Homework 8 – Due 11/16/2016

Problems (not review questions): 10.1, 10.3, 10.5, 10.32, 10.34

Solutions for 10.1, 10.3 and 10.5 are in book_soulutions.pdf on mycourses

For 10.32, 10.34 use the following equation to find transmission zero frequency → *fz = gm / (2*pi*C_{gd})*

Solutions for 10.32: A_M = -36.4 V/V, f_H = 15.2 kHz, f_Z = 1.6 GHz

Solutions for 10.34: A_M = -81 V/V, f_H = 554 kHz, f_Z = 11.2 GHz

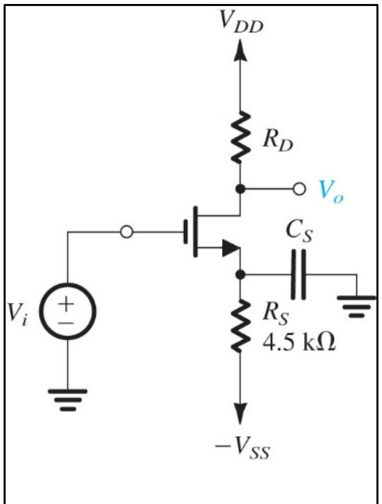

Figure P10.5

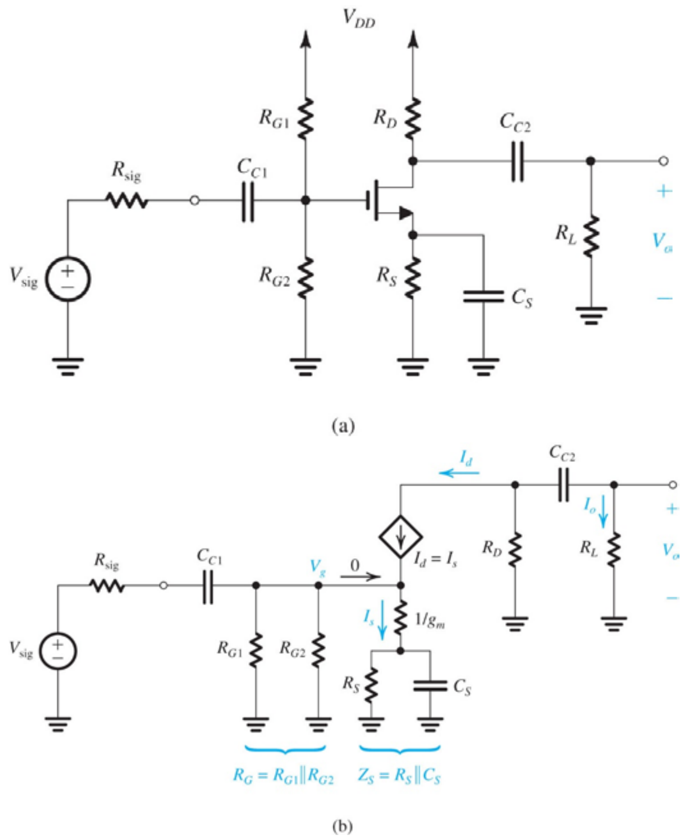

Figure 10.3 (**a**) Capacitatively coupled common-source amplifier. (**b**) The amplifier equivalent circuit at low frequencies. Note that the T model is used for the MOSFET and r_o is neglected.

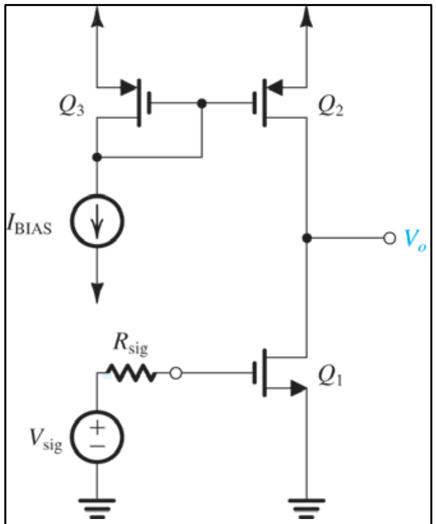

Figure P10.34

EE381 HOMEWORK FORMAT GUIDELINES

Things to remember

1) Re-Draw the Circuit on your homework sheet.
2) Show all work.
3) Final answer should be in decimal form.
4) Final answers should be boxed.
5) Your name should be on every page.

