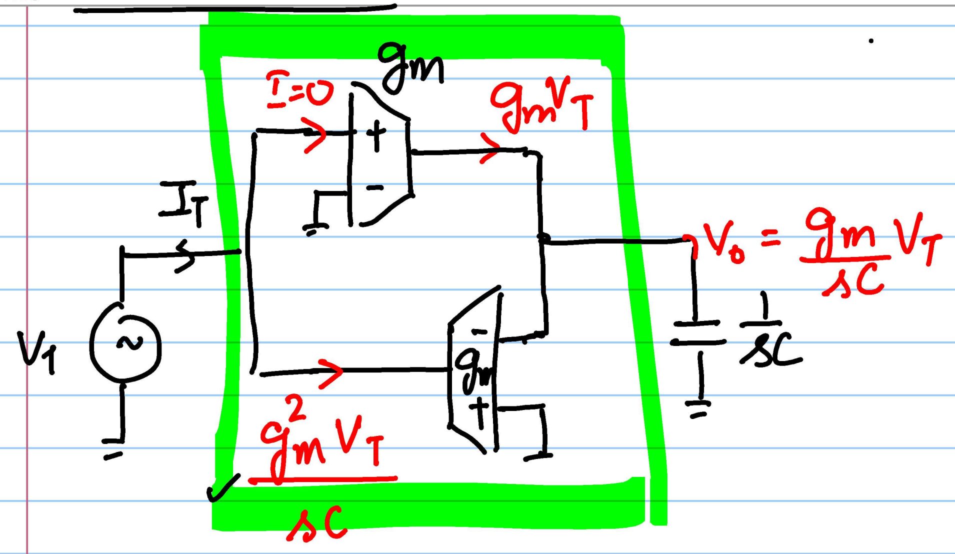
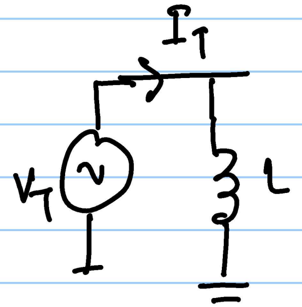
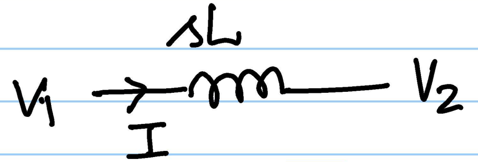
Note Title

