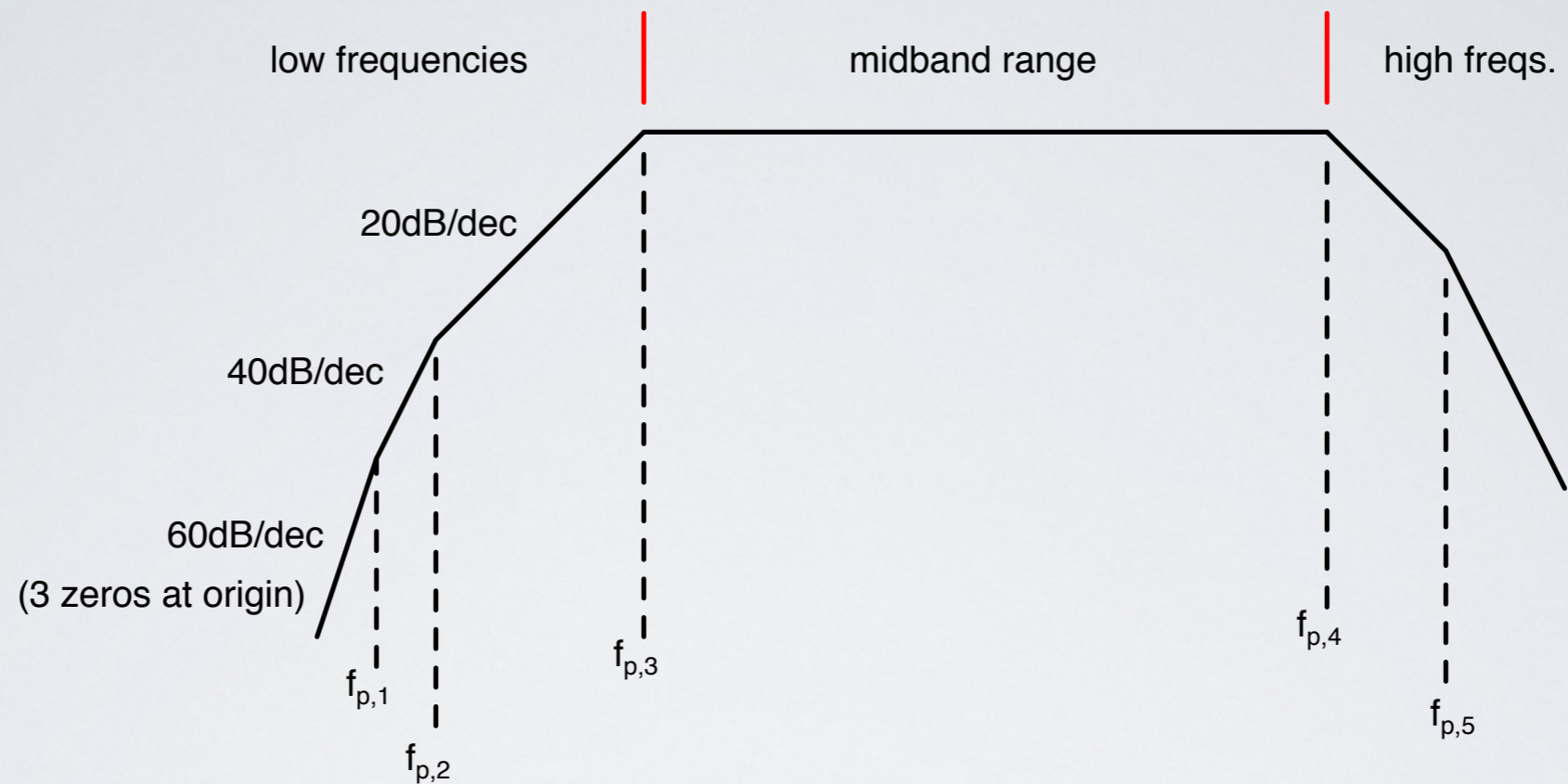


REPASO EXAMEN I

INEL4202 - Primer semestre 2012-2013

- Lugar: s228 de 8:00pm a 10:00pm
- Jueves 13 de septiembre
- Bate con formulas básicas será provisto
- No puede usar su propio bate
- Se permite el uso de calculadora

FREQUENCY RESPONCE



Midband gain

$$A(s) = A_M \left(\frac{s}{s + \omega_{p,1}} \right) \left(\frac{s}{s + \omega_{p,2}} \right) \left(\frac{s}{s + \omega_{p,3}} \right) \left(\frac{1}{s/\omega_{p,4} + 1} \right) \left(\frac{1}{s/\omega_{p,5} + 1} \right)$$

Low-frequency poles and zeros

High-frequency poles

BAJAS FRECUENCIAS

- Método complejo: reemplazar cada condensador externo por impedancia y analizar
- Método simplificado: desde los terminales de cada condensador
 - buscar resistencia equivalente R_{EQ}
 - calcular frecuencias de los polos

$$f_L = \frac{1}{2\pi R_{EQ}C}$$

- para condensador de bypass, calcular frecuencia del cero

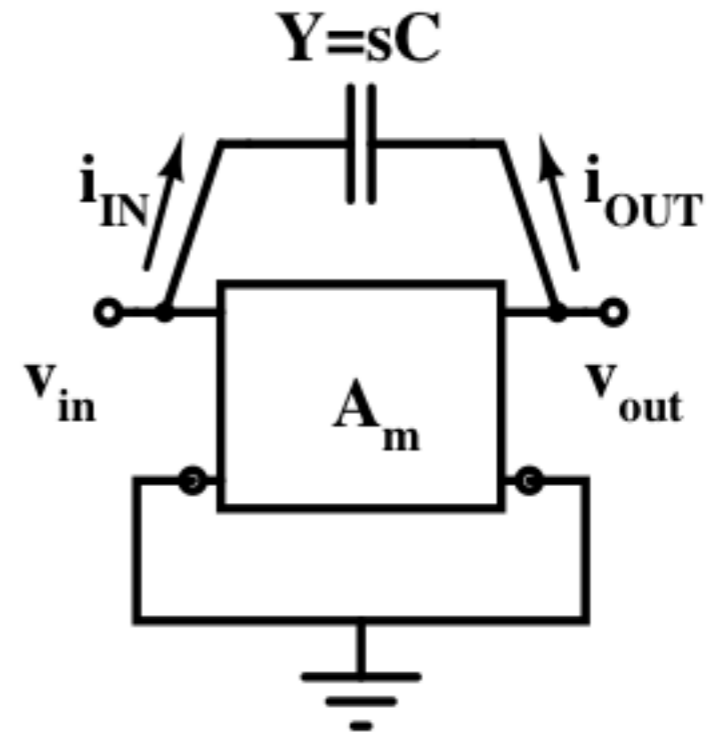
$$f_Z = \frac{1}{2\pi R_E C}$$

- frecuencia polo mas alta es la dominante y determina el ancho de banda si esta a mas de una decada de las demas. Si no sumar todos los polos para obtener una aproximación de la frecuencia de 3dB.

Efecto de Miller

Entrada

$$\begin{aligned}i_{IN} &= Y(v_{IN} - v_{OUT}) \\ &= sC(1 - A_M)v_{IN}\end{aligned}$$



Actúa como un condensador $C(1 - A_M)$

Salida

$$\begin{aligned}i_{OUT} &= Y(v_{OUT} - v_{IN}) \\ &= sC \left(1 - \frac{1}{A_M} \right) v_{OUT}\end{aligned}$$

FRECUENCIAS ALTAS - CE/CS

- Usar Miller para reemplazar C_μ con una capacitancia equivalente que aparece en paralelo con C_π

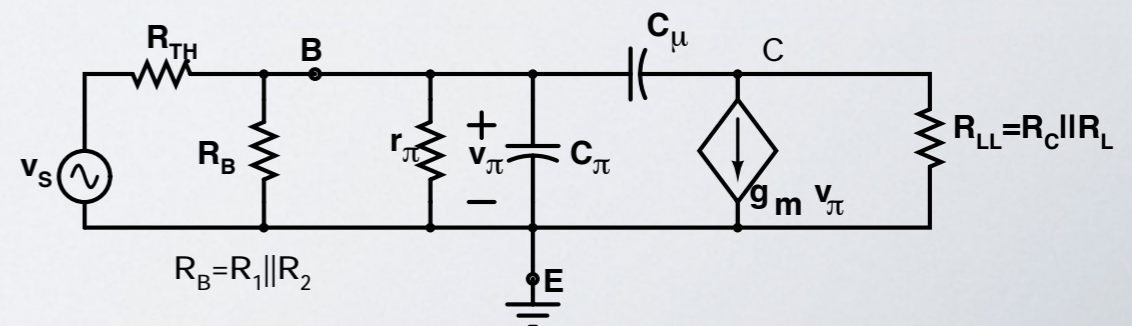
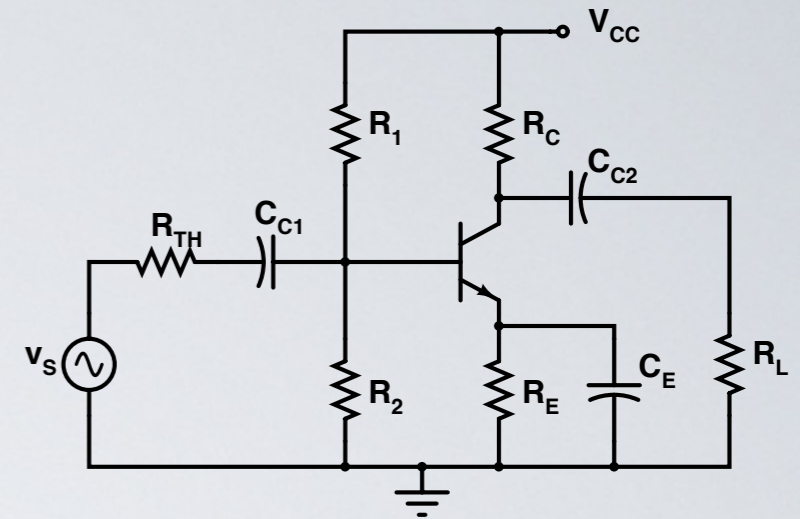
- $C_M = C_\pi + (1 - A_M)C_\mu$

