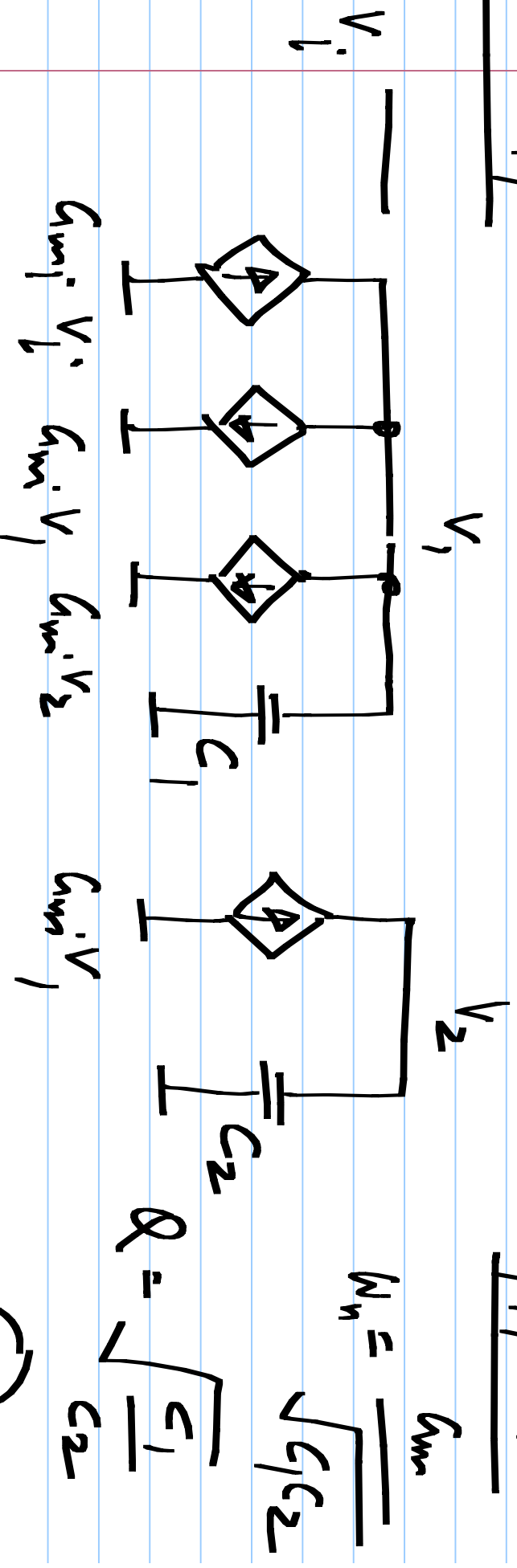


EE2019

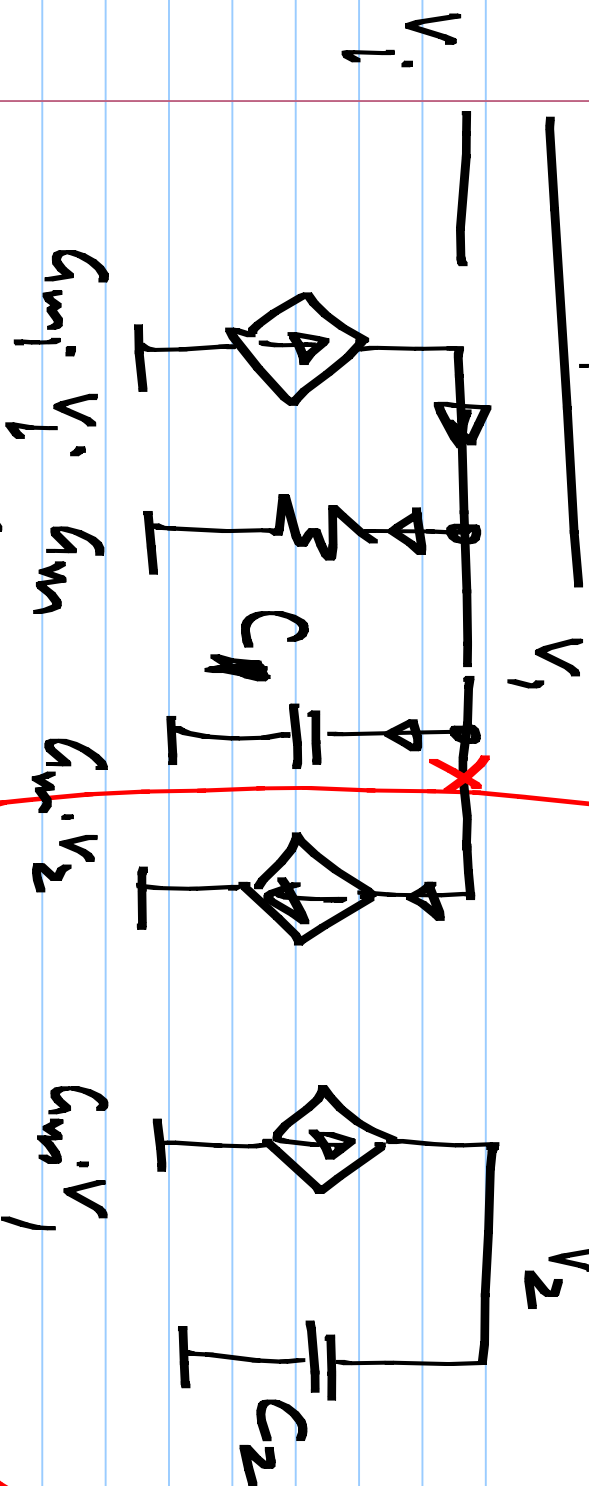
Opamp-RC / Active-RC filter

3/4/2018



$$\frac{V_2}{V_1} = \frac{g_{m1}/g_m}{s^2 C_1 C_2 / g_m^2 + s C_2 / g_m + 1} \quad \text{LP}$$
