9.17 $g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.1}{0.2} = 1 \text{ mA/V}$

$$f_T = \frac{g_m}{2\pi\,(C_{gs} + C_{gd})} = \frac{1 \times 10^{-3}}{2\pi\,(20 + 5) \times 10^{-15}}$$

$= 6.3$ GHz

9.20 The intrinsic gain A_O is

$$\equiv g_m \cdot r_O = \left(\frac{2I_D}{V_{OV}}\right) \cdot \left(\frac{V_A}{I_D}\right) = \frac{2V_A}{V_{OV}} \text{ and}$$

$$V_A = V_A' \cdot L = 5 \text{ V/}\mu\text{m} \times L$$

$$A_O = \frac{2 \times 5[\text{V}/\mu\text{m}] \cdot L}{0.2[\text{V}]} = 50 \times L \text{ V/V with}$$

L in mm.

* From problem 9.19

$$f_T = \frac{3\mu_n V_{OV}}{4\pi \cdot L^2} = \frac{3 \times 450\left[\frac{\text{cm}^2}{\text{V} \cdot \text{S}}\right] \cdot 0.2[\text{V}]}{4\pi L^2}$$

$$= \frac{2.15 \times 10^{-3}}{L^2}$$

$$L_{\min} = 0.18 \times 10^{-6} \text{ m}$$

	$1\,L_{\min}$	$2\,L_{\min}$	$3\,L_{\min}$	$4\,L_{\min}$	$5\,L_{\min}$
A_O [V/V]	9	18	27	36	45
f_T[GHz]	66.35	16.59	7.37	4.14	2.65

9.29 $C_{\text{in}} = C_{gs} + C_{eq}$

$$= C_{gs} + C_{gd}\,(1 + g_m R_L')$$

$$= 0.5 + 0.1(1 + 29) = 3.5 \text{ pF}$$

Neglecting R_G:

$$f_H = \frac{1}{2\pi \cdot C_{\text{in}} \cdot R_{\text{sig}}} \quad \text{i.e } R_G \text{ is very large if}$$

$$f_H > 10 \text{ MHz} \Rightarrow \frac{1}{2\pi \cdot 3.5 \times 10^{-12} \times 10^6} > R_{\text{sig}}$$

$$\Rightarrow R_{\text{sig}} < 4.55 \text{ k}\Omega$$

9.33 $R_G = 1 \text{ M}\Omega,\ g_m = 5 \frac{\text{mA}}{\text{V}},$

$r_o = 100 \text{ k}\Omega,\ R_D = 10 \text{ k}\Omega$

$C_{gs} = 2 \text{ pF},\ C_{gd} = 0.4 \text{ pF},\ R_{\text{sig}} = 500 \text{ k}\Omega,$

$R_L = 10 \text{ k}\Omega$

a) Using Eq. 9.44 where $R_L' = r_o \,\|\, R_D \,\|\, R_L$

$$A_M = \frac{-R_G}{R_G + R_{\text{sig}}} \cdot g_m(r_o \,\|\, R_D \,\|\, R_L)$$

$$= \frac{-1 \times 5}{1 + 0.5}(100 \text{ K} \,\|\, 10 \text{ K} \,\|\, 10 \text{ K})$$

$$A_M = -15.9 \text{ V/V}$$

b) Eq. 9.54: $f_H = \frac{1}{2\pi \cdot C_{\text{in}} \cdot R'_{\text{sig}}}$ where

$$C_{\text{in}} = C_{gs} + C_{gd}(1 + g_m\,(r_o \,\|\, R_D \,\|\, R_L))$$

$$= 2 + 0.4(1 + 5(100 \,\|\, 10 \,\|\, 10)) = 11.9 \text{ pF}$$

$$R'_{\text{sig}} = R_{\text{sig}} \,\|\, R_G = 0.5 \text{ M} \,\|\, 1 \text{ M} = 333.3 \text{ k}\Omega$$

$$f_H = \frac{1}{2\pi \cdot 11.9 \times 10^{-12} \times 333.3 \times 10^3}$$

$= 40.1$ KHz

9.35 If $g_m = 1 \frac{\text{mA}}{\text{V}}$ and $r_o = 100 \text{ k}\Omega$:

$$A_M = \frac{R_G}{R_G + R_{\text{sig}}} g_m(r_o \,\|\, R_D \,\|\, R_L) \text{ where}$$

$$R_G = 10 \text{ M} \,\|\, 47 \text{ M}$$

$$R_G = 8.25 \text{ M}\Omega$$

$$A_M = -\frac{8.25}{8.25 + 0.1} 1(100 \text{ K} \,\|\, 4.7 \text{ K} \,\|\, 10 \text{ K})$$