- A_M es usualmente $-g_m R'_L$ para CE/CS

- $R'_L = R_L || R_C =$ carga equivalente en ac

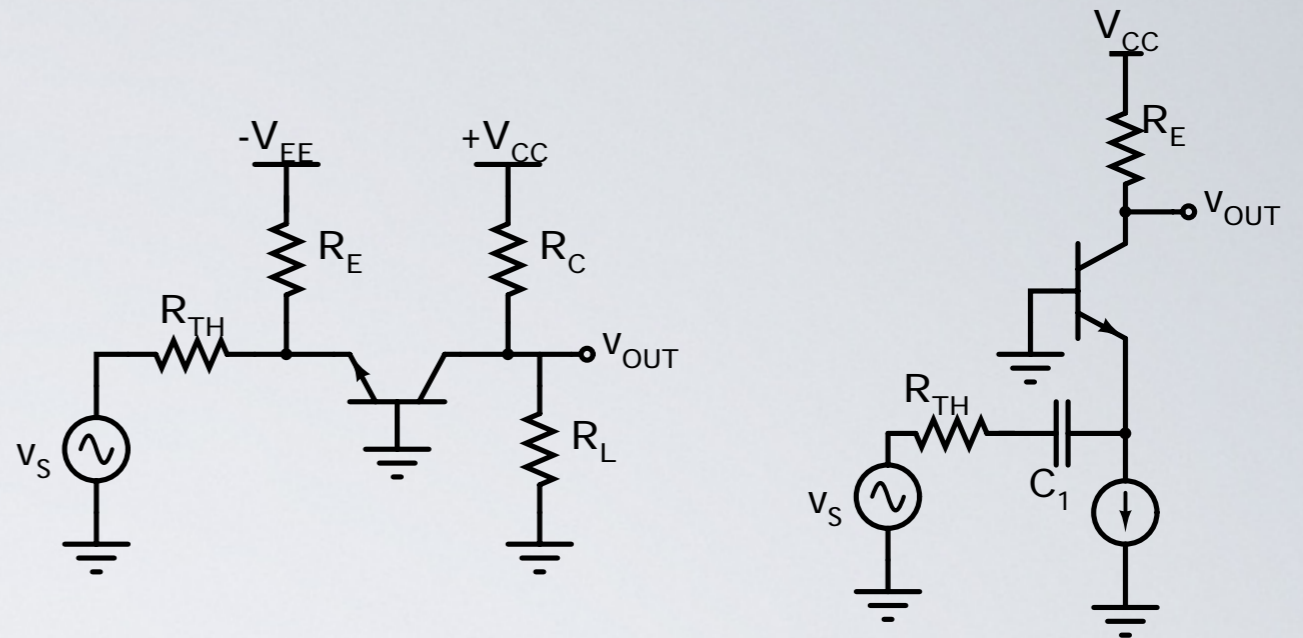
- Determine polo de alta frecuencia usando $f_H = \frac{1}{2\pi C_M R_{EQ}}$

- $R_{EQ} =$ res. equivalente desde terminales de C_M

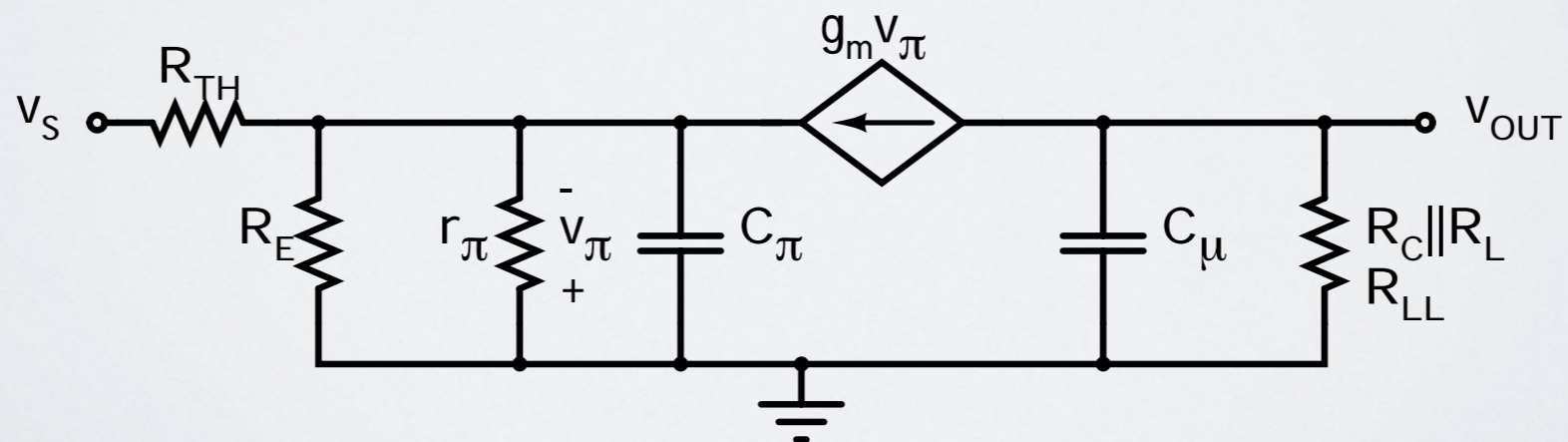


Common-base/-gate

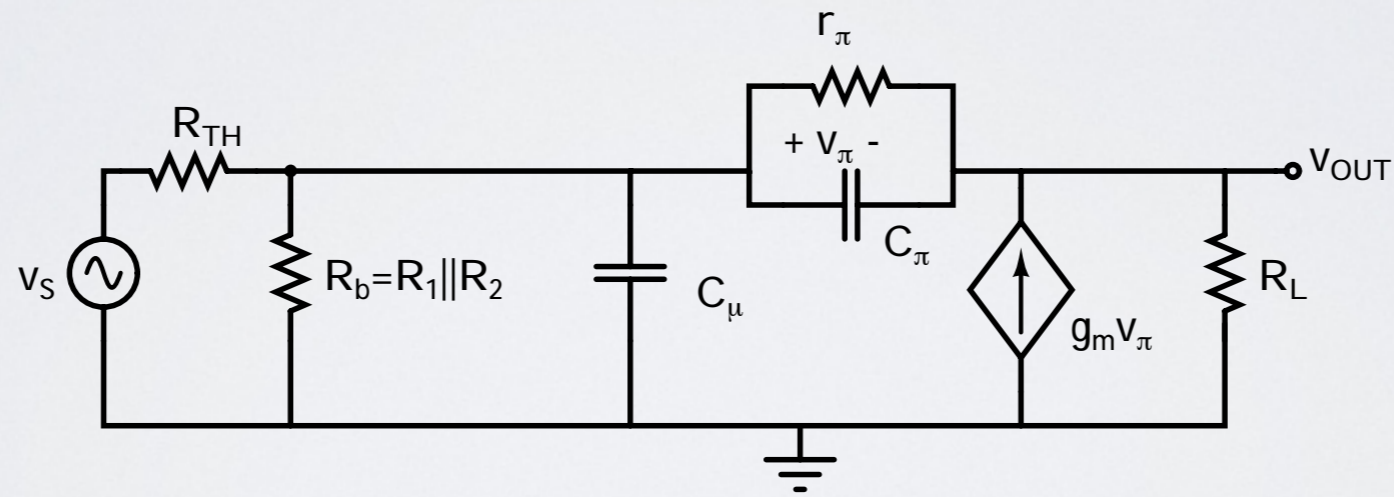
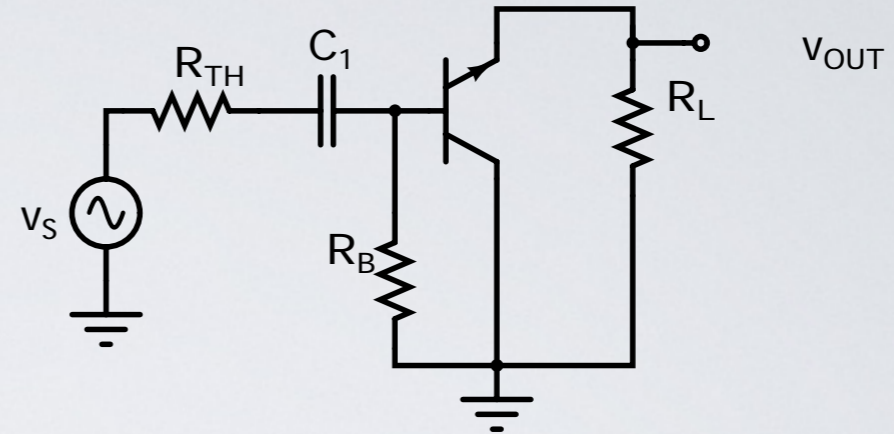
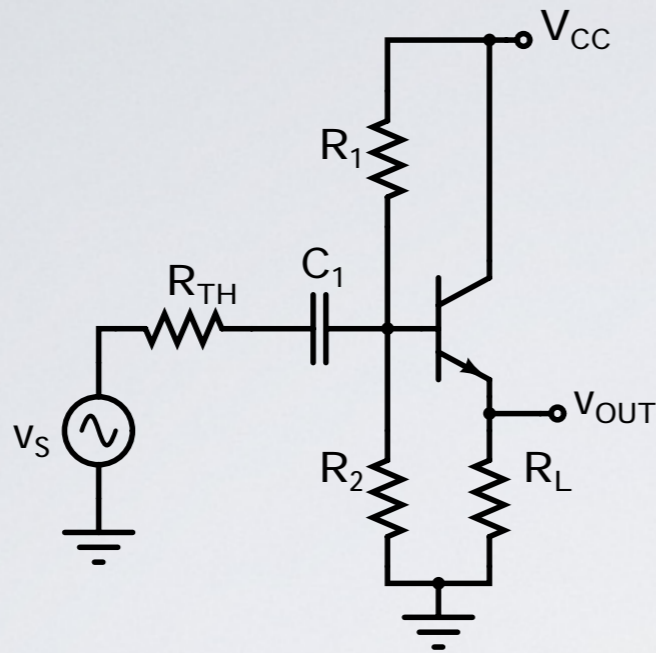
- $A_v = \frac{v_c}{v_e}$
- $C_\pi \rightarrow$ emisor a tierra
- $C_\mu \rightarrow$ colector a tierra
- dos polos



$$f_{H1} = \frac{1}{2\pi C_\mu R_{EQ,1}} \quad f_{H2} = \frac{1}{2\pi C_\pi R_{EQ,2}}$$