$$\frac{V_1}{V_i} = \frac{g_{m1}/g_m}{D_2(s)} \quad \text{BP}$$

g_m -C filter

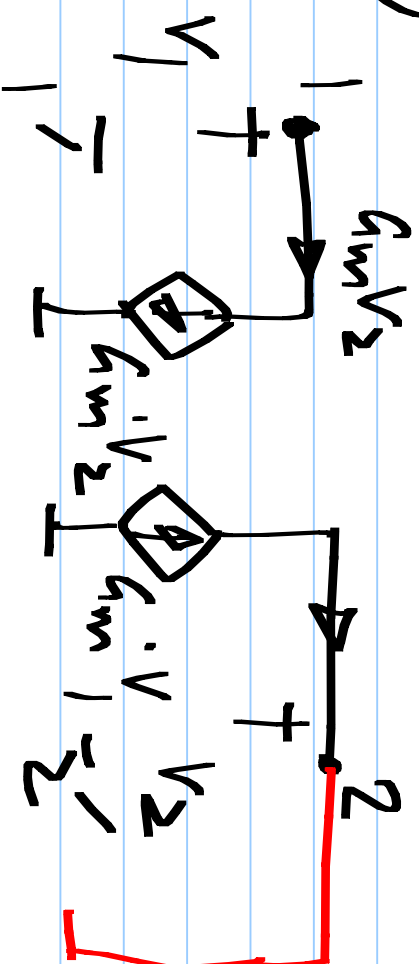


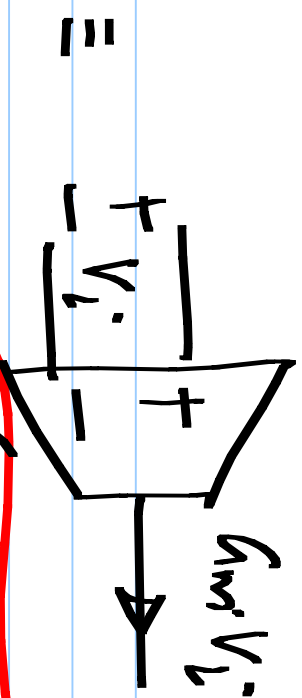
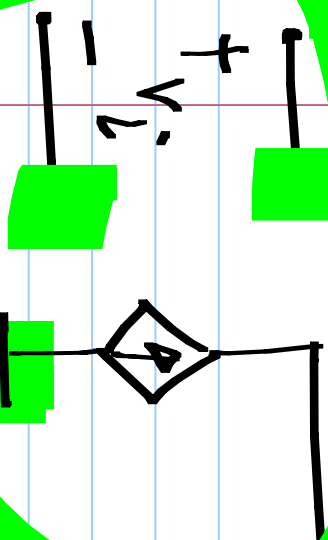
$$= \left[\frac{C_2}{g_{m3}} \right]^*$$

(g_a)

