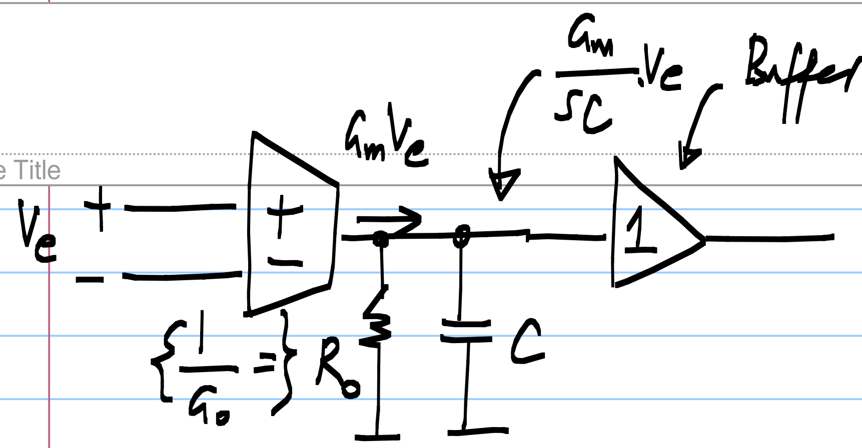


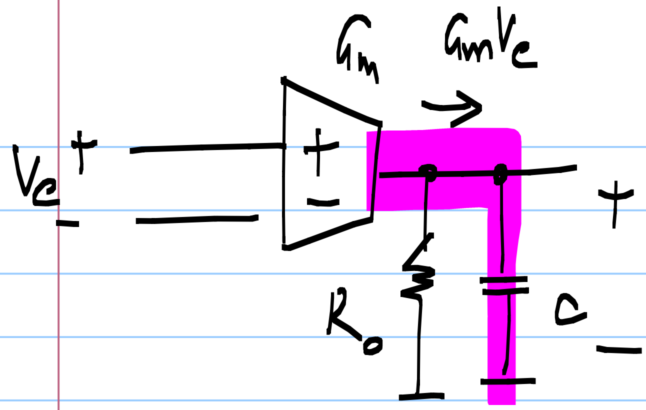
$$\omega_u = \frac{G_m}{C}$$

$$\frac{V_o}{V_e} = \cancel{\frac{G_m}{sC}} = \frac{G_m}{sC + G_o}$$

$$= \frac{G_m R_o}{sCR_o + 1} = \frac{1}{sC/G_m + 1/G_m R_o}$$

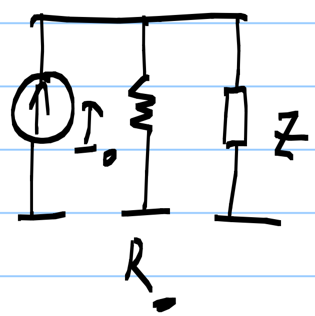
dc gain

* Buffers can be inconvenient to implement
* Limitations on how high $G_m R_o$ can be



$G_m(R_o \| R_L)$

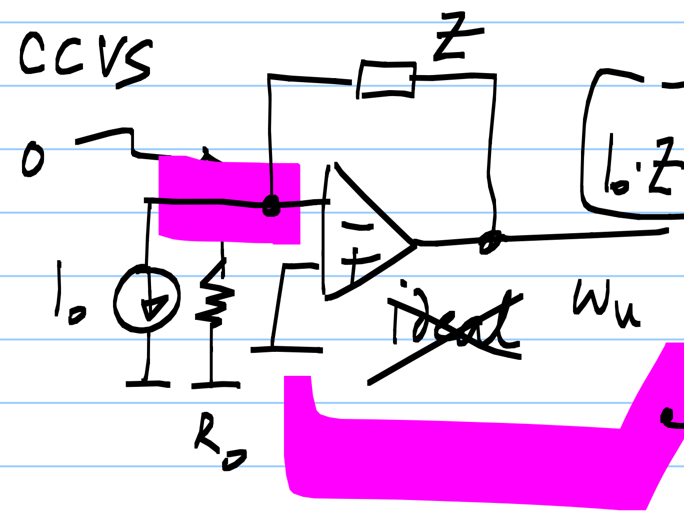
* Increase R_o
* Alternative topologies within $\omega_{u,loop}$ frequencies where $|\text{loop gain}| \gg 1$