Common-collector/common-drain



FRECUENCIA DE GANANCIA UNITARIA

- f_t Unity-gain frequency
- frecuencia a la cual $\beta(s) = i_C/i_B = 1$
- concepto se usa tambien en los amplificadores operacionales
- mas facil de medir que C_π
- problemas pueden especificar f_t y C_μ . C_π se puede obtener como sigue:

$$f_t = \frac{\beta}{2\pi r_\pi (C_\pi + C_\mu)} = \frac{g_m}{2\pi (C_\pi + C_\mu)}$$
$$C_\pi = \frac{\beta}{2\pi r_\pi f_t} - C_\mu = \frac{g_m}{2\pi f_t} - C_\mu$$

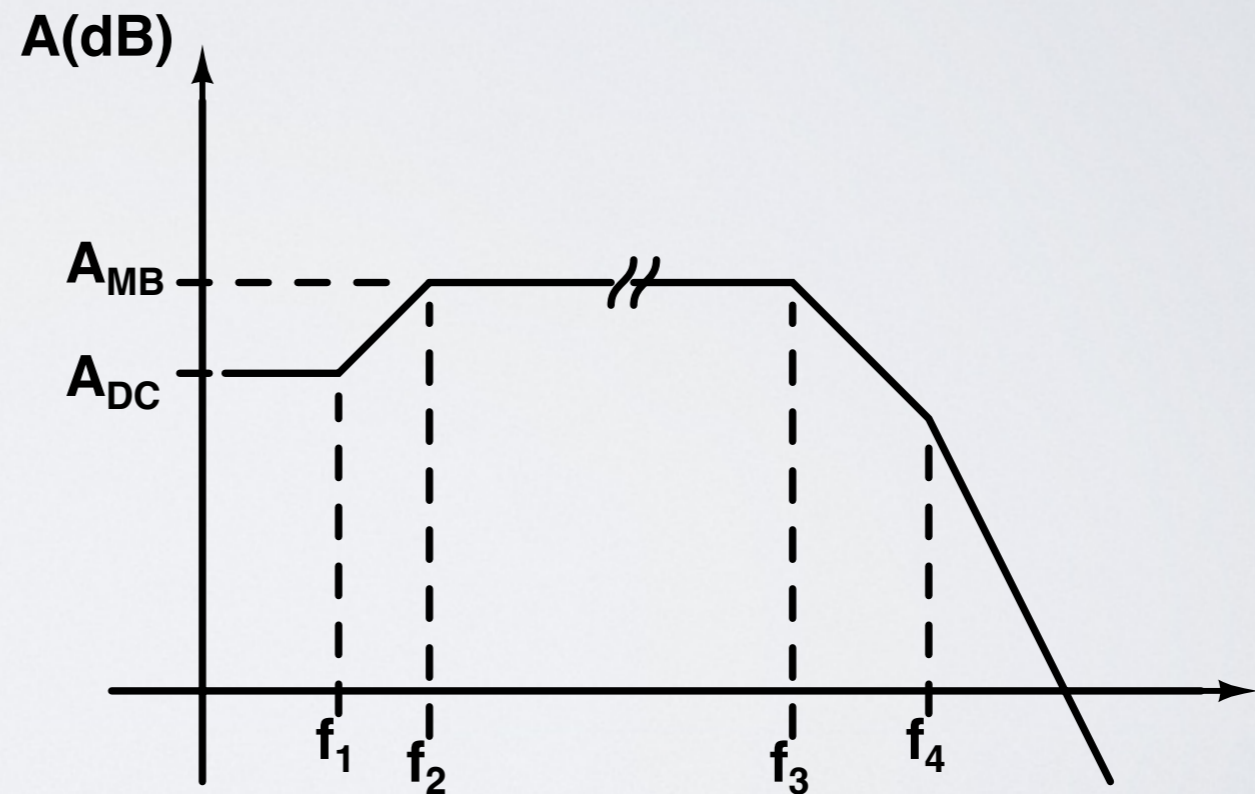
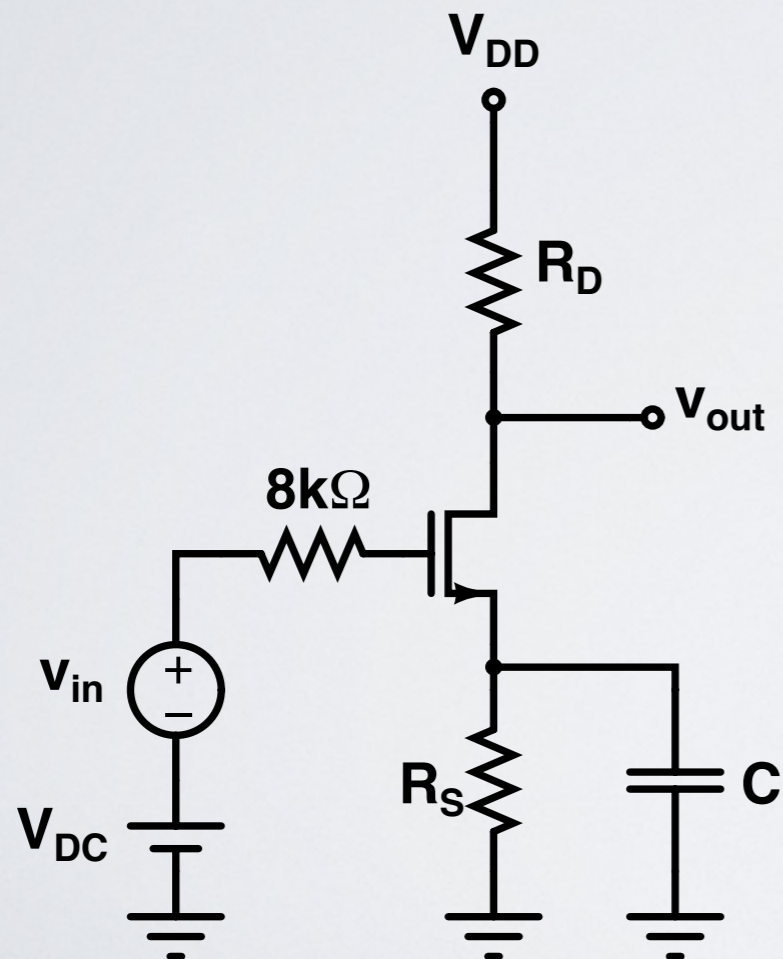
- Para el mosfet, use

$$f_t = \frac{g_m}{2\pi (C_{gs} + C_{gd})}$$

EJEMPLO

El siguiente amplificador produce una respuesta que puede aproximarse con el *Bode plot* que se muestra, donde $f_1 = 10Hz$, $f_2 = 100Hz$, $f_3 = 1MHz$ y $f_4 = 30MHz$. Si $I_{DQ} = 2mA$ y $K_N = 1mA/V^2$,

1. determine R_S y C .
2. calcule valores para C_{gs} y C_{gd} si $A_{MB} = 40dB$.



Respuesta

R_S y C .

Para el condensador de *bypass*,

$$\tau_p = R_{os}C$$

$$\tau_z = R_S C$$

donde $R_{os} = R_S \parallel 1/g_m$. Dado que el diagrama muestra que $\tau_z = 10\tau_p$

$$10 = \frac{\tau_z}{\tau_p} = \frac{R_S}{R_S \parallel 1/g_m} = \frac{R_S}{\frac{R_S/g_m}{R_S + 1/g_m}} = g_m R_S + 1$$

$$R_S = \frac{9}{g_m} = \frac{9}{2\sqrt{K_N I_{DQ}}} = \frac{9}{2.82\text{mA/V}} = \boxed{3.2\text{k}\Omega}$$

$$C = \frac{1}{2\pi \times 3.2\text{k}\Omega \times 10} \simeq \boxed{5\mu\text{F}}$$

C_{gs} y C_{gd} si $A_{MB} = 40dB$.