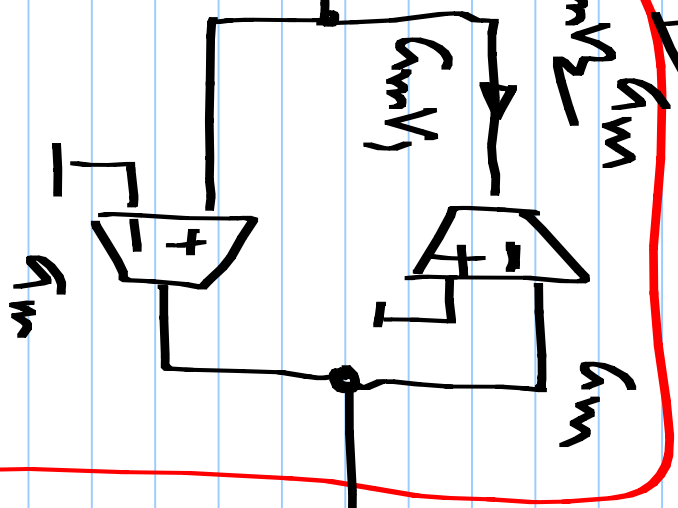
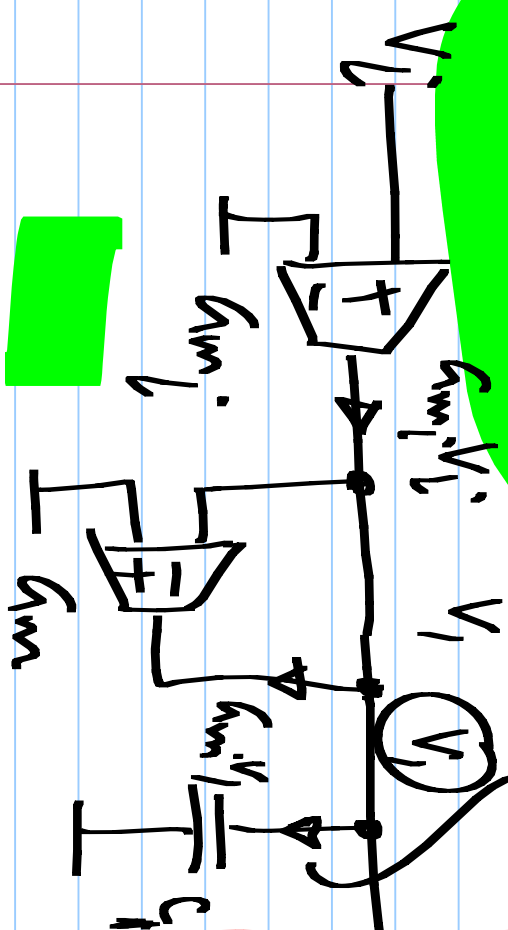
generator

