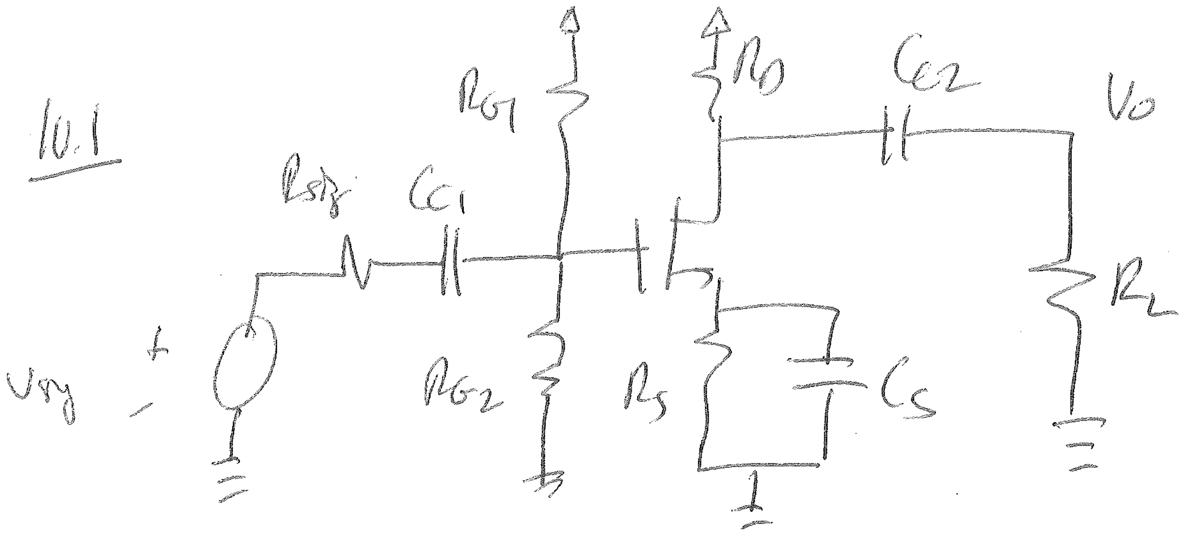
Homework #3 - Solutions

9/14/2016

Ivan Puchades

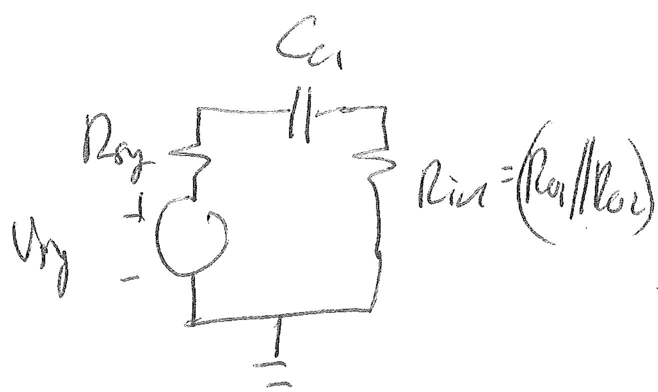
10.1



$R_{G1}=2M\Omega$, $R_{G2}=1M\Omega$, $R_{sig}=200k\Omega$.

$f_{c1}=10Hz$ or lower

$$\omega_{c1}=\frac{1}{(C_{c1})(R_{sig}+R_{in})}$$



$$R_{in}=\frac{2M\Omega\cdot 1M\Omega}{3M\Omega}=0.667M\Omega$$

$$f_{c1}=\frac{1}{2\pi(C_{c1})(866.67k\Omega)}=10Hz$$

$$C_{c1}=\frac{1}{2\pi(10Hz)(866.67k\Omega)}=18.9nF$$

$$\boxed{\approx 20nF}$$

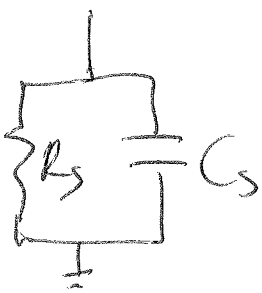
nano $=10^{-9}$

10.3

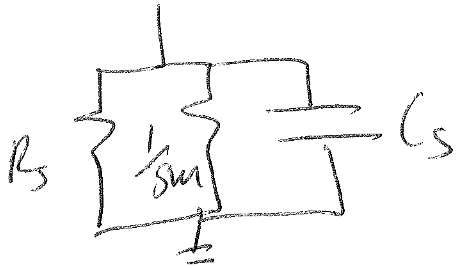
$g_m = 5\,mA/V$ $\quad R_s = 1.8\,k\Omega$

C_s? for $\omega_p = 100\,Hz$.