$$|A_{MB}| = 40dB = 100V/V = g_m R_C = 2.82mA/V \times R_D$$

$$R_D = 100/2.82k\Omega = 35.5k\Omega$$

Aplicando el teorema de Miller, en el *gate* tenemos un condensador equivalente igual a

$$C_{in} = C_{gs} + 101 \times C_{gd}$$

En el *drain*, tenemos otro condensador equivalente de valor aproximado igual a $C_{out} \simeq C_{gd}$. Las constantes de tiempo son

$$\tau_{in} = 8k\Omega(C_{gs} + 101 \times C_{gd})$$

y

$$\tau_{out} = 35.5k\Omega \times C_{gd}$$

Se puede observar que $\tau_{in} > \tau_{out}$, y por lo tanto τ_{in} debe estar asociado a f_3 . Consecuentemente,

$$30MHz = \frac{1}{2\pi C_{gd}R_D} \rightarrow C_{gd} = \frac{1}{2\pi \times 30 \times 10^6 \times 35460} = \boxed{0.15pF}$$

y

$$1MHz = \frac{1}{2\pi \times 10k\Omega(C_{gs} + 101 \times 0.15pF)}$$

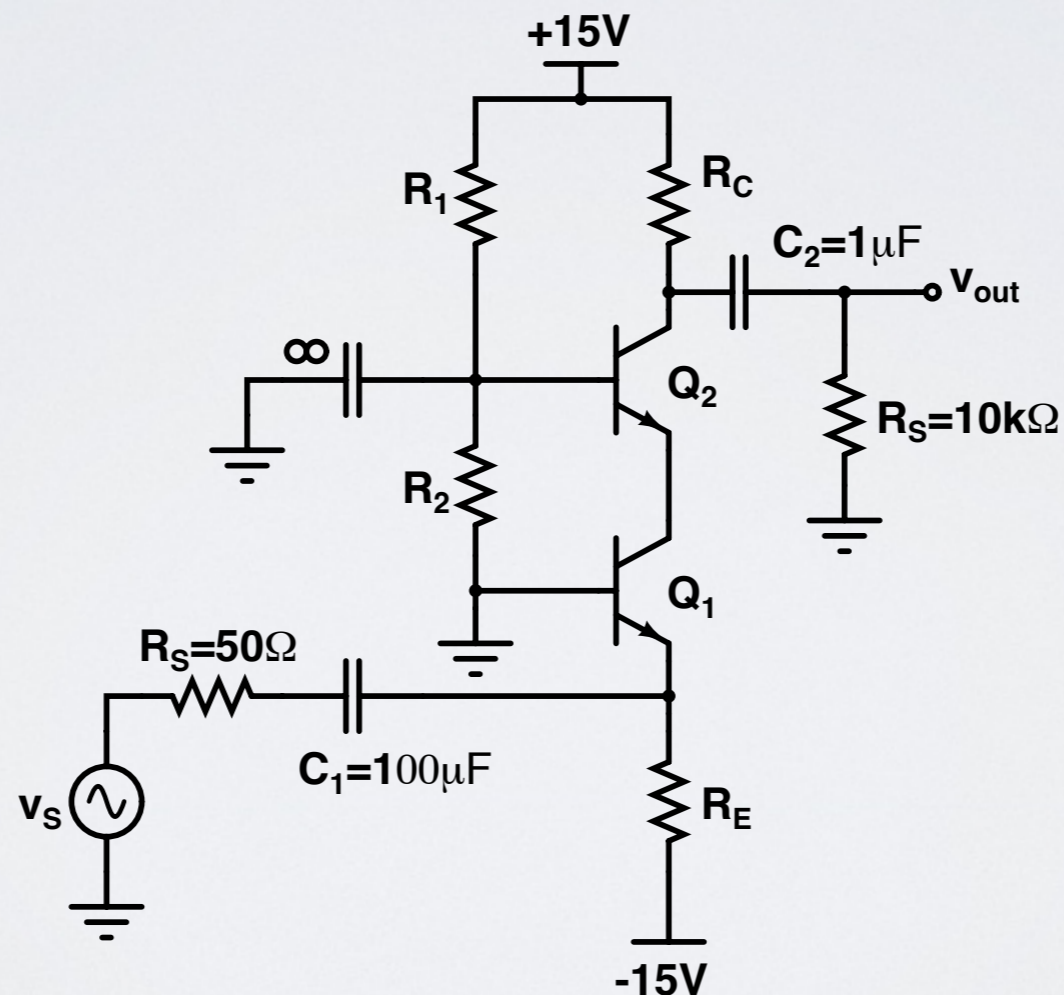
$$C_{gs} + 101 \times 0.15pF = \frac{1}{2\pi \times 8k\Omega \times 10^6} = 19.9pF = C_{gs} + 15.15pF$$

$$\boxed{C_{gs} = 4.7pF}$$

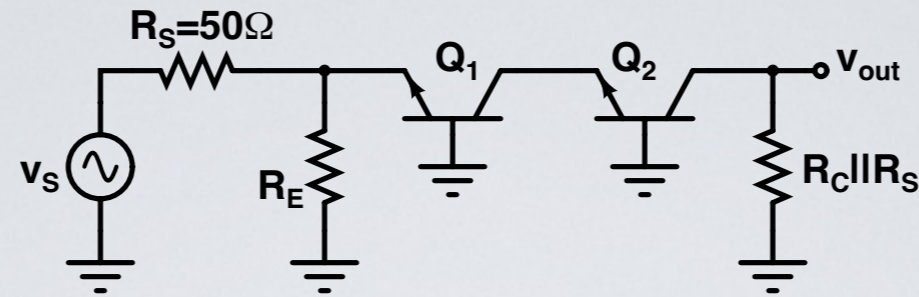
EJEMPLO

Para el siguiente amplificador, $R_1 = 10k\Omega$, $R_2 = 30k\Omega$, $R_C = 5k\Omega$, $R_E = 14.3k\Omega$, $h_{fe} = 100$, $C_\pi = 3pF$ y $C_\mu = 0.5pF$. Determine

1. la ganancia de frecuencias intermedias (*midband gain* A_{MB}),
2. las frecuencias de los polos de baja frecuencia, y
3. las frecuencias de los polos de alta frecuencia.



RESPUESTA



la ganancia de frecuencias intermedias (*midband gain* A_{MB}),

$$A_v = \frac{14.3k\Omega \parallel \frac{r_{\pi 1}}{h_{fe} + 1}}{14.3k\Omega \parallel \frac{r_{\pi 1}}{h_{fe} + 1} + 50} (g_{m1} \times \frac{r_{\pi 2}}{h_{fe} + 1}) (g_{m2} \times 3.33k\Omega)$$

$$I_{CQ1} = \frac{14.3V}{14.3k\Omega} = 1mA \simeq I_{CQ2}$$

$$g_{m1} \simeq g_{m2} = 40mA/V$$

$$r_{\pi 1} = r_{\pi 2} = 2.5k\Omega$$

$$A_v = \frac{14.3k\Omega \parallel \frac{2.5k}{101}}{14.3k\Omega \parallel \frac{2.5k}{101} + 50} (40mA/V \times \frac{2.5k}{101}) (40mA/V \times 3.33k\Omega)$$

$$\simeq \frac{24.75}{74.75} (1)(133.2) = \boxed{44.1V/V}$$

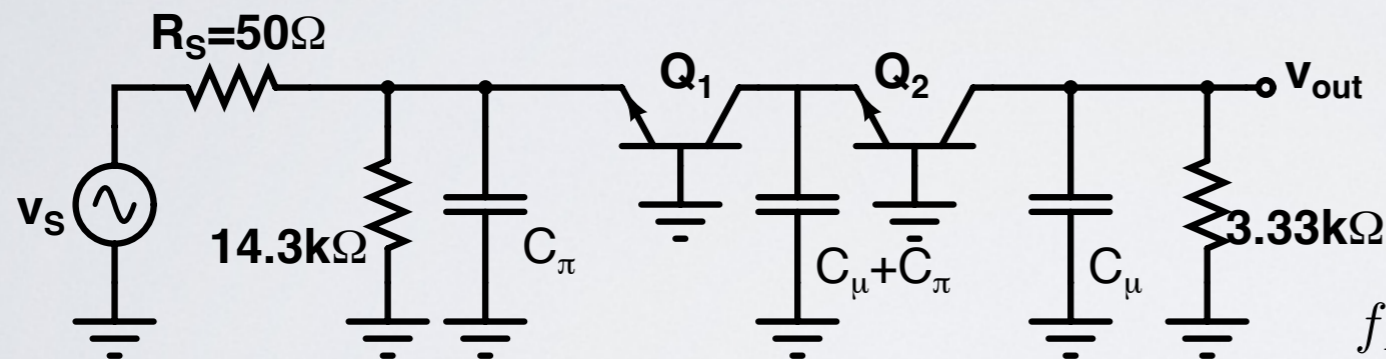
frecuencias de los polos de baja frecuencia, y
 Respuesta:

$$f_{L1} = \frac{1}{2\pi \times 100\mu F \times 74.75\Omega} = \boxed{21.3Hz}$$

$$f_{L2} = \frac{1}{2\pi \times 1\mu F \times 15k\Omega} = \boxed{10.6Hz}$$

frecuencias de los polos de alta frecuencia:

Podemos representar el circuito de alta frecuencia usando el circuito equivalente de frecuencias intermedias y condensadores C_π y C_μ externos,



$$f_{H1} = \frac{1}{2\pi C_\pi \times 50\Omega \parallel 24.75\Omega} = \boxed{3.2GHz}$$