lecture # 39

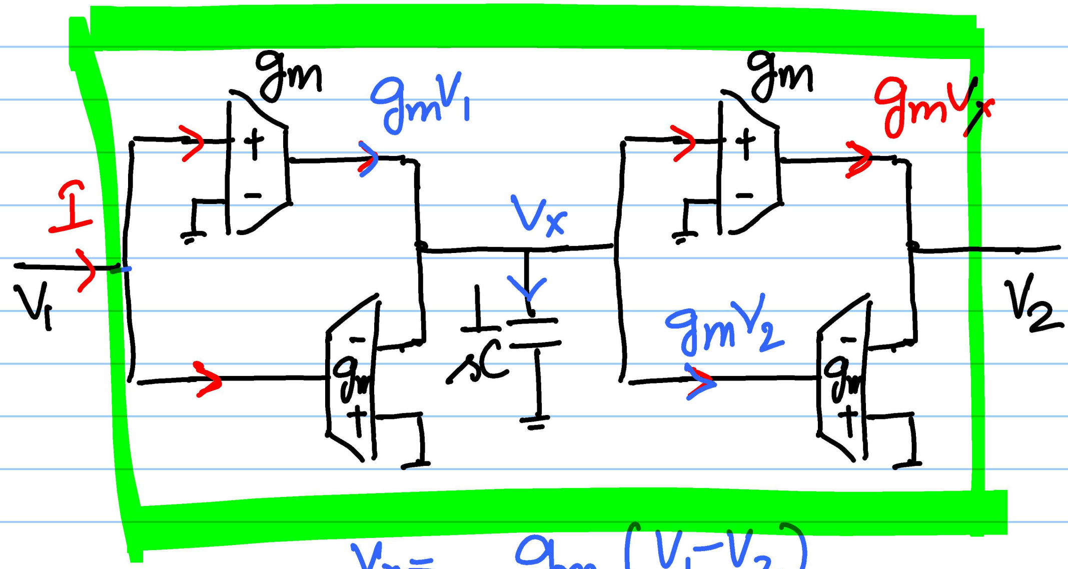


$$\frac{V_T}{I_T} = s\left(\frac{C}{g_m^2}\right) = sL$$





$$I = \frac{V_1 - V_2}{sL}$$

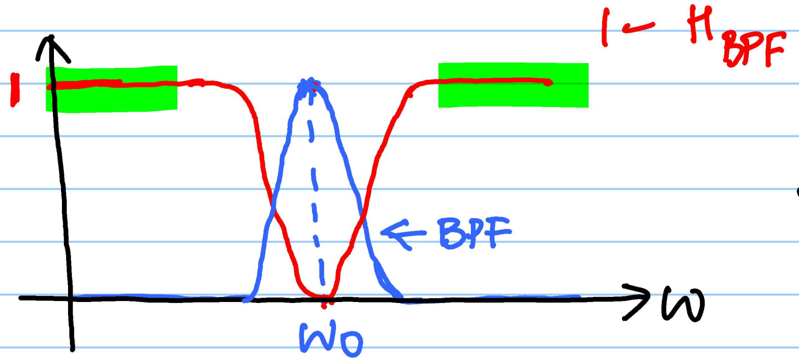


$$V_x = \frac{g_m (V_1 - V_2)}{sC}$$

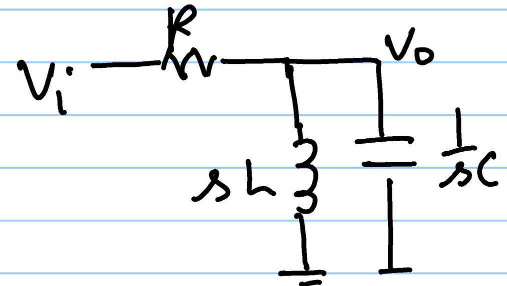
$$I = \frac{g_m^2 (V_1 - V_2)}{sC} = \frac{V_1 - V_2}{s(C/g_m^2)}$$

$$= \frac{V_1 - V_2}{sL}$$

BandReject filter (BRF)

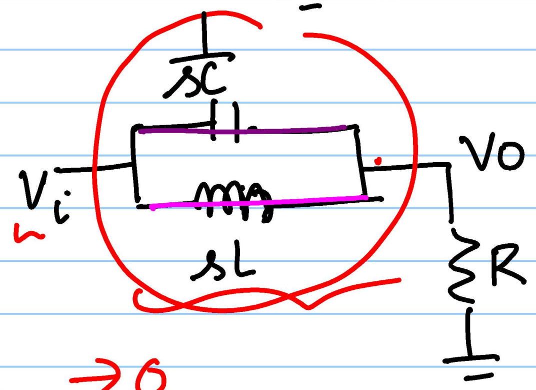


$H_{BRF} = 1 - H_{BPF}$ ✓



$$\frac{V_o}{V_i} = \frac{s/\omega_0 Q_p}{\frac{s^2}{\omega_0^2} + \frac{s}{\omega_0 Q_p} + 1}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}$$