$$\begin{bmatrix} 0 & g_m \\ -g_m & 0 \end{bmatrix}$$

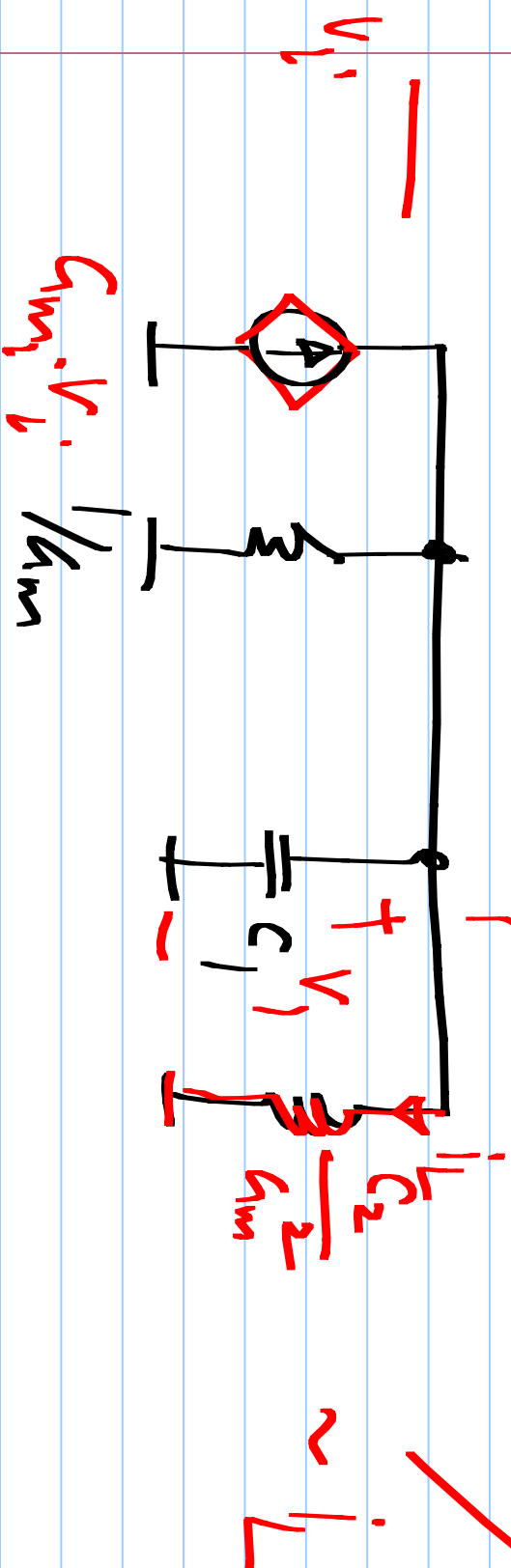
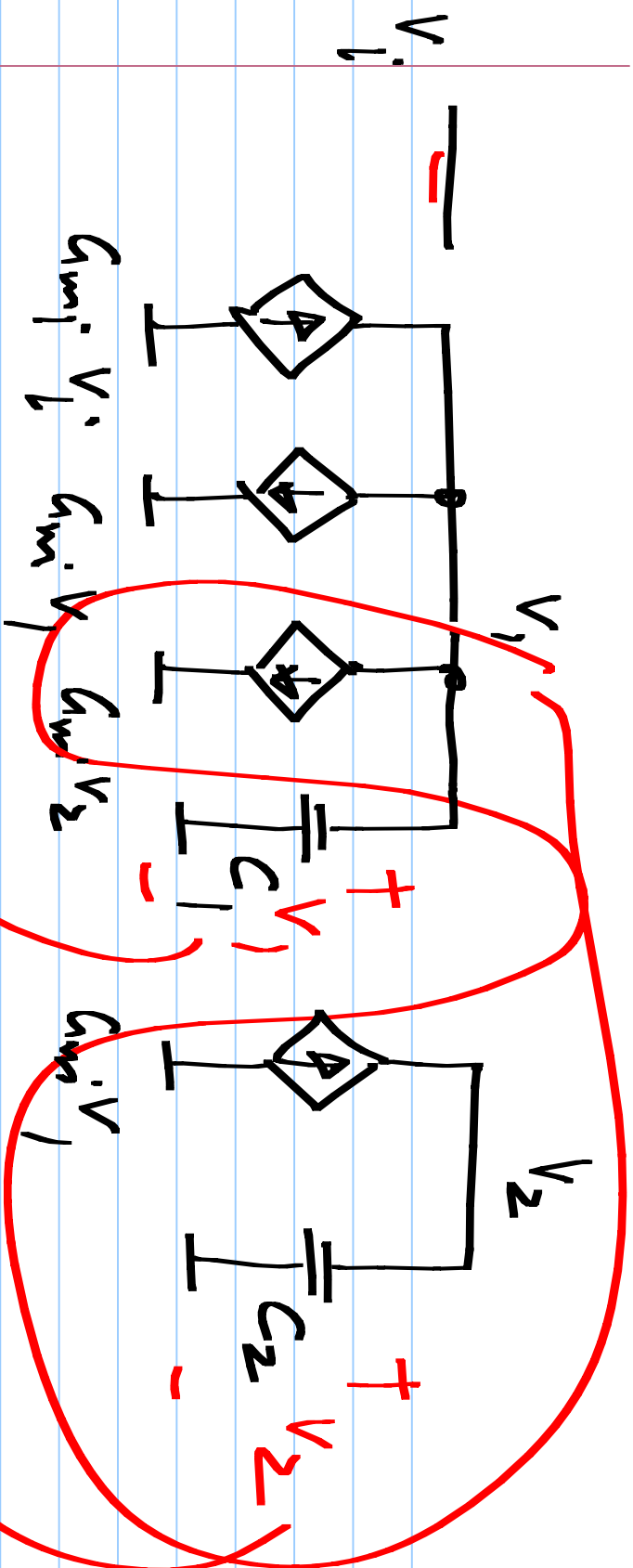