$$f_{H2} = \frac{1}{2\pi (C_\pi + C_\mu) \times 24.75\Omega} = \boxed{1.8GHz}$$

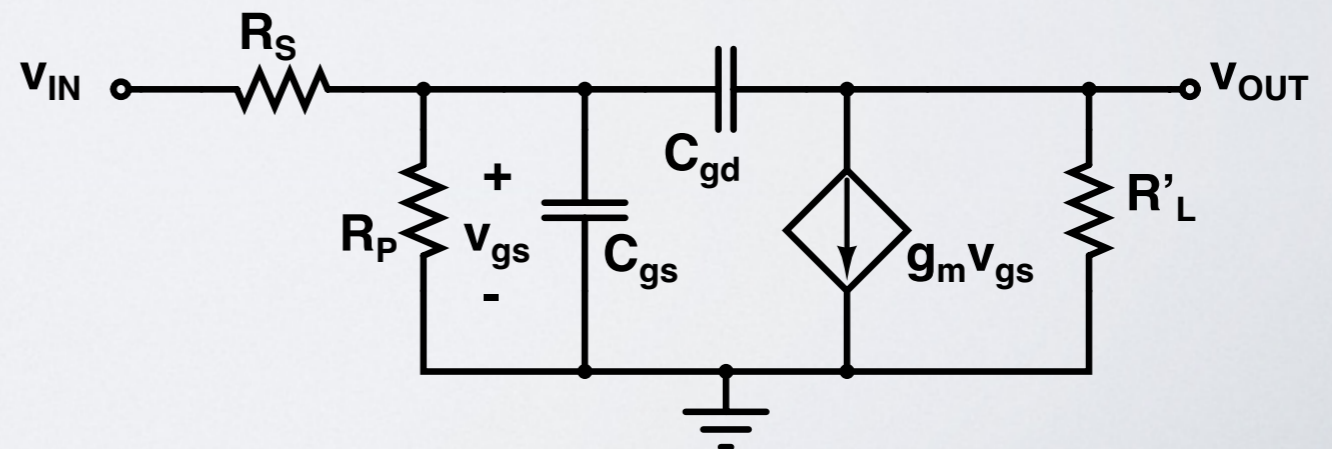
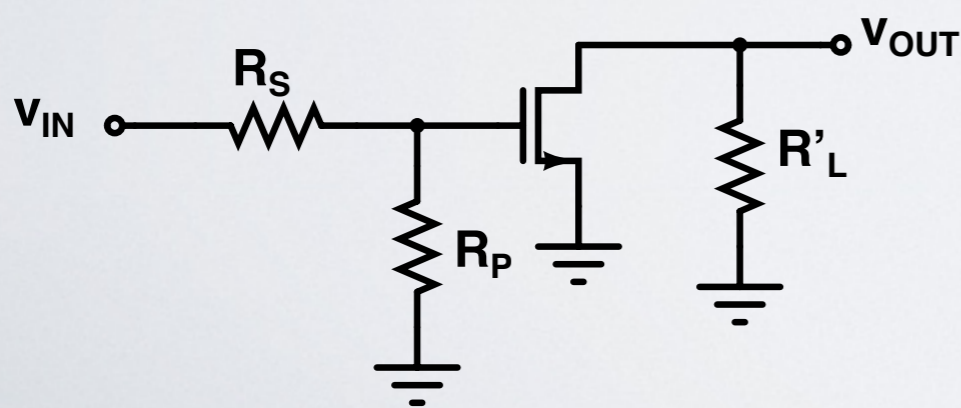
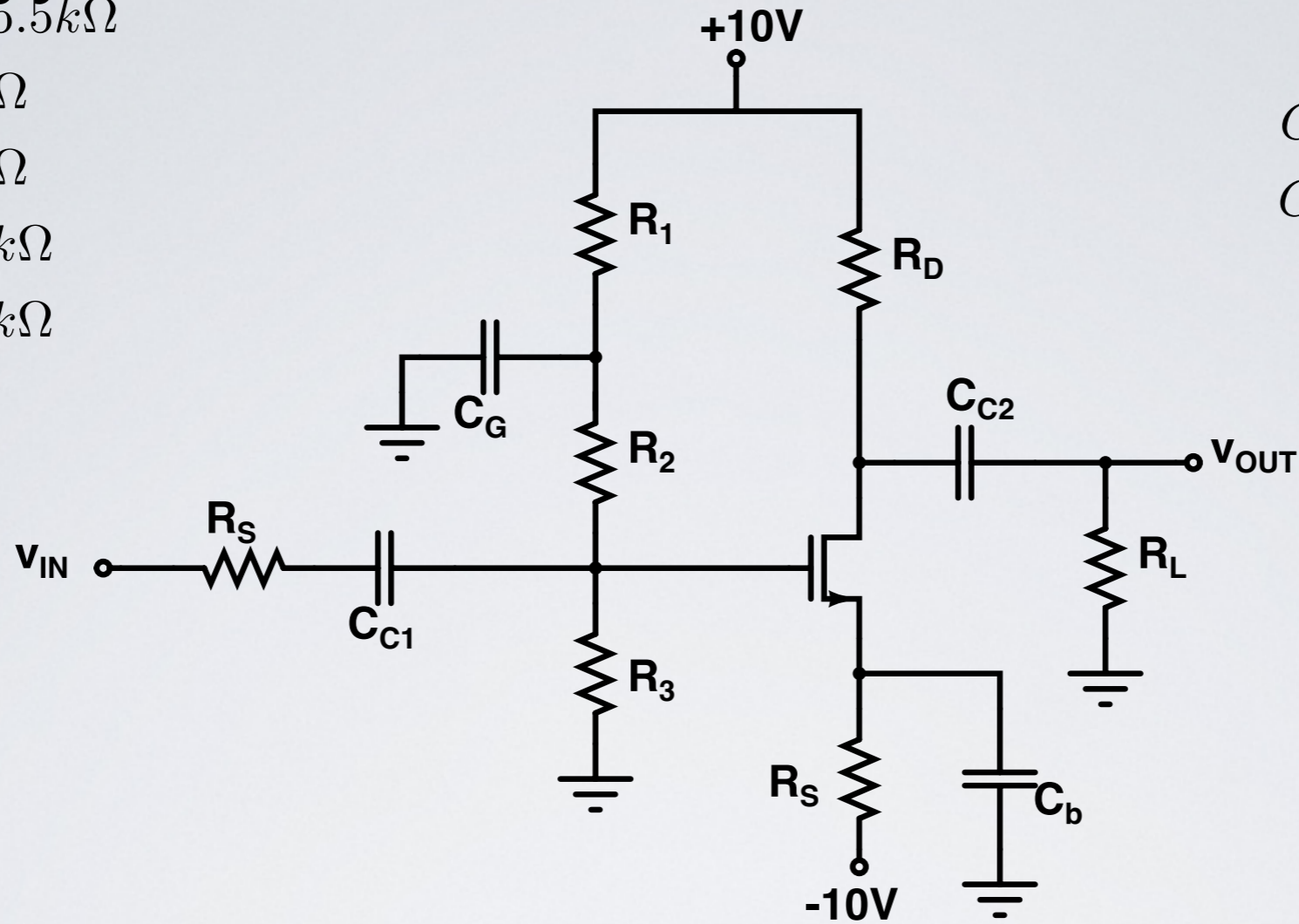
y

$$f_{H3} = \frac{1}{2\pi C_\mu \times 3333\Omega} = \boxed{95.5MHz}$$

Ejemplo

- $R_1 = 179.5k\Omega$
- $R_2 = 179k\Omega$
- $R_3 = 145.5k\Omega$
- $R_S = 2k\Omega$
- $R_D = 3k\Omega$
- $R_L = 10k\Omega$
- $R_S = 10k\Omega$

- $K_N = 1.2mA/V^2$
- $V_{TN} = 2V$
- $\lambda = 0$
- $C_{gs} = 5pF$
- $C_{gd} = 0.8pF$



Los siguientes problemas provienen de otro libro de texto escrito por Naeman

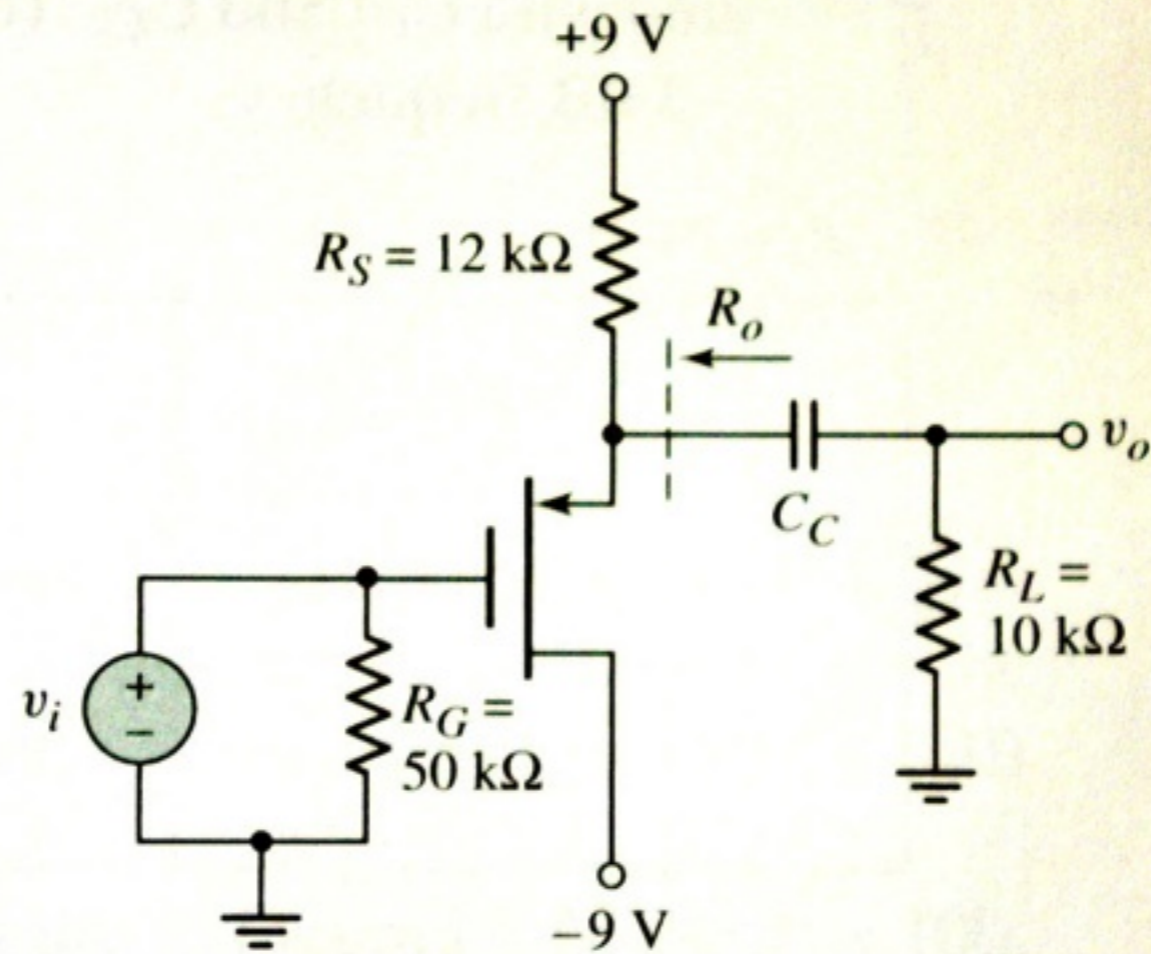


Figure P7.16

*D7.16 The transistor in the circuit in Figure P7.16 has parameters $K_p = 0.5 \text{ mA/V}^2$, $V_{TP} = -2 \text{ V}$, and $\lambda = 0$. (a) Determine R_o . (b) What is the expression for the circuit time constant? (c) Determine C_C such that the lower 3 dB frequency is 20 Hz.