$= -3.06$ V/V

$$f_H = \frac{1}{2\pi C_{\text{in}} R'_{\text{sig}}} \text{ where}$$

$$R'_{\text{sig}} = R_{\text{sig}} \,\|\, R_G = 0.1 \text{ M} \,\|\, 8.25 \text{ M}\Omega$$

$$R'_{\text{sig}} \cong 0.1 \text{ M}\Omega$$

$$C_{\text{in}} = C_{gs} + C_{gd}(1 + g_m\,(r_o \,\|\, R_D \,\|\, R_L))$$

$$C_{\text{in}} = 1 + 0.2(1 + 1(100 \text{ K} \,\|\, 4.7 \text{ K} \,\|\, 10 \text{ K}))$$

$= 1.82$ pF

$$f_H = \frac{1}{2\pi \times 1.82 \times 10^{-12} \times 0.1 \times 10^6}$$

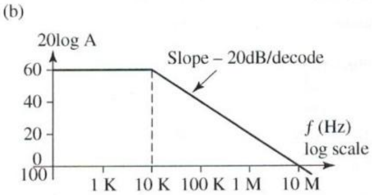
$= 875$ KHz

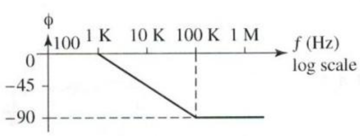
9.44

a) Gain $A = 60$ dB $= 1000$

$$A(s) = \frac{1000}{\left(1 + \frac{1}{2\pi \times 10 \times 10^3}\right)} = \frac{1000}{\left(1 + \frac{1}{2\pi \times 10^4}\right)}$$

(b)

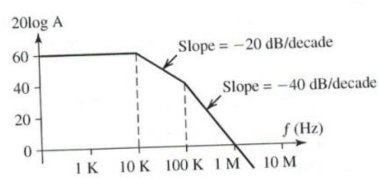




(c) Gain-bandwidth product = 1000 × 10 K
= 10 MHz

(d) From the gain plot, unity gain frequency = 10 MHz

(e) From the plot unity gain frequency = 1 MHz



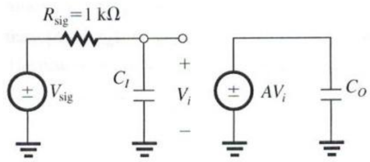
9.57 Using Miller's therem Eq. 9.76

$$Z_1 = \frac{Z}{1-K} \Rightarrow C_I = 0.2 \times (1-(-1000))$$

$$\Rightarrow C_I = 200.2 \text{ pF}$$

$$C_O = 0.2 \times \left(\frac{-1}{1000} + 1\right)$$

$$= 199.8 \text{ fF}$$



$$v_O = A v_i = A \cdot v_{sig} \frac{1/C_I s}{R_{sig} + \dfrac{1}{C_I \cdot s}}$$

$$\Rightarrow \frac{v_O}{v_{sig}} = \frac{A}{1 + C_I R_{sig} \cdot s}$$

$$\omega_H = \frac{1}{C_I R_{sig}} = \frac{1}{200.2\text{pF} \times 1 \text{ k}\Omega} = 4.99 \text{ M rad/s}$$

$$\Rightarrow f_H = 795 \text{ KHz}$$

9.60 $A_M = -g_m \cdot R_L' = -4 \times 20$

$$= -80 \text{ V/V}$$

$$C_{in} = C_{gs} + C_{gd}(1 + g_m \cdot R_L')$$

(See Example 9.8)

$C_{in} = 2 + 0.1\,(1 + 4 \times 20) = 10.1$ pF

$$f_H \simeq \frac{1}{2\pi C_{in} \cdot R_{sig}'}$$

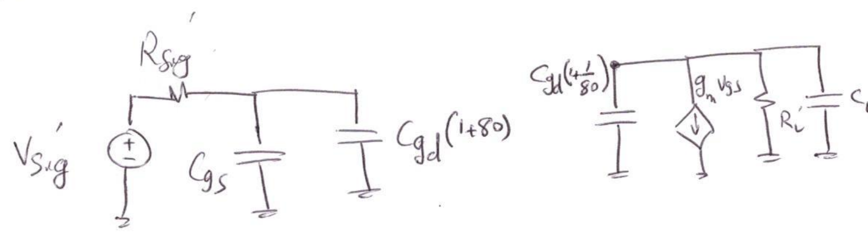
$$= \frac{1}{2\pi \times 10.1 \times 10^{-12} \times 20 \times 10^3} = 788 \text{ KHz}$$

Note : The Miller approximation consists on reflecting C_{gd} towards the input using the Miller theorem, but neglecting the effect of C_L and of C_{gd} reflected towards the load.