10.1 Refer to Fig. 10.3(b).

$$\frac{V_g}{V_{\text{sig}}} = \frac{R_G}{R_G + R_{\text{sig}} + \dfrac{1}{sC_{C1}}}$$

where

$R_G = R_{G1} \parallel R_{G2} = 2\ \text{M}\Omega \parallel 1\ \text{M}\Omega = 667\ \text{k}\Omega$

and

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

$$\frac{V_g}{V_{\text{sig}}} = \frac{R_G}{R_G + R_{\text{sig}}}\ \frac{s}{s + \dfrac{1}{C_{C1}(R_G + R_{\text{sig}})}}$$

Thus,

$$f_{P1} = \frac{1}{2\pi C_{C1}(R_G + R_{\text{sig}})}$$

We required

$f_{P1} \leq 10\ \text{Hz}$

thus we select C_{C1} so that

$$\frac{1}{2\pi C_{C1}(R_G + R_{\text{sig}})} \leq 10$$

$$C_{C1} \geq \frac{1}{2\pi \times 10 \times (667 + 200) \times 10^3} = 18.4\ \text{nF}$$

$\Rightarrow C_{C1} = 20\ \text{nF}$

10.3 Refer to Fig. 10.3(b).

$$I_s = \frac{V_g}{\dfrac{1}{g_m} + Z_S}$$

$$I_s = \frac{g_m V_g Y_S}{Y_S + g_m}$$

$$\frac{I_s}{V_g} = \frac{g_m\left(\dfrac{1}{R_S} + sC_S\right)}{g_m + \dfrac{1}{R_S} + sC_S}$$

$$= g_m \frac{s + 1/C_S R_S}{s + \dfrac{g_m + 1/R_S}{C_S}}$$

Thus,

$$f_{P2} = \frac{g_m + 1/R_S}{2\pi C_S}$$

$$f_Z = \frac{1}{2\pi C_S R_S}$$

where

$g_m = 5$ mA/V and $R_S = 1.8$ kΩ

To make $f_{P2} \leq 100$ Hz,

$$\frac{g_m + 1/R_S}{2\pi C_S} \leq 100$$

$$\Rightarrow C_S \geq \frac{5 \times 10^{-3} + (1/1.8 \times 10^3)}{2\pi \times 100} = 8.8\ \mu\text{F}$$

Select $C_S = 10\ \mu$F.

Thus,

$$f_{P2} = \frac{5 \times 10^{-3} + (1/1.8 \times 10^3)}{2\pi \times 10 \times 10^{-6}} = 88.4\ \text{Hz}$$

and

$$f_Z = \frac{1}{2\pi \times 10 \times 10^{-6} \times 1.8 \times 10^3} = 8.84\ \text{Hz}$$

10.5

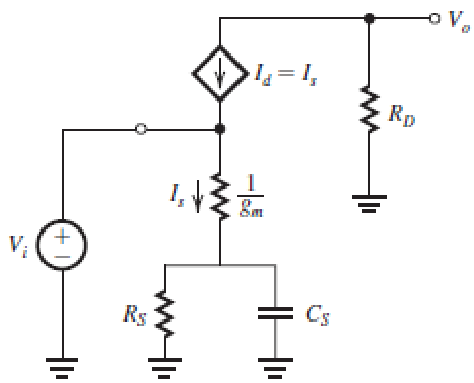

Figure 1

Replacing the MOSFET with its T model results in the circuit shown in Fig. 1.

(a) $A_M \equiv \frac{V_o}{V_i} = -g_m R_D$

$-20 = -2 \times R_D$

$\Rightarrow R_D = 10 \text{ k}\Omega$

(b) $f_P = \frac{g_m + 1/R_S}{2\pi C_S}$

$100 = \frac{2 \times 10^{-3} + (1/4.5 \times 10^3)}{2\pi C_S}$

$\Rightarrow C_S = 3.53 \ \mu\text{F}$

(c) $f_Z = \frac{1}{2\pi C_S R_S} =$

$\frac{1}{2\pi \times 3.53 \times 10^{-6} \times 4.5 \times 10^3} = 10 \text{ Hz}$

(d) Since $f_P \gg f_Z$,

$f_L \simeq f_P = 100 \text{ Hz}$

(e) The Bode plot for the gain is shown in Fig. 2.