ω_z



ω_p



$R_s = 1.8\,k\Omega$

$\frac{1}{g_m} = 200\,\Omega$

$R_s \| \frac{1}{g_m} = 180\,\Omega$

$$\omega_p = \frac{1}{\left(R_s \| \frac{1}{g_m}\right) C_s}$$

$$C_s = \frac{1}{2\pi \cdot 180\Omega \cdot 100Hz} = 8.84\,\mu F \;\; \boxed{\approx 10\,\mu F}$$

$$f_z = \frac{1}{2\pi R_s C_s} = \frac{1}{2\pi \cdot 1.8k\Omega \cdot 10\times10^{-6}F} = \boxed{8.84\,Hz}$$

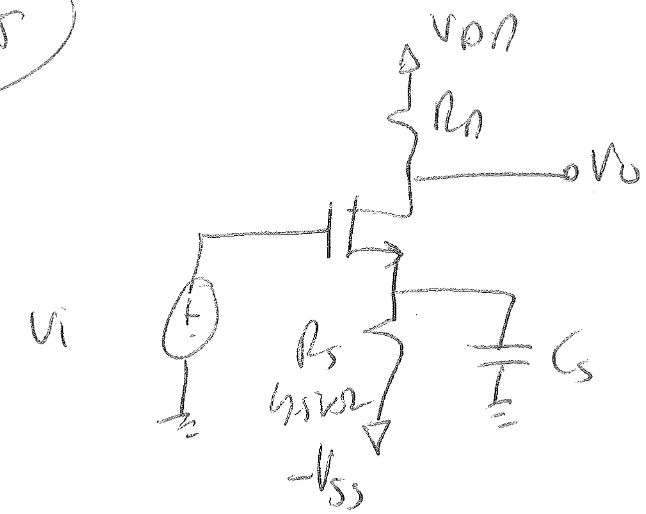
$$f_p = \frac{1}{2\pi \cdot 180\Omega \cdot 10\mu F} = \boxed{88.4\,Hz}$$

Homework #8 – Solution _ 2

(2) 4/14/2016

Ivan Richards.

10.5



$g_m = 2mA/V$

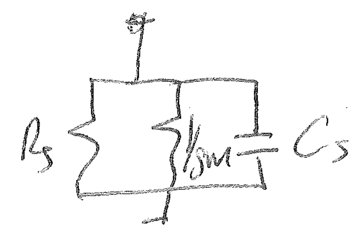
$r_o \to \infty$

a) $\frac{v_o}{v_i} = -g_m R_D = -2mA/V \cdot R_D = -20V/V$

$C_s \to$ short

$\boxed{R_D = \frac{-20V/V}{-2mA/V} = 10k\Omega}$

b) C_s for $\omega_p = 100Hz$



$$f_p = \frac{1}{2\pi (R_s \| \frac{1}{g_m}) C_s}$$

$$C_s = \frac{1}{2\pi \cdot 450 \cdot 100} = 3.53 \times 10^{-6} F$$

$\frac{1}{g_m} = 500\Omega$

$R_s = 4.5k\Omega$

$(\frac{1}{g_m} \| R_s) = 450\Omega$

(c) $$f_z = \frac{1}{2\pi R_s C_s}$$

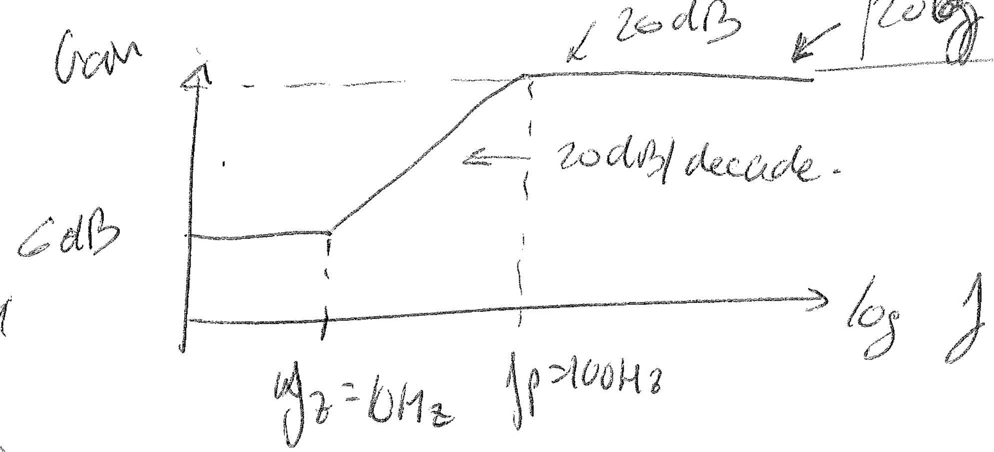
$$= \frac{1}{2\pi \cdot 4.5k\Omega \cdot 3.53\mu F}$$