@ ω_0: $sL \parallel \frac{1}{sC} = \frac{sL}{1+s^2LC} \to \infty$

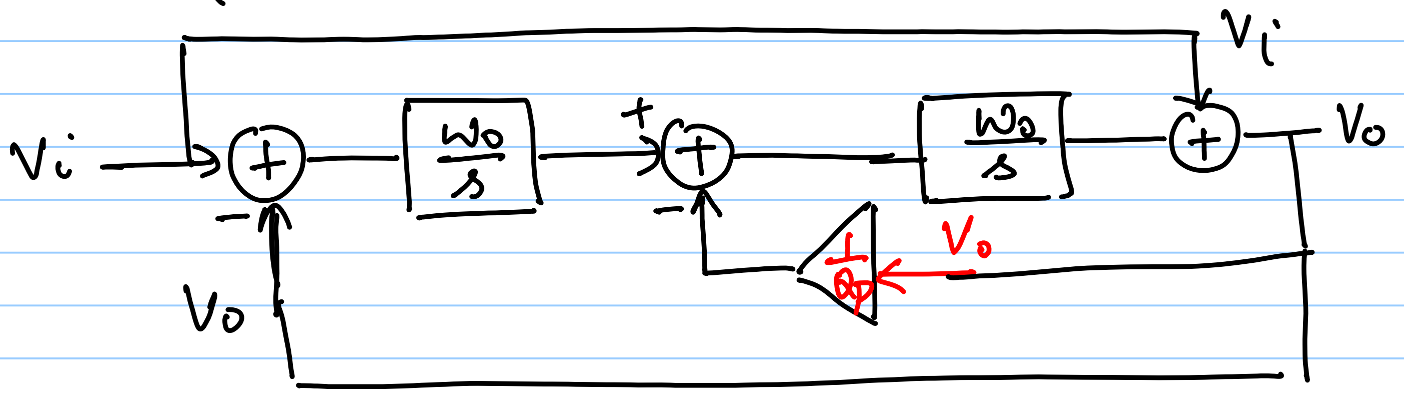
$$\frac{V_o}{V_i} = \frac{R}{R + \underbrace{\left(sL \parallel \frac{1}{sC}\right)}_{\to \infty}} \to 0$$

$$H_{BRF} = 1 - H_{BPF} = 1 - \frac{s/\omega_0 Q_p}{\frac{s^2}{\omega_0^2} + \frac{s}{\omega_0 Q_p} + 1} = \frac{1 + s^2/\omega_0^2}{1 + \frac{s}{\omega_0 Q_p} + \frac{s^2}{\omega_0^2}}$$

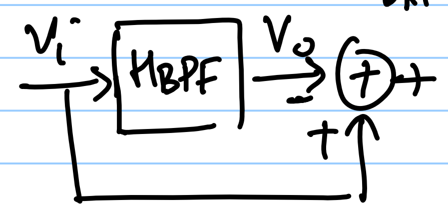
$$\frac{V_o}{V_i} = \frac{1 + s^2/\omega_0^2}{1 + \frac{s^2}{\omega_0^2} + \frac{s}{\omega_0 Q_p}}$$

$$V_o\left(1 + \frac{\omega_0}{s Q_p} + \frac{\omega_0^2}{s^2}\right) = V_i\left(\frac{\omega_0^2}{s^2} + 1\right)$$

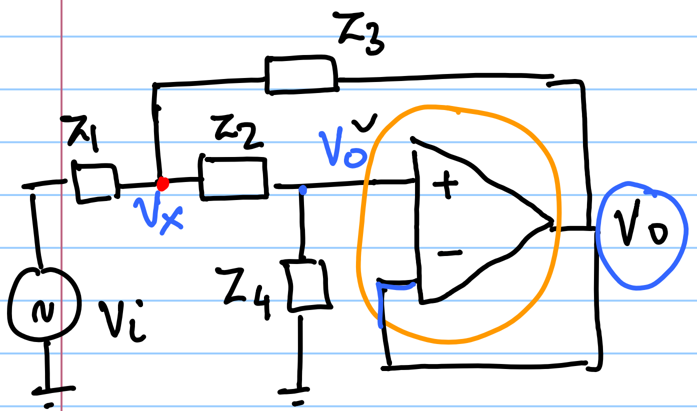
$$V_o = \left((V_i - V_o)\frac{\omega_0}{s} - \frac{1}{Q_p}V_o\right)\frac{\omega_0}{s} + V_i$$