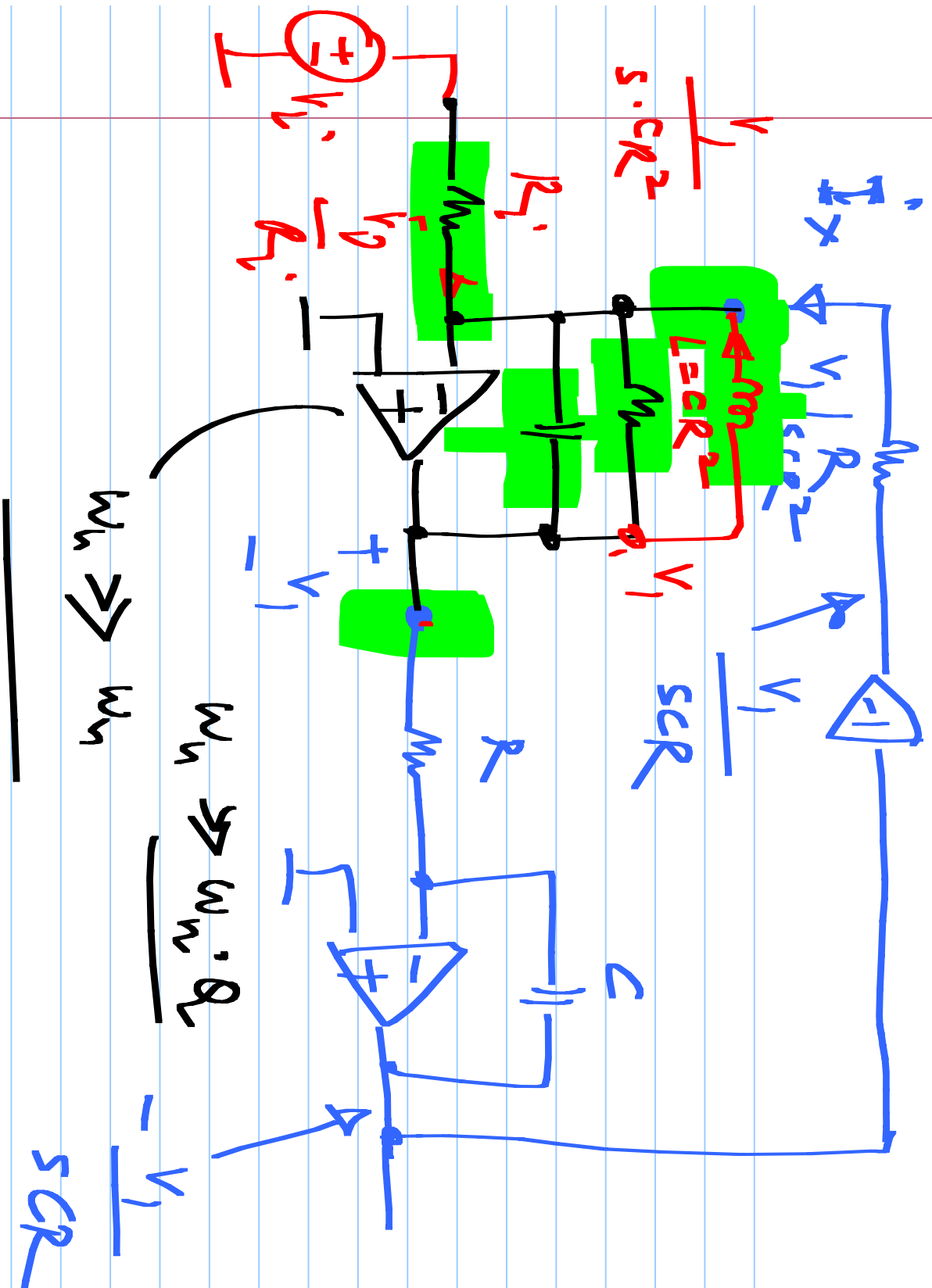


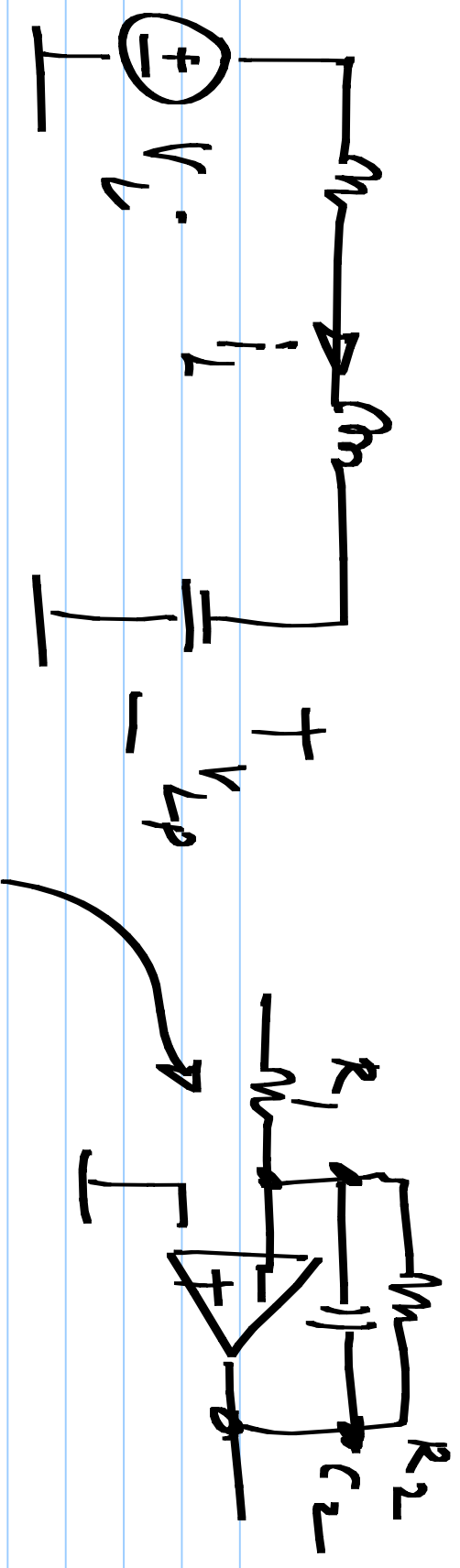
$$g_m V_L - g_m V_1 - g_m V_2$$



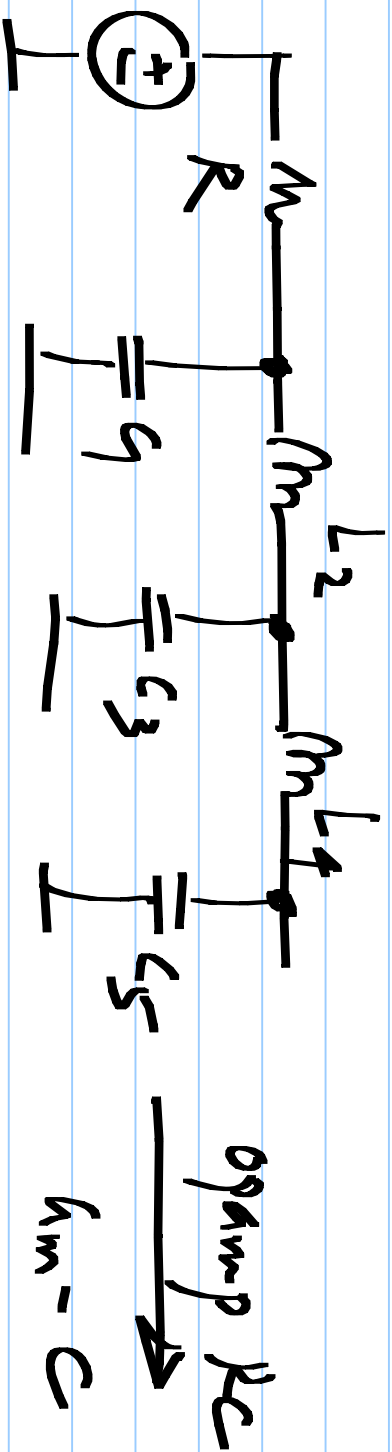