$f_z = 10.02\ Hz$

d) $f_p >> f_z$. $\therefore f_p = f_L = 100 Hz$

$20\,V/V$

e)



$\boxed{20 \log 20 = 26dB}$

$20 \cdot \log 2$

DC gain ($\omega \to 0$) $C_s \to$ open.

$$\frac{v_o}{v_i} = -g_m v_{gs} \cdot R_D$$

$$v_i = +g_m v_{gs} \cdot \left(R_s + \frac{1}{g_m}\right)$$

$$\frac{v_o}{v_i} = \frac{-g_m \cdot v_{gs} R_D}{+g_m v_{gs} \left(R_s + \frac{1}{g_m}\right)}$$

$$\boxed{\frac{v_o}{v_i} = \frac{R_D}{R_s + \frac{1}{g_m}} = -\frac{10k}{4.5k + 0.5k} = -2\,V/V}$$

HW#8 Solutions _ 3

3 11/14/2016

Ivan Puchades

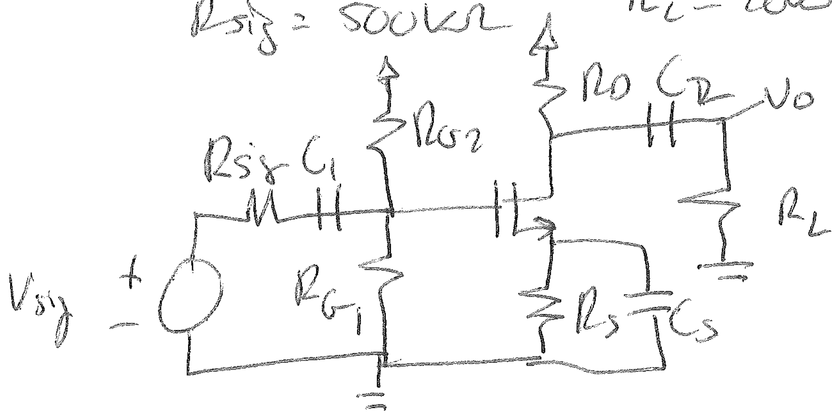
10.32

Discrete C.S. amplifier.

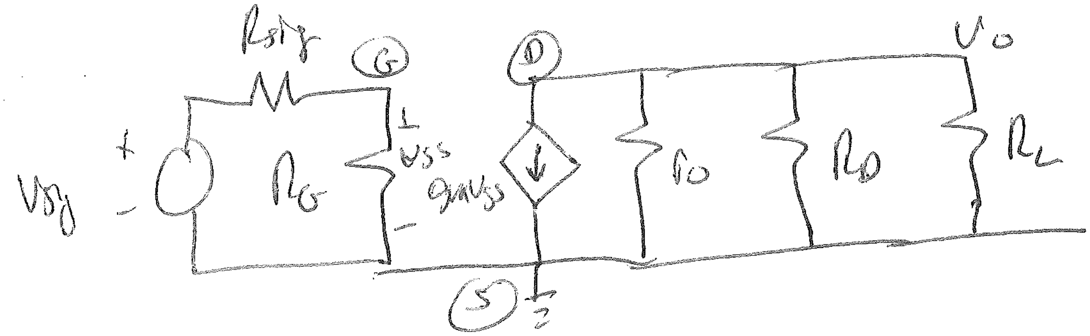
$R_G = 2M\Omega$, $g_m = 5mA/V$ $r_o = 100k\Omega$ $R_D = 20k\Omega$

$C_{gs} = 3pF$ $C_{gd} = 0.5pF$

$R_{sig} = 500k\Omega$ $R_L = 20k\Omega$.