H_{BRF}



Sallen Key Filter



(LP/HP)

$$V_o = \frac{Z_4}{Z_4 + Z_2} V_x \Rightarrow V_x = V_o\left(1 + \frac{Z_2}{Z_4}\right) \checkmark$$

$$V_x\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right) = \frac{V_o}{Z_2} + \frac{V_o}{Z_3} + \frac{V_i}{Z_1} \checkmark$$

$$V_o\left(1 + \frac{Z_2}{Z_4}\right)\left(\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3}\right) = V_o\left(\frac{1}{Z_2} + \frac{1}{Z_3}\right) + \frac{V_i}{Z_1}$$

$$V_o\left(\frac{1}{Z_1} + \cancel{\frac{1}{Z_2}} + \cancel{\frac{1}{Z_3}} + \frac{Z_2}{Z_1 Z_4} + \frac{1}{Z_4} + \frac{Z_2}{Z_3 Z_4}\right) = V_o\left(\cancel{\frac{1}{Z_2}} + \cancel{\frac{1}{Z_3}}\right) + \frac{V_i}{Z_1}$$

$$\frac{V_o}{V_i} = \frac{1}{1 + \frac{Z_1 Z_2}{Z_1 Z_4} + \frac{Z_1}{Z_4} + \frac{Z_1 Z_2}{Z_3 Z_4}} = \frac{Z_3 Z_4 \,/\, Z_1 Z_2 Z_3 Z_4}{(Z_1 Z_2 + Z_1 Z_3 + Z_2 Z_3 + Z_3 Z_4) \,/\, \frac{Z_1 Z_2 Z_3}{Z_4}}$$

$$= \frac{Y_1 Y_2}{Y_3 Y_4 + Y_2 Y_4 + Y_1 Y_4 + Y_1 Y_2}$$

$$Y_1 = \frac{1}{Z_1}, \quad Y_2 = \frac{1}{Z_2}, \quad Y_3 = \frac{1}{Z_3}, \quad Y_4 = \frac{1}{Z_4}$$

$$\frac{V_o}{V_i} = \frac{1}{1 + \underbrace{\frac{s}{\omega_p Q_p}} + \underbrace{\frac{s^2}{\omega_p^2}}}$$

$$Z_1 = R_1, \quad Z_2 = R_2, \quad Z_3 = \frac{1}{sC_3}, \quad Z_4 = \frac{1}{sC_4}$$

$$\frac{V_o}{V_i} = \frac{Z_3 Z_4}{(Z_1 Z_2 + Z_1 Z_3 + Z_2 Z_3 + Z_3 Z_4)} = \frac{1/s^2 C_3 C_4}{R_1 R_2 + \frac{R_1}{sC_3} + \frac{R_2}{sC_3} + \frac{1}{s^2 C_3 C_4}}$$

$$\frac{V_o}{V_i} = \frac{1}{1 + sC_4 (R_1 + R_2) + s^2 C_3 C_4 R_1 R_2}$$

(LPF)

HPF

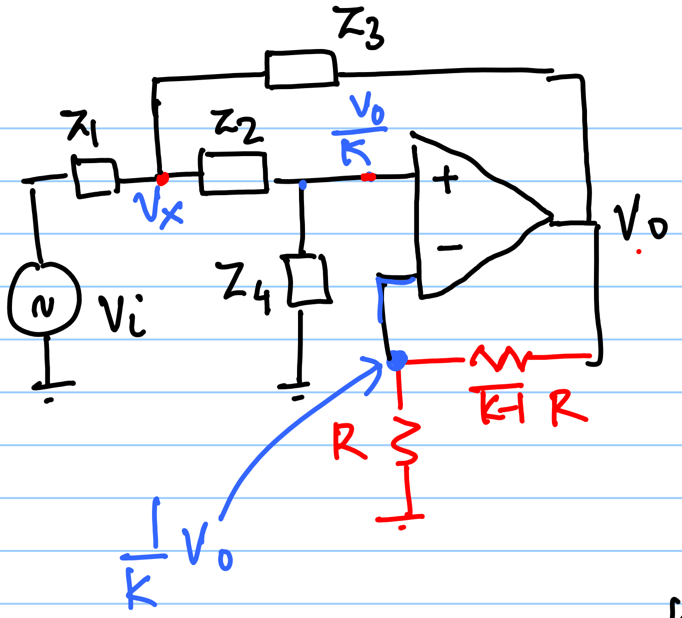
$$\frac{V_o}{V_i} = \frac{s^2/w_0^2}{\frac{s^2}{w_0^2} + \frac{s}{w_0 Q_p} + 1} = \frac{Y_1 Y_2}{Y_3 Y_4 + Y_2 Y_4 + Y_1 Y_4 + Y_1 Y_2}$$

