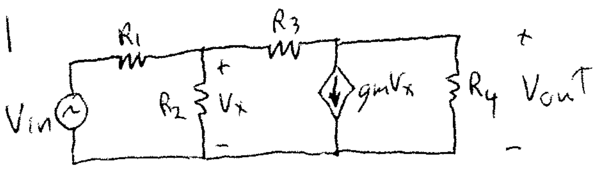
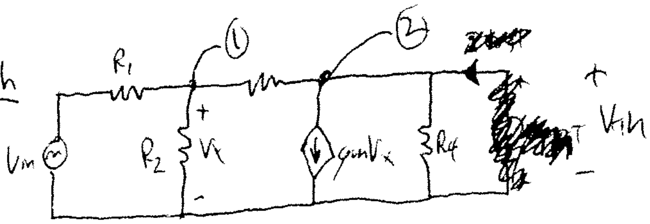
R1.1



Vth



① $$\frac{V_{in}-V_x}{R_1}=\frac{V_x}{R_2}+\frac{V_x-V_{th}}{R_3}$$

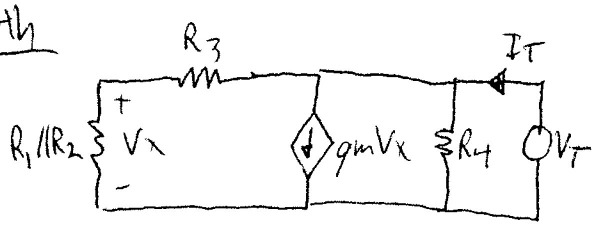
$$V_{in}=\left(V_x\left(\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_1}\right)-\frac{V_{th}}{R_3}\right)R_1$$

② $$\frac{V_x-V_{Th}}{R_3}=g_mV_x+\frac{V_o}{R_4}\rightarrow V_x=\frac{-V_{Th}(R_3+R_4)}{R_4(R_3\cdot g_m-1)}$$

$$V_{in}=-V_{Th}\left[\frac{(R_3+R_4)}{R_4(R_3\cdot g_m-1)}\left(\frac{R_1}{R_2}+\frac{R_1}{R_3}+1\right)-\frac{R_1}{R_3}\right]$$

$$V_{th}=\frac{-V_{in}}{\left[\frac{(R_3+R_4)}{R_4(R_3g_m-1)}\left(\frac{R_1}{R_2}+\frac{R_1}{R_3}+1\right)-\frac{R_1}{R_3}\right]}$$

Rth



$$I_T=g_mV_x+\frac{V_T}{(R_3+R_1//R_2)//R_4}$$

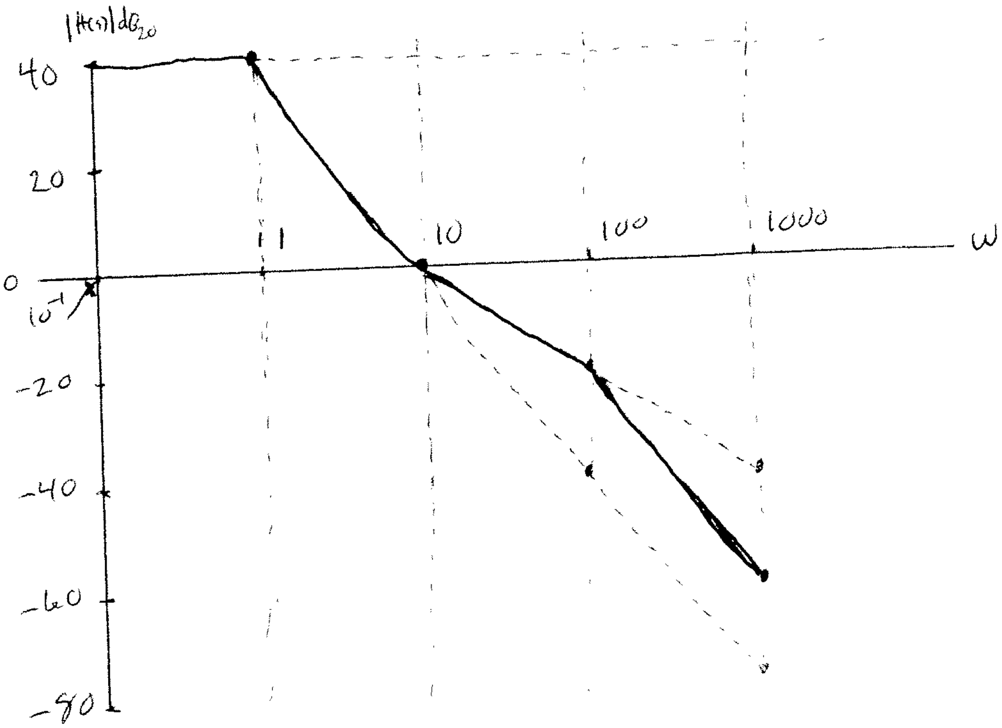
$$V_x=V_T\frac{R_1//R_2}{R_1//R_2+R_3}$$