7.16

a.

$$\frac{9 - V_{SG}}{R_S} = I_D = K_P (V_{SG} + V_{TP})^2$$

$$9 - V_{SG} = (0.5)(12)(V_{SG}^2 - 4V_{SG} + 4)$$

$$6V_{SG}^2 - 23V_{SG} + 15 = 0$$

$$V_{SG} = \frac{23 \pm \sqrt{(23)^2 - 4(6)(15)}}{2(6)} \Rightarrow V_{SG} = 3 \text{ V}$$

$$g_m = 2K_P (V_{SG} + V_{TP}) = 2(0.5)(3 - 2) \Rightarrow g_m = 1 \text{ mA/V}$$

$$R_o = \frac{1}{g_m} \parallel R_S = 1 \parallel 12 \Rightarrow \underline{R_o = 0.923 \text{ k}\Omega}$$

b.
$$\underline{r = (R_o + R_L)C_C}$$

c.
$$f_L = \frac{1}{2\pi\tau} \Rightarrow r = \frac{1}{2\pi f_L} = \frac{1}{2\pi(20)} = 7.96 \text{ ms}$$

$$C_C = \frac{r}{R_o + R_L} = \frac{7.96 \times 10^{-3}}{(0.923 + 10) \times 10^3} \Rightarrow \underline{C_C = 0.729 \text{ }\mu\text{F}}$$

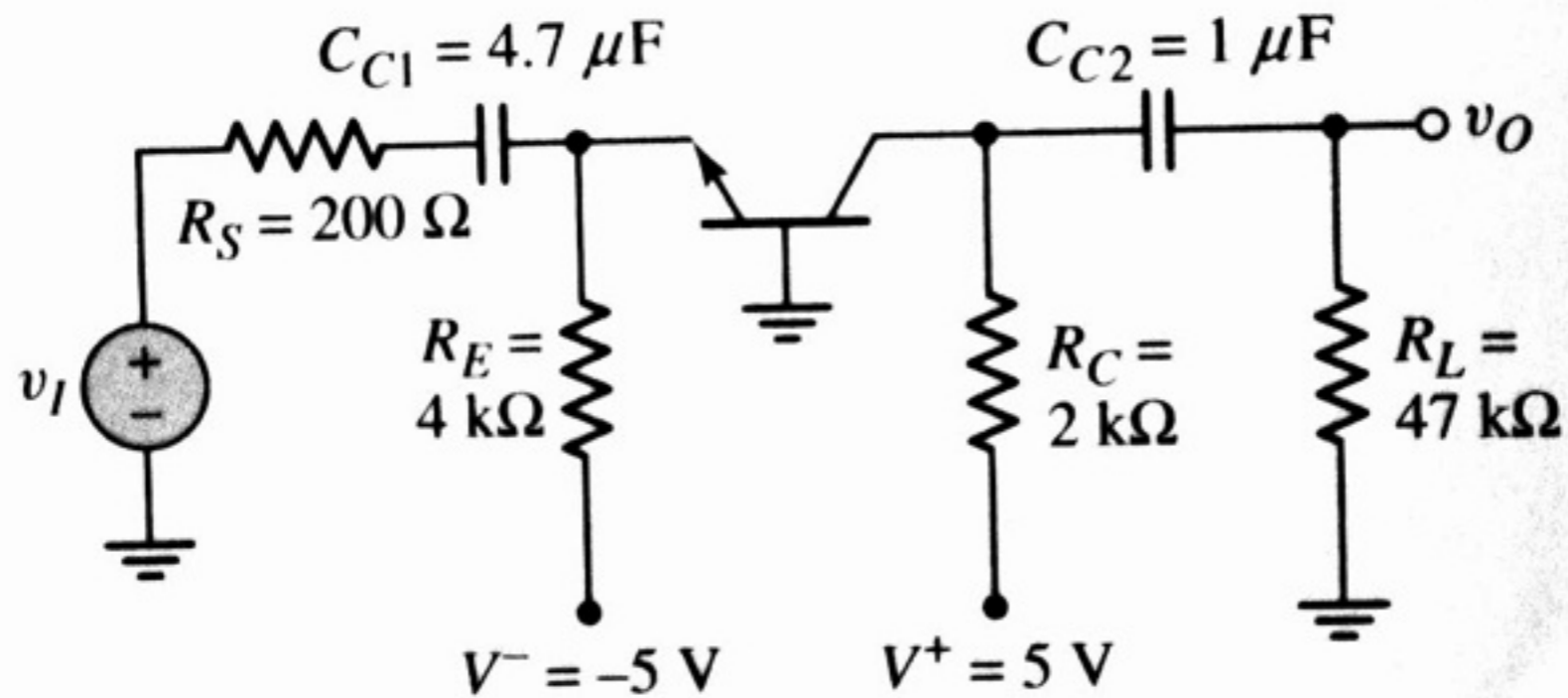


Figure P7.18

- 7.18 The parameters of the transistor in the circuit in Figure P7.18 are $V_{BE(\text{on})} = 0.7 \text{ V}$, $\beta = 100$, and $V_A = \infty$. (a) Determine the quiescent and small-signal parameters of the transistor. (b) Find the time constants associated with C_{C1} and C_{C2} . (c) Is there a dominant -3 dB frequency? Estimate the -3 dB frequency.

7.18

(a)

$$I_{EQ} = \frac{5 - 0.7}{4} = 1.075 \text{ mA} \quad I_{CQ} = 1.064 \text{ mA}$$

$$V_{CEQ} = 10 - (1.064)(2) - (1.075)(4)$$

$$V_{CEQ} = 3.57 \text{ V}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1.064}{0.026} = 40.92 \text{ mA/V}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}} = \frac{(100)(0.026)}{1.064} = 2.44 \text{ K}$$

(b)

$$\text{For } C_{C1}, R_{eq1} = R_S + R_E \left\| \frac{r_\pi}{1 + \beta} = 200 + 4000 \left\| \frac{2440}{101} \right.$$

$$R_{eq1} = 224.0 \text{ K}, \tau_1 = R_{eq1} C_{C1} = \underline{1.053 \text{ ms}}$$

$$\text{For } C_{C2}, R_{eq2} = R_C + R_L = 2 + 47 = 49 \text{ K}$$

$$\tau_2 = R_{eq2} \cdot C_{c2} = 49 \text{ ms}$$

$$(c) \quad f_1 = \frac{1}{2\pi\tau_1} = \frac{1}{2\pi(1.053 \times 10^{-3})} \Rightarrow \underline{f_1 = 151 \text{ Hz}}$$

- 7.20 The parameters of the transistor in the circuit in Figure P7.20 are $K_p = 1 \text{ mA/V}^2$, $V_{TP} = -1.5 \text{ V}$, and $\lambda = 0$. (a) Determine the quiescent and small-signal parameters of the transistor. (b) Find the time constants associated with C_{C1} and C_{C2} . (c) Is there a dominant pole frequency? Estimate the -3 dB frequency.

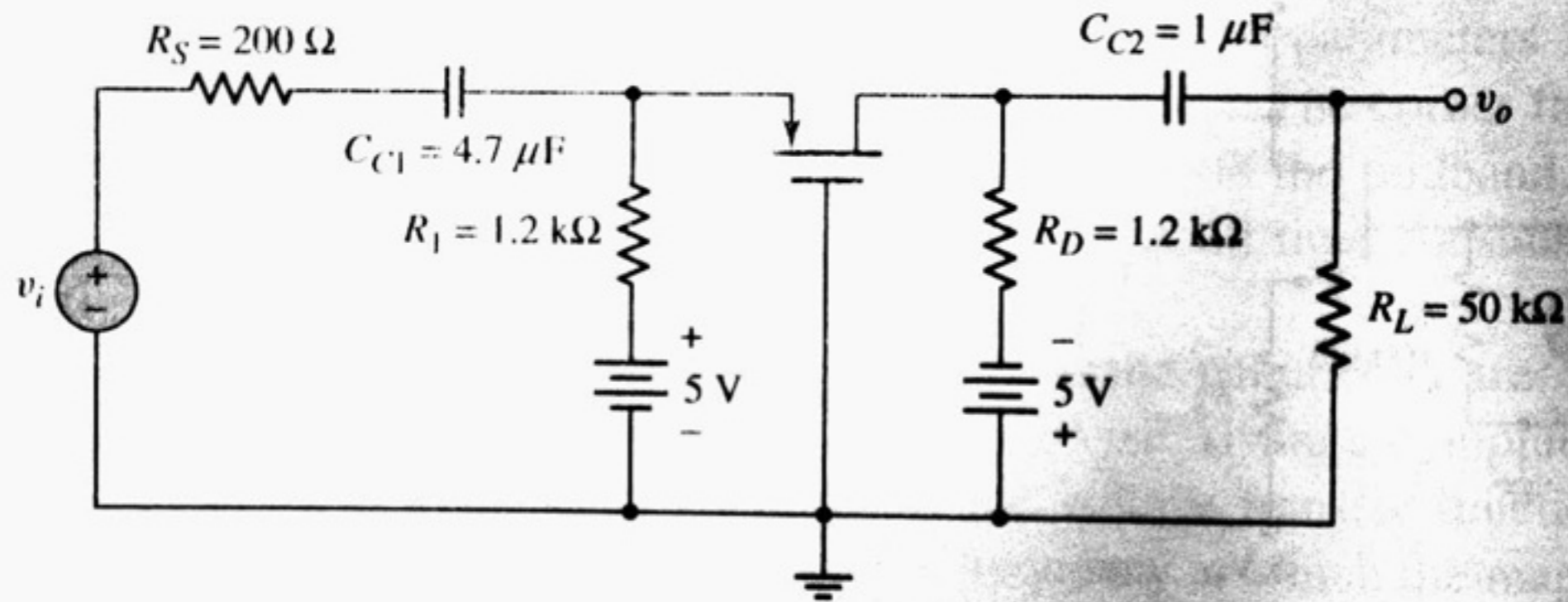


Figure P7.20

7.20

(a)