$$Y_1 = sC_1$$
$$Y_2 = sC_2$$
$$Y_3 = G_3 = 1/R_3$$
$$Y_4 = G_4 = 1/R_4$$

$$= \frac{s^2 C_1 C_2}{\frac{1}{R_3 R_4} + \frac{s C_2}{R_4} + \frac{s C_1}{R_4} + s^2 C_1 C_2}$$

$$= \frac{s^2 C_1 C_2 R_3 R_4}{1 + s R_3 (C_1 + C_2) + s^2 C_1 C_2 R_3 R_4}$$

(HPF)



$$\frac{V_0}{V_i} = \frac{K}{1 + s\left[R_1C_3(1-K) + R_1C_4 + R_2C_4\right] + s^2 C_3C_4R_1R_2}$$

$$\checkmark \quad \frac{V_0}{V_i} = \frac{1}{1 + sC_4(R_1+R_2) + s^2 C_3C_4R_1R_2}$$

Previous Exp. $K=1$

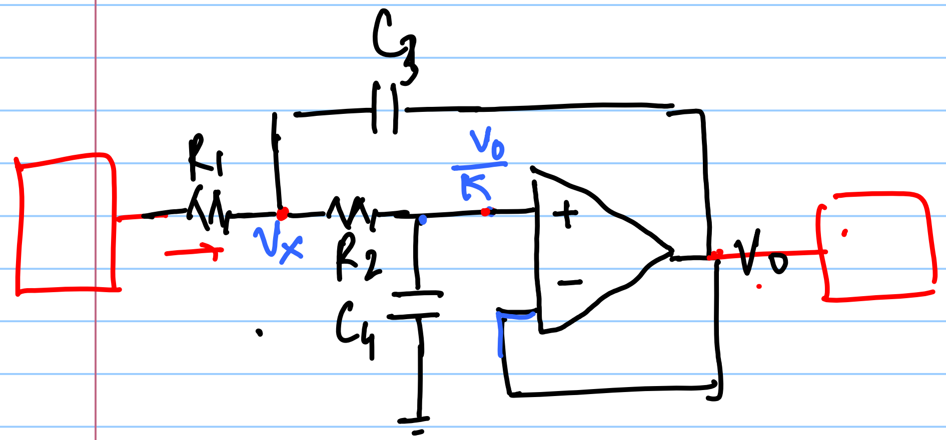
$$D(S) = 1 + s\overbrace{\left(R_1C_3(1-K) + R_1C_4 + R_2C_4\right)}^{b} + s^2 C_3C_4R_1R_2$$

$$s = \frac{-\underbrace{\left(R_1C_3(1-K) + R_1C_4 + R_2C_4\right)}_{<0} \pm \sqrt{(b^2) - 4C_3C_4R_1R_2}}{2C_3C_4R_1R_2}$$

For poles to be in L.H.P: $R_1C_3(1-K) + R_1C_4 + R_2C_4 > 0$

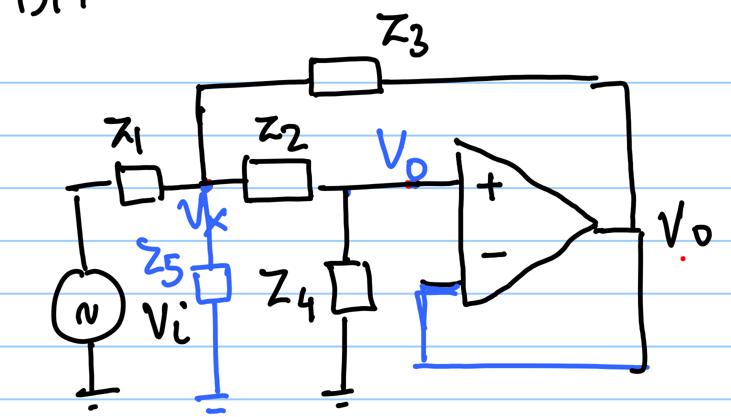
$$\Rightarrow \quad K < \frac{R_1C_3 + R_1C_4 + R_2C_4}{R_1C_3}$$