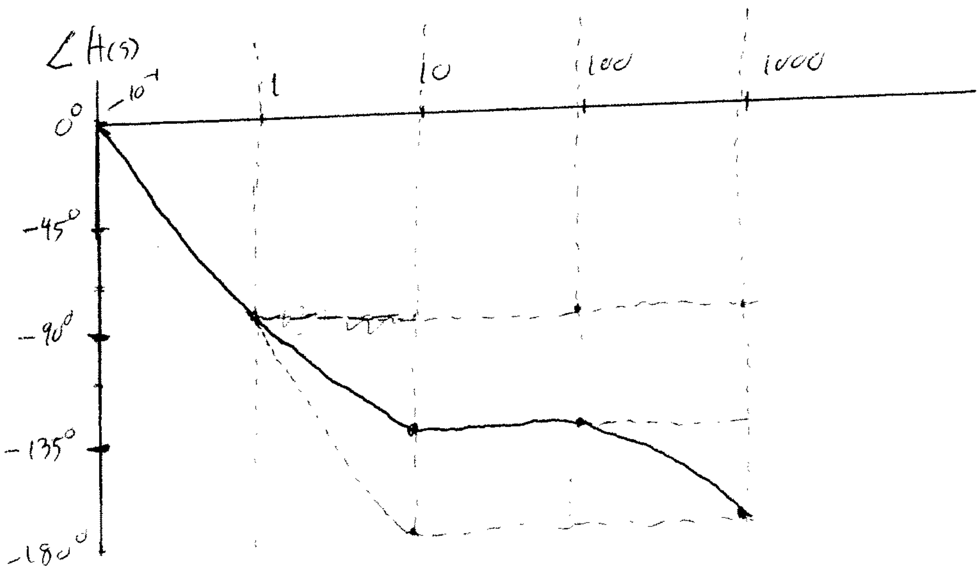
$$\frac{V_T}{I_T}=R_{th}=\frac{(R_1//R_2+R_3)\left[(R_3+R_1//R_2)//R_4\right]}{g_mR_1//R_2\left[(R_3+R_1//R_2)//R_4\right]+R_1//R_2+R_3}$$

R1.2 $H(s) = \dfrac{1000(s+10)}{(s+100)(s^2+2s+1)} = \dfrac{100\left(\frac{s}{10}+1\right)}{\left(\frac{s}{100}+1\right)(s^2+2s+1)}$

$$20\log(|H(s)|) = 40\,dB + 20\log\left(\left|\tfrac{s}{10}+1\right|\right) - 20\log\left(\left|\tfrac{s}{100}+1\right|\right) - 20\log\left(|s^2+2s+1|\right)$$

constant	$+20\frac{dB}{dec}$ @ $w=10$	$-20\frac{dB}{dec}$ @ $w=100$	$-40\frac{dB}{dec}$ @ $w=1$
0°	0° @ $w=1 \rightarrow 90^\circ$ @ $w=100$	0° @ $w=10 \rightarrow -90^\circ$ @ $w=1000$	0° @ $w=0.1 \rightarrow -180^\circ$ @ $w=10$





$\angle @ 10^{-1} = 0+0+0+0 = 0$

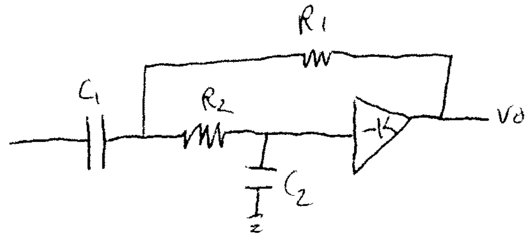
$\angle @ 1 = 0+0+0-90 = -90^\circ$

$\angle @ 10 = 0+45+0-180 = -135^\circ$

$\angle @ 100 = 0+90-45-180 = -135^\circ$

$\angle @ 1000 = 0+90-90-180 = -180^\circ$

R1.3



$h = -20$

$w_n = 2\pi\, 100\times10^3$ rad/s

$d = 1/7$

$$\frac{T_1 T_2}{1+K} = 1 \qquad h = -K/T_2$$

↓

Choose group for T_2

Choose

$R_1 = R_2$

$p = 1$ → Group VII

$$T_2 = \frac{d(1+K)}{2(1+p)}\left[1 \pm \sqrt{1 - \frac{4(1+p)}{d^2(1+K)}}\right] = \frac{d(1-hT_2)}{2(1+p)}\left[1 \pm \sqrt{1 - \frac{4(1+p)}{d^2(1-hT_2)}}\right]$$

$$T_2 = \frac{\pm\sqrt{-4p + d^2 - 2dh + h^2 - 4} + d + h}{2(p + dh + 1)} = 23.2169,\ -0.0503$$