→ small-signal at mid-band all C → shorted.



$$\text{Overall gain} = \frac{V_o}{V_{sig}} = \frac{V_{gs}}{V_{sig}} \frac{V_o}{V_{gs}}$$

$$V_o = -g_m \cdot V_{gs} \cdot (r_o \| R_D \| R_L)$$

$$V_{gs} = V_{sig} \cdot \frac{R_G}{R_G + R_{sig}}$$

$$A_m = \left(\frac{\cancel{V_{sig}} \frac{R_G}{R_G + R_{sig}}}{\cancel{V_{sig}}} \right) \left(\frac{-g_m \cdot \cancel{V_{gs}} (r_o \| R_D \| R_L)}{\cancel{V_{gs}}} \right)$$

$$A_M = \left(\frac{R_G}{R_G + R_{sig}}\right)\left(-g_m\left(R_D \| r_o \| R_L\right)\right)$$

$R_G = 2M\Omega$

$R_{sig} = 500k\Omega$

$R_D = 20k\Omega$

$r_o = 100k\Omega$

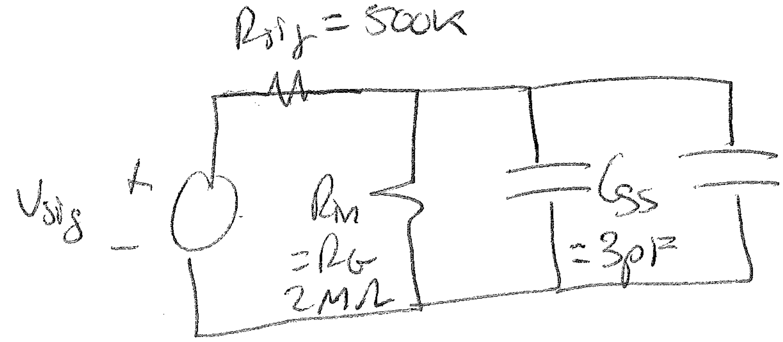
$R_L = 20k\Omega$

$g_m = 5mA/V$

$$A_M = \underbrace{\left(\frac{2M\Omega}{2M\Omega + 500k\Omega}\right)}_{0.8}\left(-5mA/V\,\underbrace{\left(20k \| 20k \| 100k\right)}_{9.1k.}\right)$$

$$A_M = -36.4\, V/V$$

(b) f_H



$C_M = C_{gd}(1 + g_m R_{eq})$

$C_M = 0.5pF(1 + 5mA/V \cdot 9..)$

$C_M = 23.25pF$

$$f_H = \frac{1}{2\pi\left(R_{sig} \| R_G\right)\left(C_{gs} + C_M\right)}$$

$$f_H = \frac{1}{2\pi\left(400k\Omega\right)\left(26.25pF\right)} = 15.2kHz$$

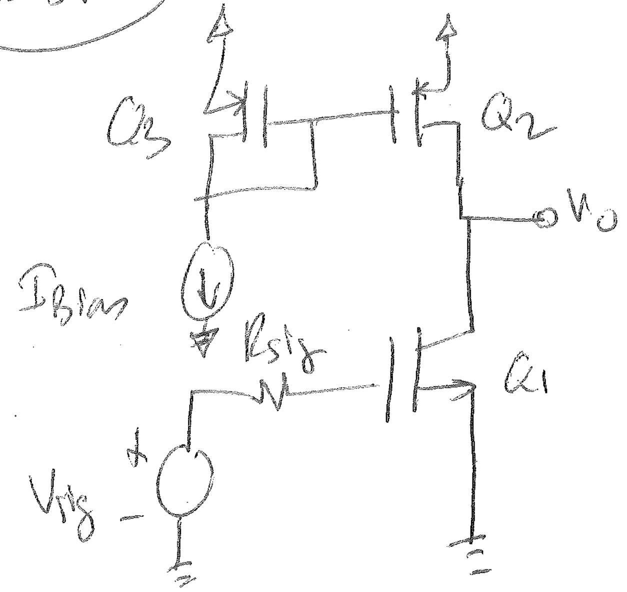
(c) $$f_Z = \frac{g_m}{2\pi C_{gd}} = \frac{5mA/V}{2\pi \cdot 0.5pF} = 1.6GHz.$$