$$\frac{5 - V_{SG}}{R_1} = K_P (V_{SG} + V_{TP})^2$$

$$5 - V_{SG} = (1)(1.2)(V_{SG} - 1.5)^2 = (1.2)(V_{SG}^2 - 3V_{SG} + 2.25)$$

$$1.2V_{SG}^2 - 2.6V_{SG} - 2.3 = 0 \Rightarrow \underline{V_{SG} = 2.84 V}$$

$$\underline{I_{DQ} = 1.8 mA}$$

$$V_{SDQ} = 10 - (1.8)(1.2 + 1.2) \Rightarrow \underline{V_{SDQ} = 5.68 V}$$

$$g_m = 2\sqrt{K_P I_{DQ}} = 2\sqrt{(1)(1.8)} = 2.683 mA/V$$

$$r_o = \infty$$

(b)

$$R_{is} = \frac{1}{g_m} = \frac{1}{2.68} = 0.3727 k\Omega$$

$$R_i = 1.2 \parallel 0.373 = 0.284 k\Omega$$

$$\text{For } C_{C1}, \tau_{s1} = (284 + 200)(4.7 \times 10^{-6}) = 2.27 ms$$

$$\text{For } C_{C2}, \tau_{s2} = (1.2 \times 10^3 + 50 \times 10^3)(10^{-6}) = 51.2 ms$$

(c)

C_{C2} dominates,

$$f_{3-dB} = \frac{1}{2\pi\tau_{s2}} = \frac{1}{2\pi(51.2 \times 10^{-3})} = 3.1 Hz$$

***7.37** For the multitransistor amplifier in Figure P7.37, choose appropriate transistor parameters. The lower 3 dB frequency is to be less than or equal to 20 Hz. Assume that all three coupling capacitors are equal. Let $C_B \rightarrow \infty$.

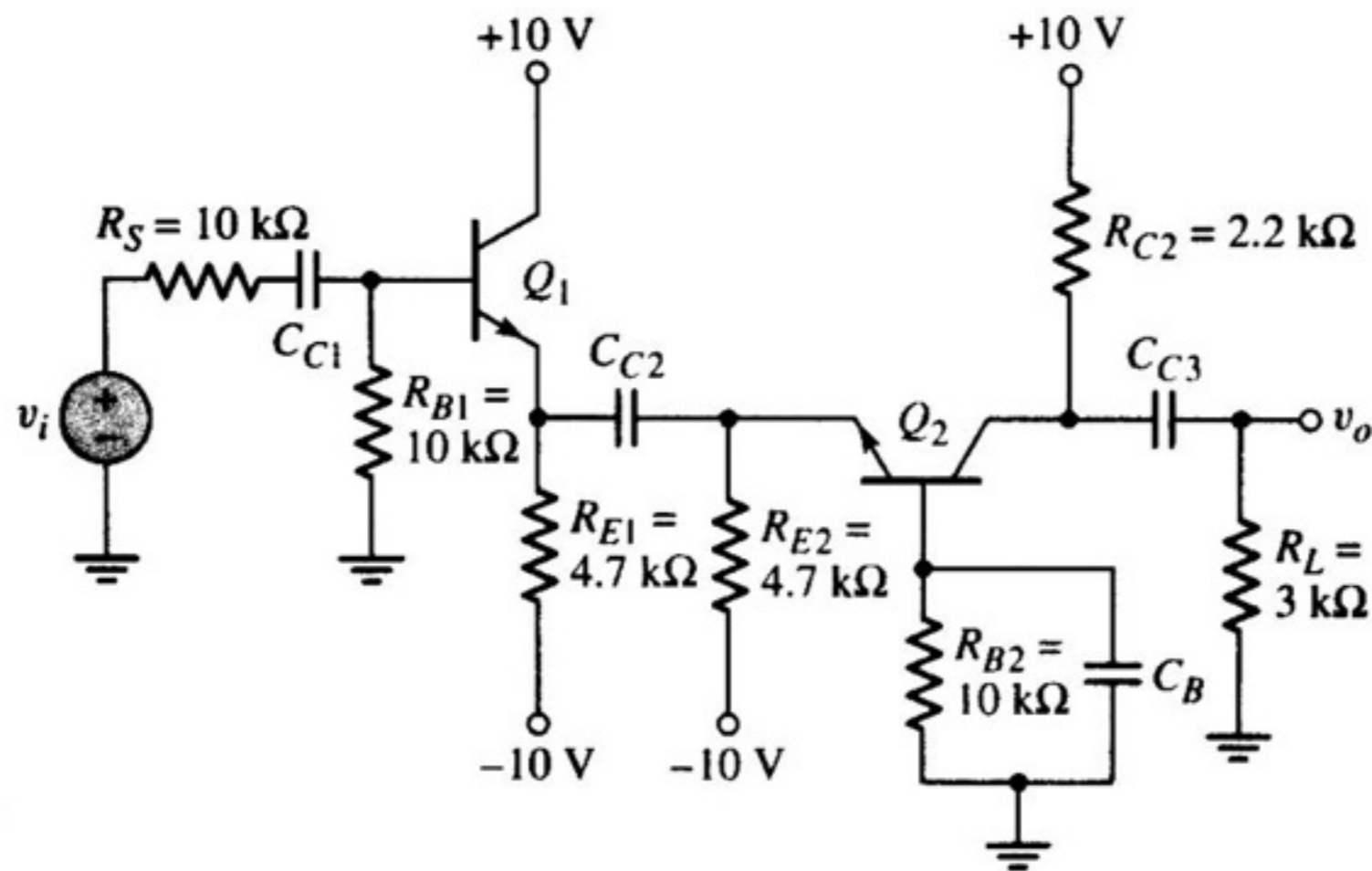


Figure P7.37

Using a computer analysis, determine the maximum values of the coupling capacitors. Determine the slope of the Bode plot of the voltage gain magnitude at very low frequencies.

7.38 A bipolar transistor is biased at $I_{CQ} = 1 \text{ mA}$ and has parameters $C_{\pi} = 10 \text{ pF}$, $C_{\mu} = 2 \text{ pF}$, and $\beta_o = 120$. Determine f_{β} and f_T .

$$f_{\beta} = \frac{1}{2\pi r_{\pi} (C_{\pi} + C_{\mu})}$$

$$f_T = \frac{g_m}{2\pi (C_\pi + C_\mu)}$$

$$g_m = \frac{I_{CQ}}{V_T} = \frac{1}{0.026} = 38.46 \text{ mA/V}$$

$$f_T = \frac{38.46 \times 10^{-3}}{2\pi (10 + 2) \times 10^{-12}}$$

$$\underline{f_T = 510 \text{ MHz}}$$

$$f_\beta = \frac{f_T}{\beta} = \frac{510}{120} \Rightarrow \underline{f_\beta = 4.25 \text{ MHz}}$$

- 7.57 The parameters of the transistor in the common-source circuit in Figure P7.57 are: $K_p = 2 \text{ mA/V}^2$, $V_{TP} = -2 \text{ V}$, $\lambda = 0.01 \text{ V}^{-1}$, $C_{gs} = 10 \text{ pF}$, and $C_{gd} = 1 \text{ pF}$. (a) Determine the equivalent Miller capacitance C_M . (b) Find the upper 3 dB frequency and midband voltage gain.

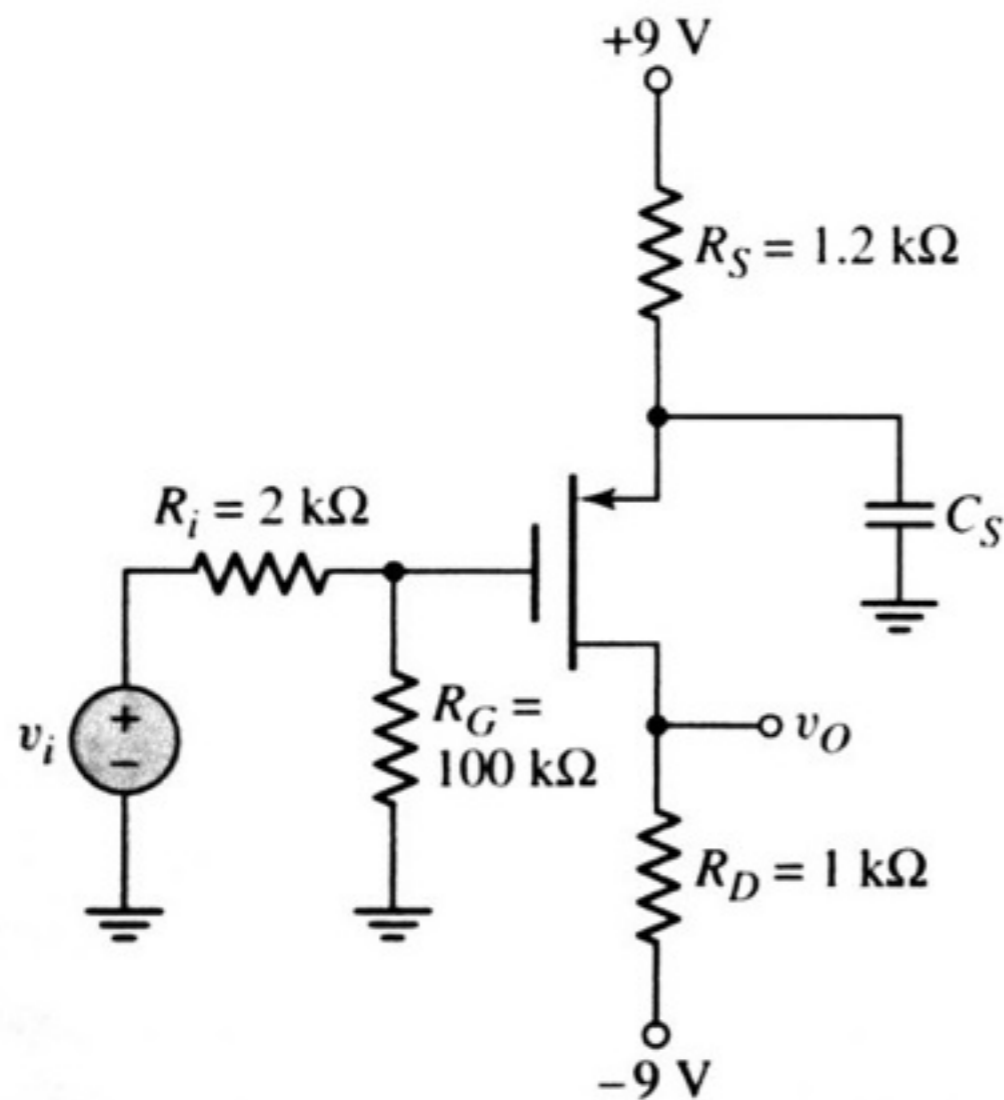


Figure P7.57

7.58

$$V_G = \left(\frac{R_2}{R_1 + R_2} \right) (20) - 10 = \left(\frac{22}{22 + 8} \right) (20) - 10$$