$K = -hT_2 = 464.338$

$T_1 = \dfrac{1+K}{T_2} = 20.0431$

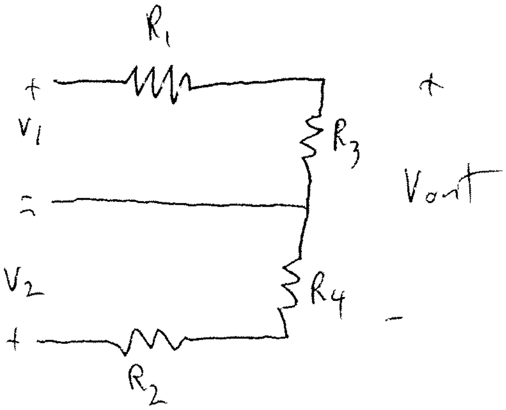
$C_2 = \dfrac{T_2}{T_1} C_1 = 11.58\,\text{nF}$

Choose

$C_1 = 10\,\text{nF}$

$R_1 = \dfrac{T_1}{w_n C_1} = 3.19\,\text{k}\Omega = R_2$

R1.4



$$V_0^+ = V_1 \frac{R_3}{R_1+R_3}$$

$$V_0^- = V_2 \frac{R_4}{R_4+R_2}$$

$$V_{out} = V_1 \frac{R_3}{R_1+R_3} - V_2 \frac{R_4}{R_4+R_2}$$

$$V_1 = V_{ic} + \frac{V_{id}}{2}$$

$$V_2 = V_{ic} - \frac{V_{id}}{2}$$

$$V_{out} = V_{ic}\left(\frac{R_3}{R_1+R_3} - \frac{R_4}{R_4+R_2}\right) + \frac{V_{id}}{2}\left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_4+R_2}\right)$$

$$V_{out} = V_{ic} A_{cm} + V_{id} A_{dm}$$

$$A_{cm} = \left(\frac{R_3}{R_1+R_3} - \frac{R_4}{R_4+R_2}\right) \qquad A_{dm} = \left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_4+R_2}\right)\frac{1}{2}$$

$$CMRR = \frac{A_{dm}}{A_{cm}} = \frac{\left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_4+R_2}\right)\frac{1}{2}}{\left(\frac{R_3}{R_1+R_3} - \frac{R_4}{R_4+R_2}\right)} = \frac{-(R_1R_4 + (R_2+2R_4)R_3)}{2(R_1R_4 - R_2R_3)}$$

Alternatively

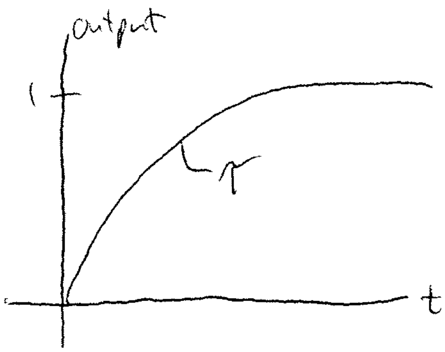
$$V_{in} = V_1 = V_2$$

$$\frac{V_{out}}{V_{in}} = \frac{R_3}{R_1+R_3} - \frac{R_4}{R_4+R_2} = A_{cm}$$

$$\frac{V_{in}}{2} = V_1 = -V_2$$

$$\frac{V_{out}}{V_{in}} = \frac{1}{2}\left(\frac{R_3}{R_1+R_3} + \frac{R_4}{R_4+R_2}\right) = A_{dm}$$

R1.5 Desired



$SR = 20\ V/\mu s$ $\qquad t_r = 100ns$

$$y(t) = 1 - e^{-t/\tau}$$

$$\tau \approx \frac{T_r}{2.2} = 45.4545ns$$

$$\frac{d}{dt}y(t) = \frac{1}{\tau}e^{-t/\tau} \longrightarrow \text{maximum @ } t=0$$

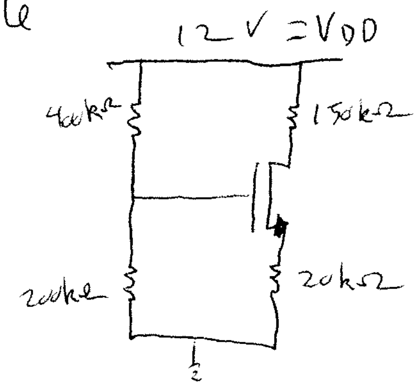
$$\left.\frac{d}{dt}y(t)\right|_{max} = 22\ V/\mu s > SR$$