$$\boxed{K < 1 + \frac{C_4}{C_3} + \frac{R_2}{R_1} \cdot \frac{C_4}{C_3}}$$



Output impedance of filter . is very low.
input impedance is very high.

BPF



$$V_o = \frac{Z_4}{Z_4+Z_2} V_x$$ ✓

$$V_x\left(\frac{1}{Z_1}+\frac{1}{Z_2}+\frac{1}{Z_3}+\frac{1}{Z_5}\right) = \frac{V_i}{Z_1}+\frac{V_o}{Z_2}+\frac{V_o}{Z_3}$$ ✓

$$\frac{V_o}{V_i} = \frac{Z_3Z_4Z_5}{Z_1Z_3Z_4 + Z_1Z_3Z_5 + Z_1Z_2Z_3 + Z_1Z_2Z_5 + Z_3Z_4Z_5 + Z_2Z_3Z_5}$$

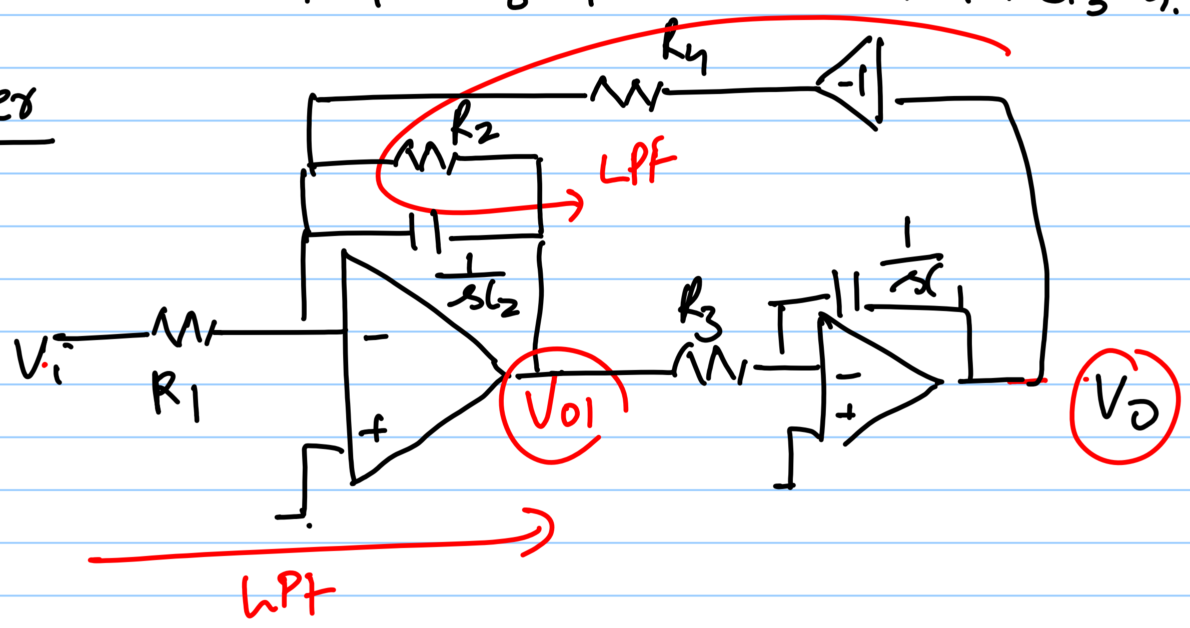
$$= \frac{Y_1Y_2}{Y_2Y_5 + Y_2Y_4 + Y_4Y_5 + Y_3Y_4 + Y_1Y_2 + Y_1Y_4} = \frac{s/\omega_0 Q_p}{\frac{s^2}{\omega_0^2} + \frac{s}{\omega_0 Q_p} + 1}$$