$$V_G = 4.67 \text{ V}$$

$$I_D = \frac{10 - V_{SG} - 4.67}{R_S} = K_P (V_{SG} + V_{TP})^2$$

$$5.33 - V_{SG} = (1)(0.5)(V_{SG}^2 - 4V_{SG} + 4)$$

$$0.5V_{SG}^2 - V_{SG} - 3.33 = 0$$

$$V_{SG} = \frac{1 \pm \sqrt{1 + 4(0.5)(3.33)}}{2(0.5)} \Rightarrow V_{SG} = 3.77 \text{ V}$$

$$g_m = 2K_P (V_{SG} + V_{TP}) = 2(1)(3.77 - 2)$$

$$g_m = 3.54 \text{ mA/V}$$

b.

$$C_M = C_{gdT} (1 + g_m (R_D \parallel R_L))$$

$$C_M = (3) [1 + (3.54)(2 \parallel 5)] \Rightarrow \underline{C_M = 18.2 \text{ pF}}$$

a.

$$r = R_{eq} (C_{gsT} + C_M)$$

$$R_{eq} = R_i \parallel R_1 \parallel R_2 = 0.5 \parallel 8 \parallel 22 = 0.461 \text{ k}\Omega$$

$$r = (0.461 \times 10^3)(15 + 18.2) \times 10^{-12} \\ = 1.53 \times 10^{-8} \text{ s}$$

$$f_H = \frac{1}{2\pi r} \Rightarrow \underline{f_H = 10.4 \text{ MHz}}$$

c.

$$V_o = -g_m V_{gs} (R_D \parallel R_L)$$

$$V_{gs} = \left(\frac{R_1 \parallel R_2}{R_1 \parallel R_2 \parallel R_i} \right) V_i = \left(\frac{5.87}{5.87 + 0.5} \right) V_i \Rightarrow V_{gs} = (0.9215) V_i$$

$$A_v = -(3.54)(0.9215)(2 \parallel 5) \Rightarrow \underline{A_v = -4.66}$$

***7.63** For the cascode circuit in Figure 7.66 in the text, circuit parameters are the same as described in Example 7.16. The transistor parameters are: $\beta_o = 120$, $V_A = \infty$, $V_{BE}(\text{on}) = 0.7 \text{ V}$, $C_\pi = 12 \text{ pF}$, and $C_\mu = 2 \text{ pF}$. (a) If C_L is an open circuit, determine the 3 dB frequencies corresponding to the input and output portions of the equivalent circuit. (b) Determine the mid-band voltage gain. (c) If a load capacitance $C_L = 15 \text{ pF}$ is connected to the output, determine if the upper 3 dB frequency is dominated by the load capacitance or by the transistor characteristics.

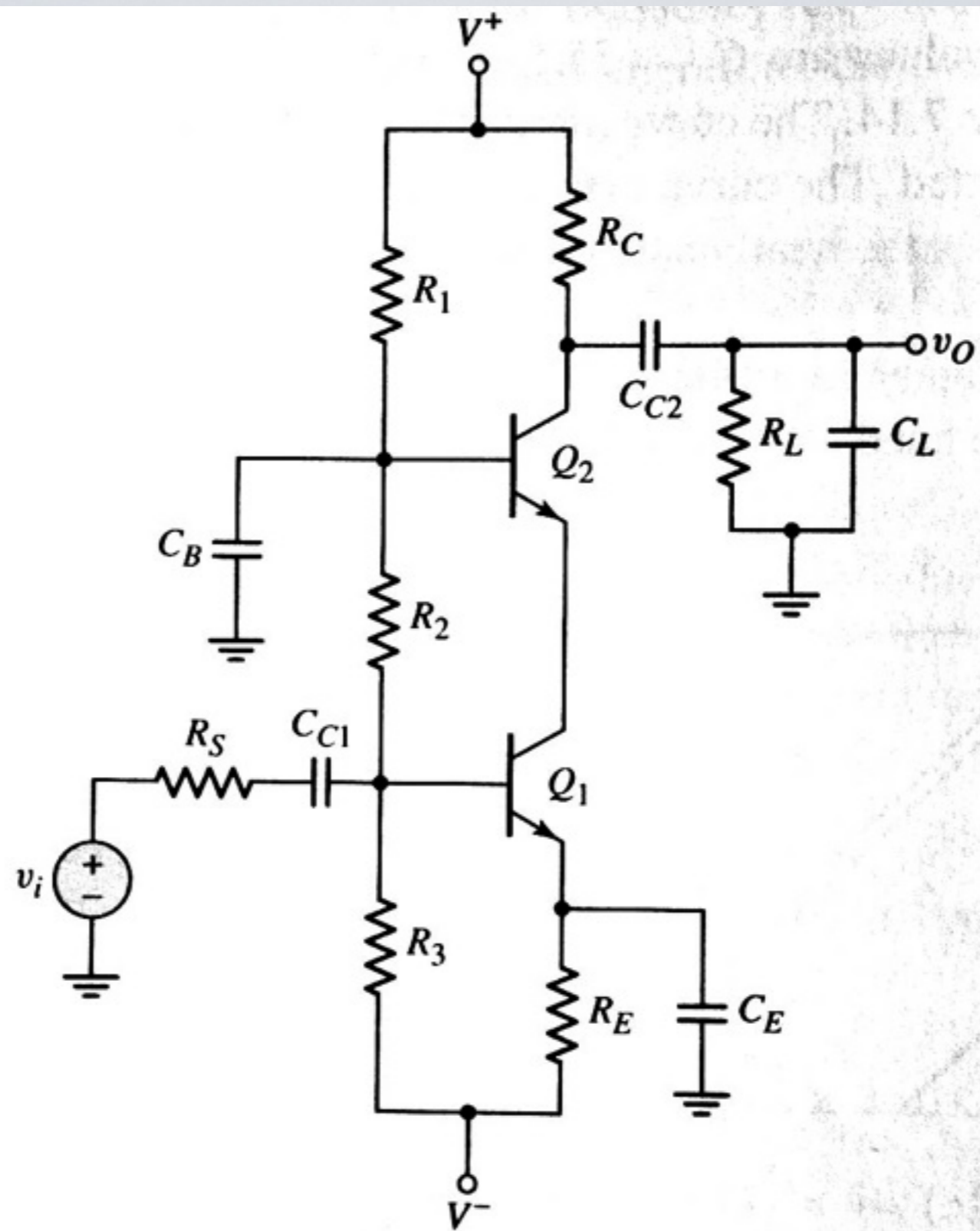


Figure 7.66 Cascode circuit

7.63

$$r_{\pi} = \frac{(120)(0.026)}{1.02} = 3.059 \text{ k}\Omega$$

$$g_m = 39.23 \text{ mA/V}$$

a.

$$\text{Input: } f_{H\pi} = \frac{1}{2\pi r_{\pi}}$$

$$r_{\pi} = \left[R_s \parallel R_2 \parallel R_3 \parallel r_{\pi} \right] (C_{\pi} + 2C_{\mu})$$

$$R_{eq} = 0.1 \parallel 20.5 \parallel 28.3 \parallel 3.06 = 0.096 \text{ k}\Omega$$

$$r_{\pi} = (96)(12 + 2(2)) \times 10^{-12} = 1.537 \times 10^{-9} \text{ s}$$

$$f_{H\pi} = \frac{1}{2\pi (1.536 \times 10^{-9})} = \underline{103.6 \text{ MHz}}$$

$$\text{Output: } f_{H\mu} = \frac{1}{2\pi r_{\mu}}$$

$$r_{\mu} = (R_C \parallel R_L) C_{\mu}$$

$$= (15 \parallel 10) \times 10^3 \times 2 \times 10^{-12}$$

$$= 6.67 \times 10^{-9}$$

$$f_{H\mu} = \frac{1}{2\pi (6.67 \times 10^{-9})} = \underline{23.9 \text{ MHz}}$$

b.

$$A = g_m (R_C \parallel R_L) \left[\frac{R_2 \parallel R_3 \parallel r_{\pi}}{R_2 \parallel R_3 \parallel r_{\pi} + R_s} \right]$$

$$R_2 \parallel R_3 \parallel r_{\pi} = 20.5 \parallel 28.3 \parallel 3.059 = 2.433 \text{ k}\Omega$$

$$A = (39.23)(5 \parallel 10) \left[\frac{2.433}{2.433 + 0.1} \right] \Rightarrow \underline{A = 125.6}$$

c. $C_L = 15 \text{ pF} > C_{\mu} \Rightarrow C_L$ dominates frequency response.