Transmission zero at $\omega_Z = \frac{g_m}{C_{gd}}.$

HW-8_Solution-4

4 Ivan Puchades
11/14/2016

10.34



$I_{Bias} = 100\mu A$

$Q_2 = Q_3 \Rightarrow V_A = 19.2V$ ~~$\mu_n C_{ox} = 90\mu A/V^2$~~

$R_{sig} = 200k\Omega$

$Q_1: \mu_n C_{ox} = 90\mu A/V^2$

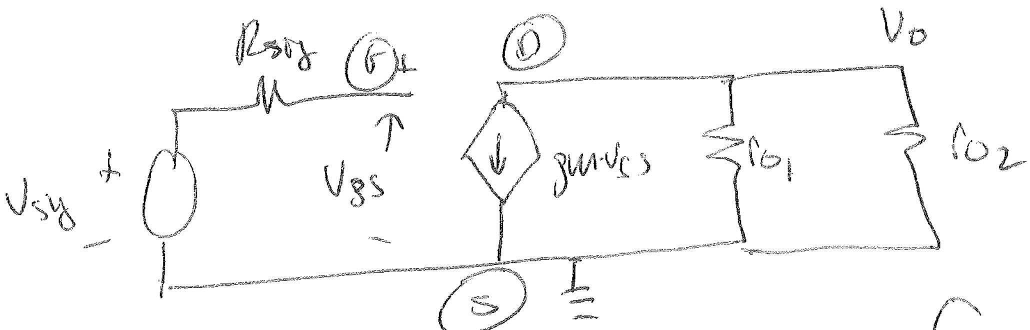
$V_A = 12.8V$

$W/L = 100\mu m / 1.6\mu m$

$C_{gs} = 0.2pF$

$C_{gd} = 0.015pF$

Small-signal gain at mid-freq



$V_o = -g_m \cdot V_{gs} \cdot (r_{o1} \| r_{o2})$

$V_{gs} = V_{sig}$

$\frac{V_o}{V_{sig}} = -g_m \underbrace{(r_{o1} \| r_{o2})}_{76.8k\Omega}$

$\rightarrow \boxed{\frac{V_o}{V_{sig}} = -81.4 \; V/V}$

$\rightarrow f_H$

$g_m = \sqrt{2\mu_n C_{ox}\left(\frac{W}{L}\right) I_{D1}}$

$g_m = \sqrt{2 \times 90\mu A/V^2 \cdot \frac{100}{1.6} \cdot 100\mu A}$

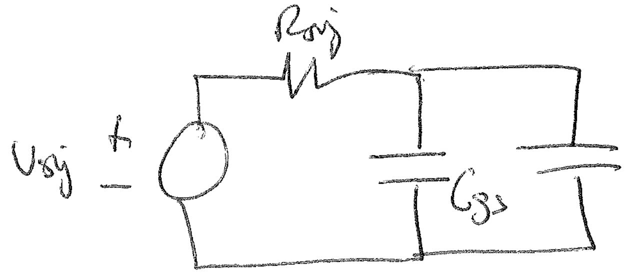
$g_m =$ ~~$0.335 mS$~~ $1.06 mA/V$

$r_{o1} = \frac{V_A}{I_D} = \frac{12.8V}{100\mu A} = 128k\Omega$

$r_{o2} = \frac{V_A}{I_D} = \frac{19.2}{100\mu A} = 192k\Omega$

→ High-frequency analysis:

<u>Input side:</u>



$C_M = C_{gd}(1 + g_m R_{eq})$

$C_{gd} = 0.015\,pF$

$C_{gs} = 0.2\,pF$

$g_m = 1.06\,mA/V$

$R_{eq} = (r_{o2} \,//\, r_{o1})$
$= 76.8\,k\Omega$

$R_{sig} = 200\,k\Omega$

$C_M = 0.015pF(1 + 81.4)$

$C_M = 1.236\,pF$

$$f_H = \frac{1}{2\pi \cdot RC} = \frac{1}{2\pi(R_{sig})(C_{gs} + C_M)}$$

$$f = \frac{1}{2\pi(200k\Omega)(1.436pF)}$$

$$\boxed{f = 554\,kHz}$$

→ Zero transmission

$$\boxed{f_z = \frac{1 \cdot g_m}{2\pi\, C_{gd}} = \frac{1.06\,mA/V}{2\pi \cdot 0.015pF} = 11.24\,GHz}$$