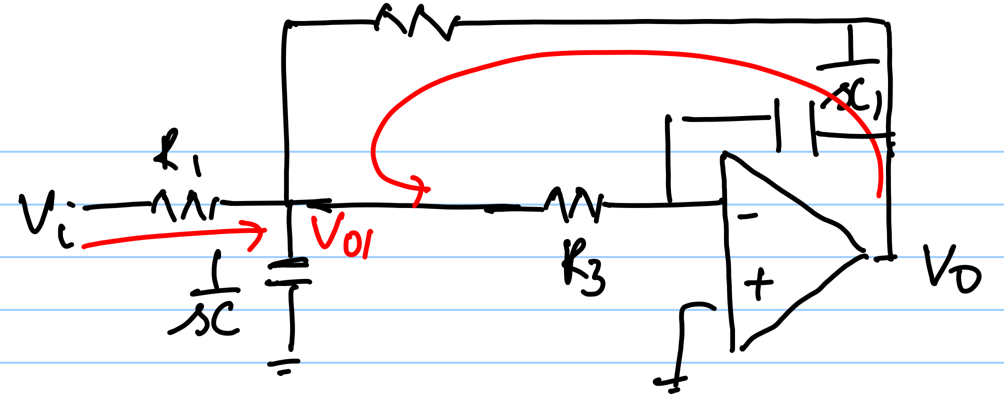
$$Y_i = \frac{1}{Z_i} \quad : \quad i: 1,2,3,4,5$$

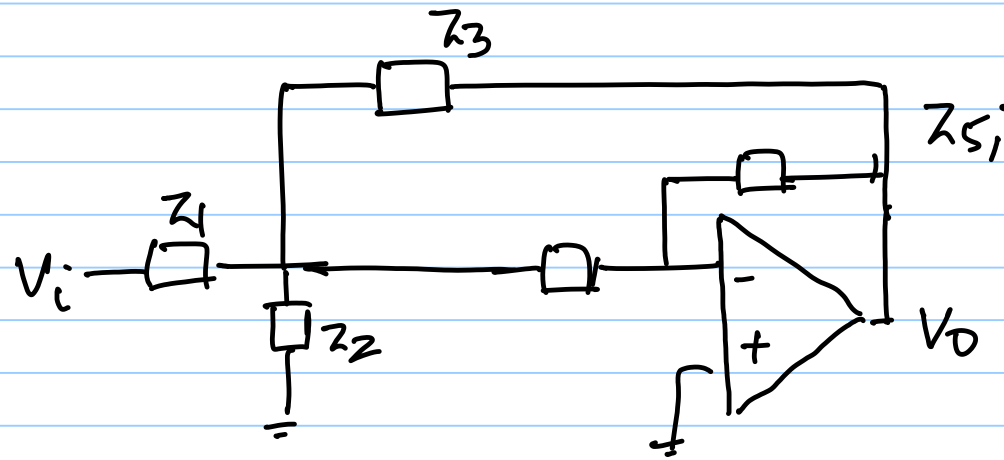
$$Y_1 = \frac{1}{R_1} = G_1,\ Y_2 = sC_2,\ Y_4 = \frac{1}{R_4} = G_4,\ Y_3 = \frac{1}{R_3} = G_3,\ Y_5 = sC_5$$

$$\frac{V_o}{V_i} = \frac{s\,C_2\,G_1 / (G_1+G_3)G_4}{1 + s\,\dfrac{(C_2G_1 + C_2G_4 + C_5G_4)}{G_1G_4 + G_3G_4} + \dfrac{s^2\,C_2C_5}{G_1G_4 + G_3G_4}}$$

Ranch filter







Z_5, Z_4, Z_1, Z_2, Z_3 can be R or C.

You can realize different filters