Question 9.60

$A_m = -80$

Using Miller's Theorem, we have:



$$f_{in} = \frac{1}{2\pi C_{in} R_{sig}'} = \frac{1}{2\pi(2+(0.1)(1+80)) \times 20^k} = 788^{kHz}$$

$$f_{out} = \frac{1}{2\pi C_{out} \cdot R_L'} = \frac{1}{2\pi\left(2+(0.1)\times\left(1+\frac{1}{80}\right)\right)\times 20^k} = 3.79^{MHz}$$

9.79 $R_O = 2r_O + (g_m r_O)r_O = 2 \times 50\ \text{k}\Omega$

$+ (1 \times 50) \times 50\ \text{k}\Omega = 2.6\ \text{M}\Omega$

$A_V = -g_m(R_O \| R_L) = -1\ \text{m}(2.6\ \text{M} \| 2\ \text{M})$

$= -1130\ \frac{\text{V}}{\text{V}}$

$A_V = -1130\ \frac{\text{V}}{\text{V}}$

$R_{\text{in2}} = \frac{r_O + R_L}{g_m r_O} = \frac{50\ \text{k}\Omega + 2\ \text{M}\Omega}{1 \times 50} = 41\ \text{k}\Omega$

$R_{d1} = r_O \| R_{\text{in2}} = 50\ \text{k}\Omega \| 41\ \text{k}\Omega = 22.5\ \text{k}\Omega$

$\tau_H = R_{\text{sig}}[C_{gs} + C_{gd}(1 + g_m R_{d1})]$

$+ R_{d1}(C_{gd} + C_{db} + C_{gs})$

$+ (R_L \| R_o)(C_L + C_{db} + C_{gd})$

$\tau_H = 100\ \text{K} \times [30\ \text{f} + 10\ \text{f}(1 + 1 \times 22.5)]$

$+ 22.5\ \text{K} \times [10\ \text{f} + 10\ \text{f} + 30\ \text{f}]$

$+ (2\ \text{M} \| 2.6\ \text{M}) \times [40\ \text{f} + 10\ \text{f} + 10\ \text{f}]$

$\tau_H = 26.5\ \text{ns} + 1.125\ \text{ns} + 67.8\ \text{ns} = 95.42\ \text{ns}$

$f_H = \frac{1}{2\pi\tau_H} = 1.67\ \text{MHz}$

9.85 $R_O = r_O \| \frac{1}{g_m} = 20\ \text{K} \| \frac{1}{5\ \text{m}}$

$= 198\ \Omega$

$R_L' = R_L \| r_O = 2\ \text{K} \| 20\ \text{K} = 1.82\ \text{k}\Omega$

$A_M = \frac{g_m R_L'}{1 + g_m R_L'} = \frac{5 \times 1.82}{1 + 5 \times 1.82} = 0.9\ \frac{\text{V}}{\text{V}}$

$f_Z = \frac{g_m}{2\pi \cdot C_{gs}} = \frac{1}{2\pi} \times \frac{5\ \text{m}}{2\ \text{p}} = 398\ \text{MHz}$

$R_{gd} = R_{\text{sig}} = 20\ \text{k}\Omega$

$R_{gs} = \frac{R_{\text{sig}} + R_L'}{1 + g_m R_L'} = \frac{20\ \text{k}\Omega + 1.82\ \text{k}\Omega}{1 + 5 \times 1.82} = 2.16\ \text{k}\Omega$

$R_{CL} = R_L \| R_O = 2\ \text{k}\Omega \| 198\ \text{k}\Omega = 180\ \Omega$

$\tau_{gd} = R_{gd} \times C_{gd} = 20\ \text{k}\Omega \times 0.1\ \text{pF} = 2\ \text{ns}$

$\tau_{gs} = R_{gs} \times C_{gs} = 2.16\ \text{k}\Omega \times 2\ \text{pF} = 4.32\ \text{ns}$

$\tau_{CL} = R_{CL} \times C_L = 180 \times 1\ \text{p} = 0.18\ \text{ns}$

$\tau_H = \tau_{gd} + \tau_{gs} + \tau_{CL} = 6.5\ \text{ns}$

$\Rightarrow f_H = \frac{1}{2\pi\tau_H} = \frac{1}{2\pi \times 6.5\ \text{ns}} = 24.5\ \text{MHz}$