gyakorlat





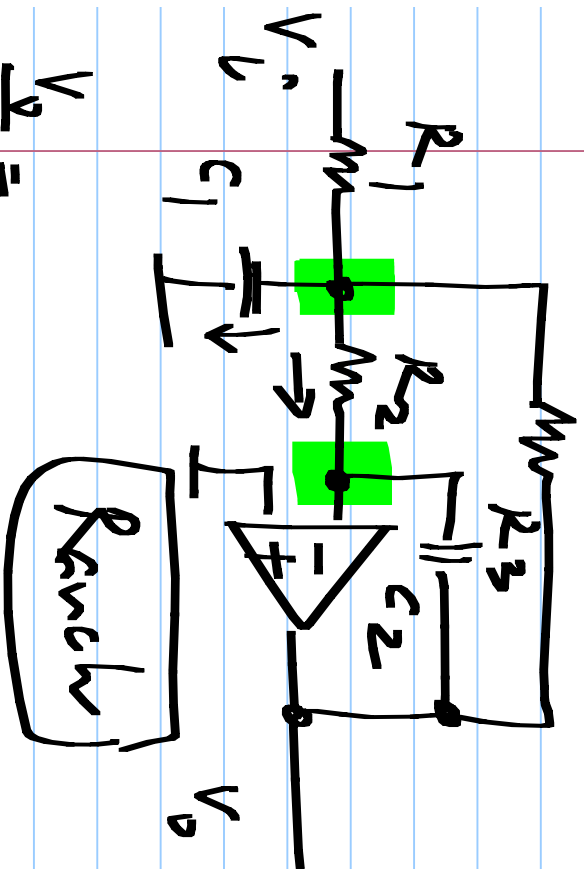


Higher order filters: 1st order, 2nd order section



Single-opamp 2nd order filters:

Sallen-Key



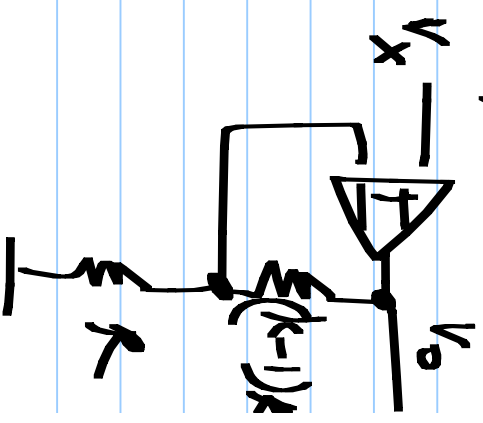
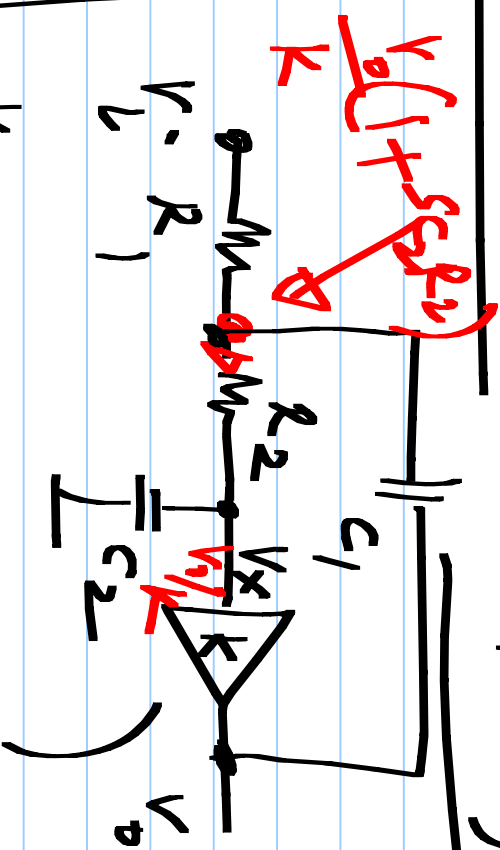
$$\frac{V_0}{V_L} =$$

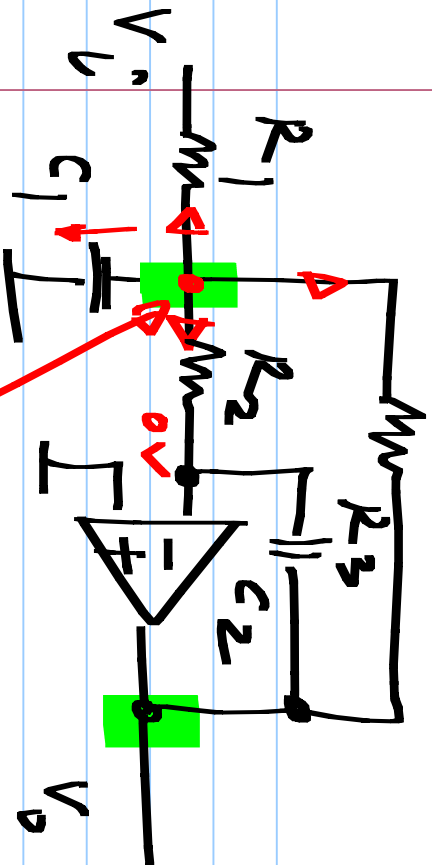
$$V_L$$

dc gain:

$$\omega_n$$

$$\frac{V_0}{V_L} =$$





$$-sC_2R_2 \cdot V_o$$

$$(sC_2R_2 \cdot V_o - V_i) + \frac{-sC_2R_2 \cdot V_o \cdot sC_1R_1}{R_1} + \frac{-sC_2R_2 \cdot V_o \cdot \frac{1}{R_2} + (sC_2R_2 \cdot V_o - V_o)}{R_2} = 0$$