$\cancel{I_o \cdot Z}$

$I_o(Z \| R_o)$

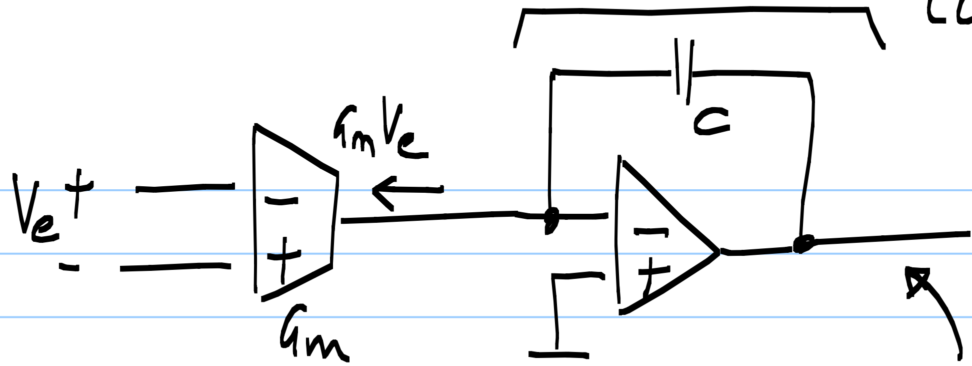
CCVS



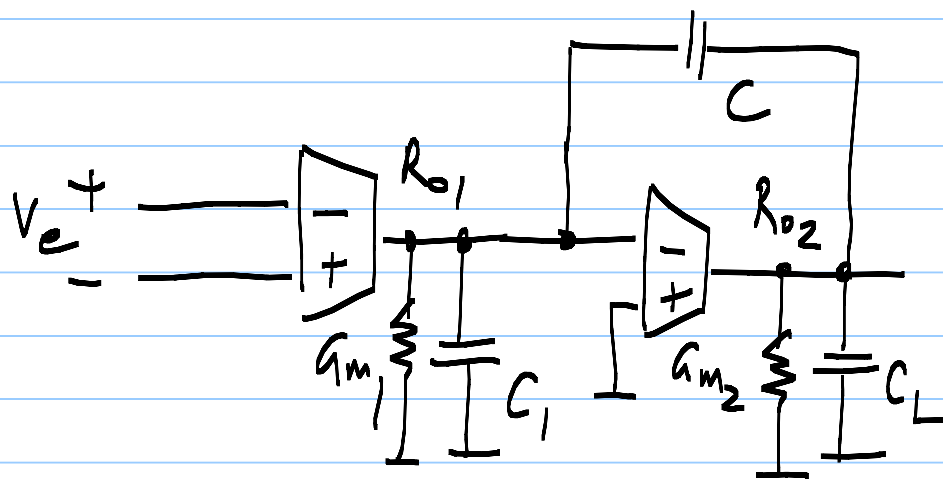
$\boxed{I_o \cdot Z}$

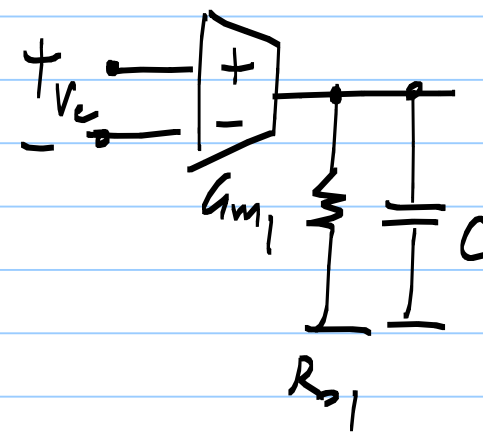
~~ideal~~ ω_u

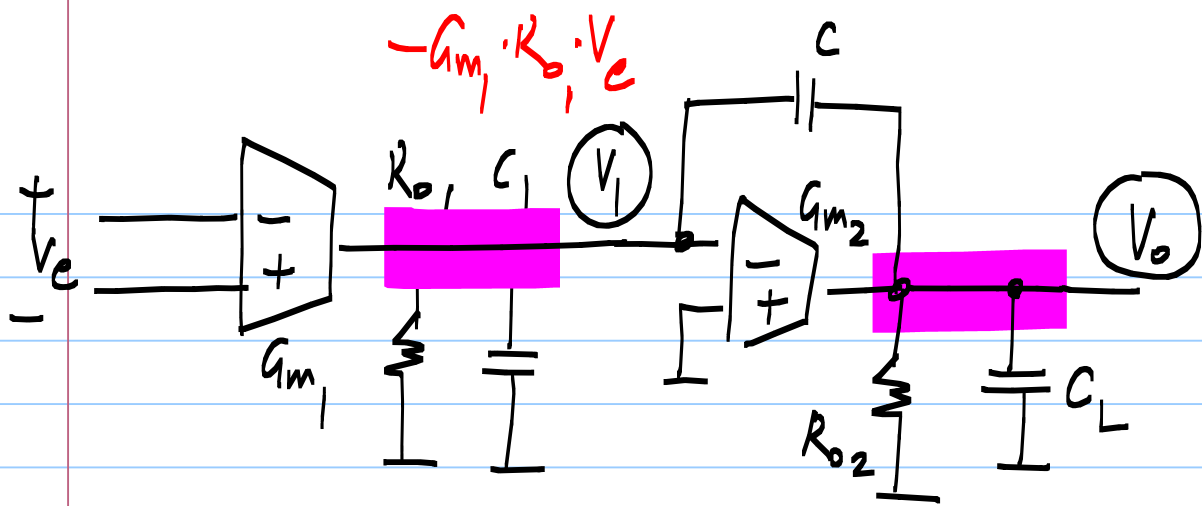
CCVS with a transimpedance $\frac{1}{sC}$



$+\frac{G_m}{sC} \cdot V_e$







* order : 2

2 poles

* dc gain :

$G_{m_1} R_{o_1} G_{m_2} R_{o_2}$

$$\begin{bmatrix} s(C_1+C)+G_{o_1} & -sC \\ G_{m_2}-sC & s(C_L+C)+G_{o_2} \end{bmatrix} \begin{bmatrix} V_1 \\ V_o \end{bmatrix} = \begin{bmatrix} -G_{m_1}V_e \\ 0 \end{bmatrix}$$