Output will be slewed

For τ @ SR

$$\left.\frac{d}{dt}y(t)\right|_{max} = \frac{1}{\tau} = 20\ V/\mu s \longrightarrow \tau = 50ns$$

R1.6



$V_{tn} = 1V$

$\lambda = 0$

$K_n = 60\mu A/V^2$

$$V_g = \frac{12 \cdot 200k}{200k + 400k} = 4V$$

$$I_D = \frac{V_{DD} - V_D}{150k} \rightarrow V_D = V_{DD} - I_D \cdot 150k$$

$$V_{DS} = V_{DD} - I_D \cdot 170k$$

$$I_D = \frac{V_S}{20k} \rightarrow V_S = I_D \cdot 20k$$

$$V_{GS} = 4 - I_D \cdot 20k$$

Assume Sat.

$$I_D = \frac{1}{2} K_n (4 - I_D \cdot 20k - V_{tn})^2 \rightarrow I_D = \frac{\pm\sqrt{2 \cdot K_n \cdot 20k (V_g - V_{tn}) + 1} + K_n \cdot 20k (V_g - V_{tn}) + 1}{K_n (20k)^2}$$

$$= 72.4\mu A,\ 311\mu A$$

$$V_{DS} = -0.2999V,\ -40.87V$$

Bad Assumption

Assume Linear

$$I_D = K_n \left[(4 - I_D \cdot 20k - V_{TN})(V_{DD} - I_D \cdot 170k) - \frac{(V_{DD} - I_D \cdot 170k)^2}{2} \right]$$

$I_D = 65.48\mu A,\ 49.76\mu A$

$V_{DS} = 0.8688V,\ 3.5414V$

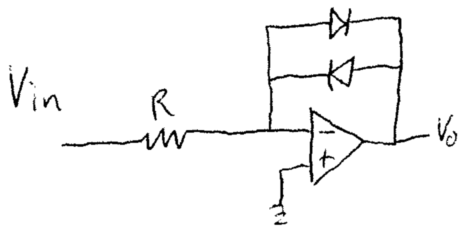
$V_{GS} = 2.6905V,\ 3.0049V$

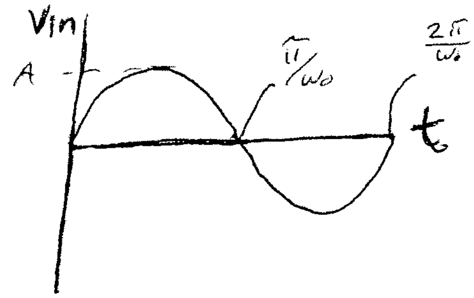
$V_{DS} < V_{GS} - V_{TN}$

R1.7

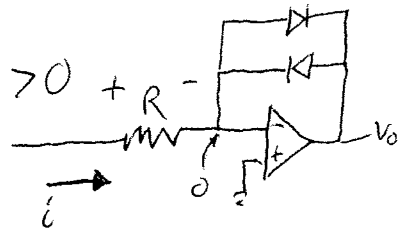
$V_{on} = 0.6\,V$

$V_{in} = A\sin(\omega_0 t)$

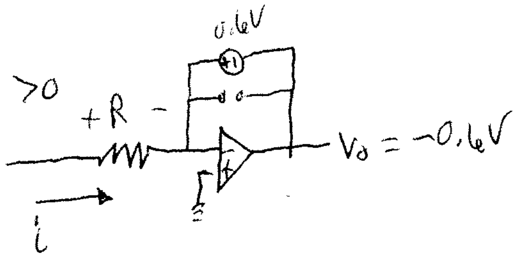




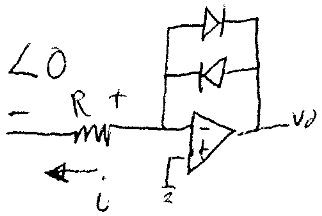
$V_{in} > 0$

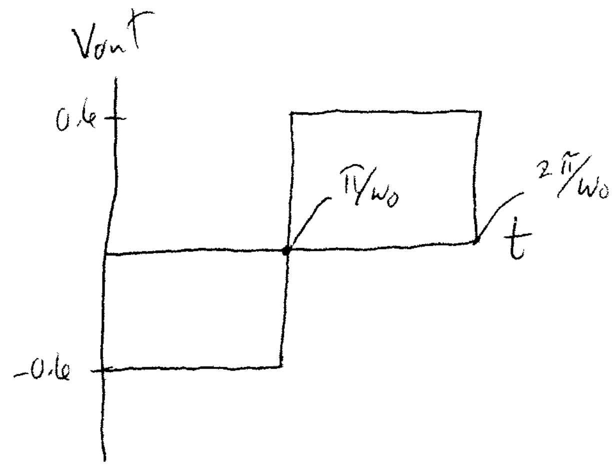


$V_{in} > 0$



$V_{in} < 0$





$V_{in} < 0$