$$\frac{V_i \cdot R_3}{R_1} = - \left(\frac{s^2 C_1 C_2 R_1 R_2 R_3}{R_1} + \frac{s C_2 R_2 R_3}{R_1} + \frac{s C_2 R_2 R_3}{R_2} + \frac{s C_2 R_2}{R_2} + \frac{V_o}{R_2} \right)$$

$$\frac{V_o}{V_i} = \frac{-R_3/R_1}{s^2(s)}$$

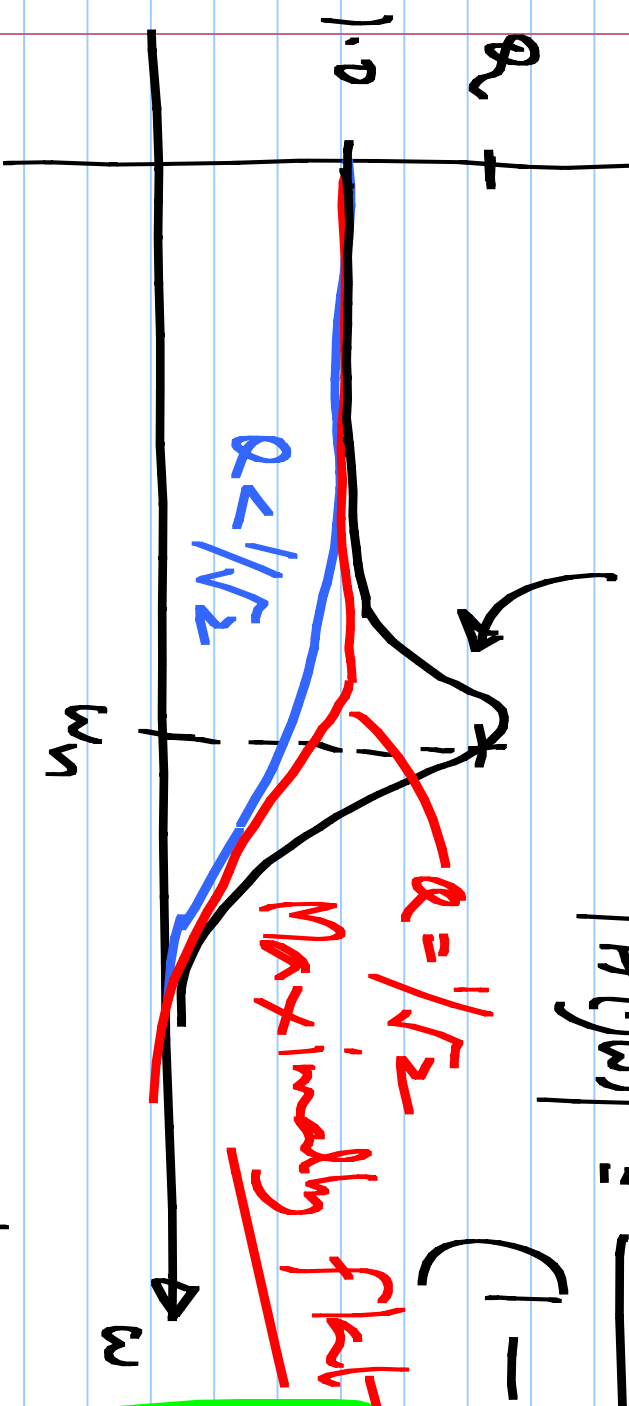
2nd-order lowpass:

$$H(s) = \frac{1}{s^2/\omega_n^2 + s/Q\omega_n + 1}$$

$$|H(j\omega)|$$

$$Q > 1/\sqrt{2}$$

$$|H(j\omega)|^2 = \frac{1}{\left(1 - \frac{\omega^2}{\omega_n^2}\right)^2 + \left(\frac{\omega}{\omega_n}\right)^2}$$



$$Q < 1/\sqrt{2} ; Q > 1/\sqrt{2}$$

$$1 + \frac{\omega^2}{\omega_n^2} \left(-2 + \frac{1}{Q^2} \right) + \frac{\omega^4}{\omega_n^4}$$

$$|H(j\omega)|^2 = \frac{1}{1 + c_2 \left(\frac{\omega}{\omega_n}\right)^2 + c_4 \left(\frac{\omega}{\omega_n}\right)^4 + \dots + \left(\frac{\omega}{\omega_n}\right)^{2N}}$$

N th order

Butterworth filter

$$1 + \left(\frac{\omega}{\omega_n}\right)^2$$

2^{th}