$$V_o = \frac{\begin{vmatrix} s(C_1+C)+G_{o1} & -G_{m1}V_e \\ G_{m2}-sC & 0 \end{vmatrix}}{\begin{vmatrix} s(C_1+C)+G_{o1} & -sC \\ G_{m2}-sC & s(C_L+C)+G_{o2} \end{vmatrix}}$$

$$= \frac{G_{m1}(G_{m2}-sC)\cdot V_e}{s^2\left(C_1C+CC_L+C_LC_1+\cancel{C^2}-\cancel{C^2}\right)+s\left(C(G_{m2}+G_{o2}+G_{o1})+C_LG_{o1}+C_1G_{o2}\right)+G_{o1}G_{o2}}$$

$$\frac{V_o}{V_e} = \frac{G_{m1}(G_{m2} - sC)}{s^2(C_1C + CC_L + C_LC_1) + s(C(G_{m2} + G_{o2} + G_{o1}) + C_1G_{o2} + C_LG_{o1}) + G_{o1}G_{o2}}$$

$$\left.\frac{V_o}{V_e}\right|_{s=0} = \frac{G_{m1}G_{m2}}{G_{o1}G_{o2}}$$; 2 poles ; 1 zero

zero $z_1 = +\frac{G_{m2}}{C}$

Approximate roots of a quadratic equation:

$$as^2 + bs + c = 0 \quad \Big\} \quad 2 \text{ roots } \quad s_1, \; s_2$$

$$\left\{ |s_1| \ll |s_2| \right\}$$

$$\cancel{as_1^2} + bs_1 + c = 0$$

$$bs_1 + c \simeq 0$$

$$\boxed{s_1 \simeq -\frac{c}{b}}$$

$$as_2^2 + bs_2 + \cancel{c} = 0$$

$$\boxed{s_2 \simeq -\frac{b}{a}}$$

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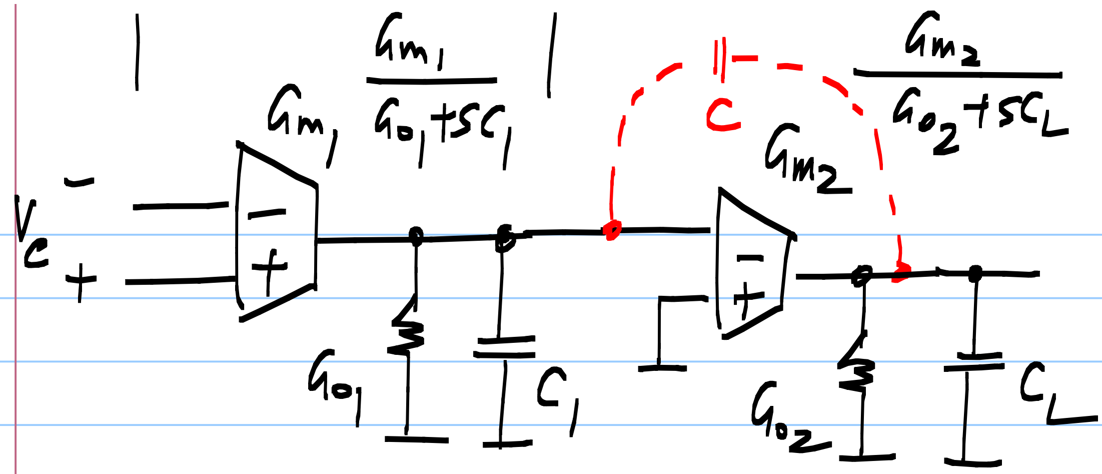
$$p_1 = -\frac{c}{b} = -\frac{G_{o1}G_{o2}}{C(G_{m2}+G_{o2}+G_{o1}) + C_1 G_{o2} + C_L G_{o1}}$$

$$= -\frac{G_{o1}}{C\left(\frac{G_{m2}}{G_{o2}} + 1 + \frac{G_{o1}}{G_{o2}}\right) + C_1 + C_L \frac{G_{o1}}{G_{o2}}}$$

$$p_2 = -\frac{b}{a} = -\frac{C(G_{m2}+G_{o2}+G_{o1}) + C_1 G_{o2} + C_L G_{o1}}{CC_1 + C_1 C_L + C_L C_1} \qquad (C+C_1)$$

$$= -\frac{\frac{C}{C+C_1}\cdot G_{m2} + G_{o2} + G_{o1}\cdot\frac{C+C_L}{C+C_1}}{C_L + C_1 C/(C+C_1)}$$



$$\text{pole}: \; -\frac{G_{o1}}{C_1}\; ; \quad -\frac{G_{o2}}{C_L}$$

	Without C	With C
p_1	$-\dfrac{G_{o1}}{C_1}$	$-\dfrac{G_{o1}}{C\left(\dfrac{G_{m2}}{G_{o2}}+1+\dfrac{G_{o1}}{G_{o2}}\right)+C_1+C_L\cdot\dfrac{G_{o1}}{G_{o2}}}$
	low frequency	
p_2	$-\dfrac{G_{o2}}{C_L}$	$-\dfrac{G_{o2}+G_{m2}\cdot\dfrac{C}{C+C_1}+G_{o1}\cdot\dfrac{C+C_L}{C+C_1}}{C_L+\dfrac{C\cdot C_1}{C+C_1}}$
	high frequency	pole splitting