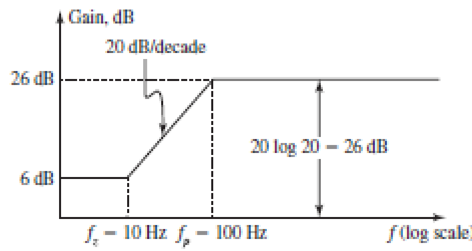

Figure 2

Observe that the dc gain is 6 dB, i.e. 2 V/V. This makes perfect sense since from Fig. 1 we see that at dc, capacitor C_S behaves as open circuit and the gain becomes

$$\text{DC gain} = -\frac{R_D}{\frac{1}{g_m} + R_S} = -\frac{10 \text{ k}\Omega}{\left(\frac{1}{2} + 4.5\right)}$$

$= -2$ V/V

10.32 (a) $A_M = -\frac{R_G}{R_G + R_{sig}} g_m R'_L$

where

$R'_L = R_D \parallel R_L \parallel r_o$

$= 20\text{ k}\Omega \parallel 20\text{ k}\Omega \parallel 100\text{ k}\Omega$

$= 9.1\text{ k}\Omega$

$A_M = -\frac{2\text{ M}\Omega}{2\text{ M}\Omega + 0.5\text{ M}\Omega} \times 5 \times 9.1$

$= -36.4\text{ V/V}$

(b) $f_H = \frac{1}{2\pi C_{in} R'_{sig}}$

where

$C_{in} = C_{gs} + C_{gd}(1 + g_m R'_L)$

$= 3 + 0.5(1 + 5 \times 9.1)$

$= 26.25\text{ pF}$

and

$R'_{sig} = R_{sig} \parallel R_G$

$= 500\text{ k}\Omega \parallel 2000\text{ k}\Omega$

$= 400\text{ k}\Omega$

Thus,

$f_H = \frac{1}{2\pi \times 26.25 \times 10^{-12} \times 400 \times 10^3}$

$= 15.2\text{ kHz}$

(c) $f_Z = \frac{g_m}{2\pi C_{gd}}$

$= \frac{5 \times 10^{-3}}{2\pi \times 0.5 \times 10^{-12}}$

$= 1.6\text{ GHz}$

10.34 $g_m = \sqrt{2\mu_n C_{ox}(W/L)_1 I_{D1}}$

$= \sqrt{2 \times 0.09 \times 100 \times 0.1}$

$= 1.34$ mA/V

$r_{o1} = \dfrac{|V_{A1}|}{I_{D1}} = \dfrac{12.8}{0.1} = 128\ \text{k}\Omega$

$r_{o2} = \dfrac{|V_{A2}|}{I_{D2}} = \dfrac{19.2}{0.1} = 192\ \text{k}\Omega$

The total resistance at the output node, R'_L, is given by

$R'_L = r_{o1} \parallel r_{o2} = 128\ \text{k}\Omega \parallel 192\ \text{k}\Omega$

$= 76.8\ \text{k}\Omega$

$A_M = -g_{m1}R'_L$

$= -1.34 \times 76.8 = -103$ V/V

$f_H = \dfrac{1}{2\pi C_{\text{in}} R_{\text{sig}}}$

where

$C_{\text{in}} = C_{gs} + C_{gd}(1 + g_{m1}R'_L)$

$= 0.2 + 0.015(1 + 103)$

$= 1.76$ pF

Thus,

$f_H = \dfrac{1}{2\pi \times 1.76 \times 10^{-12} \times 200 \times 10^3}$

$= 452$ kHz

$f_Z = \dfrac{g_m}{2\pi C_{gd}} = \dfrac{1.34 \times 10^{-3}}{2\pi \times 0.015 \times 10^{-12}}$

$= 14.2$ GHz