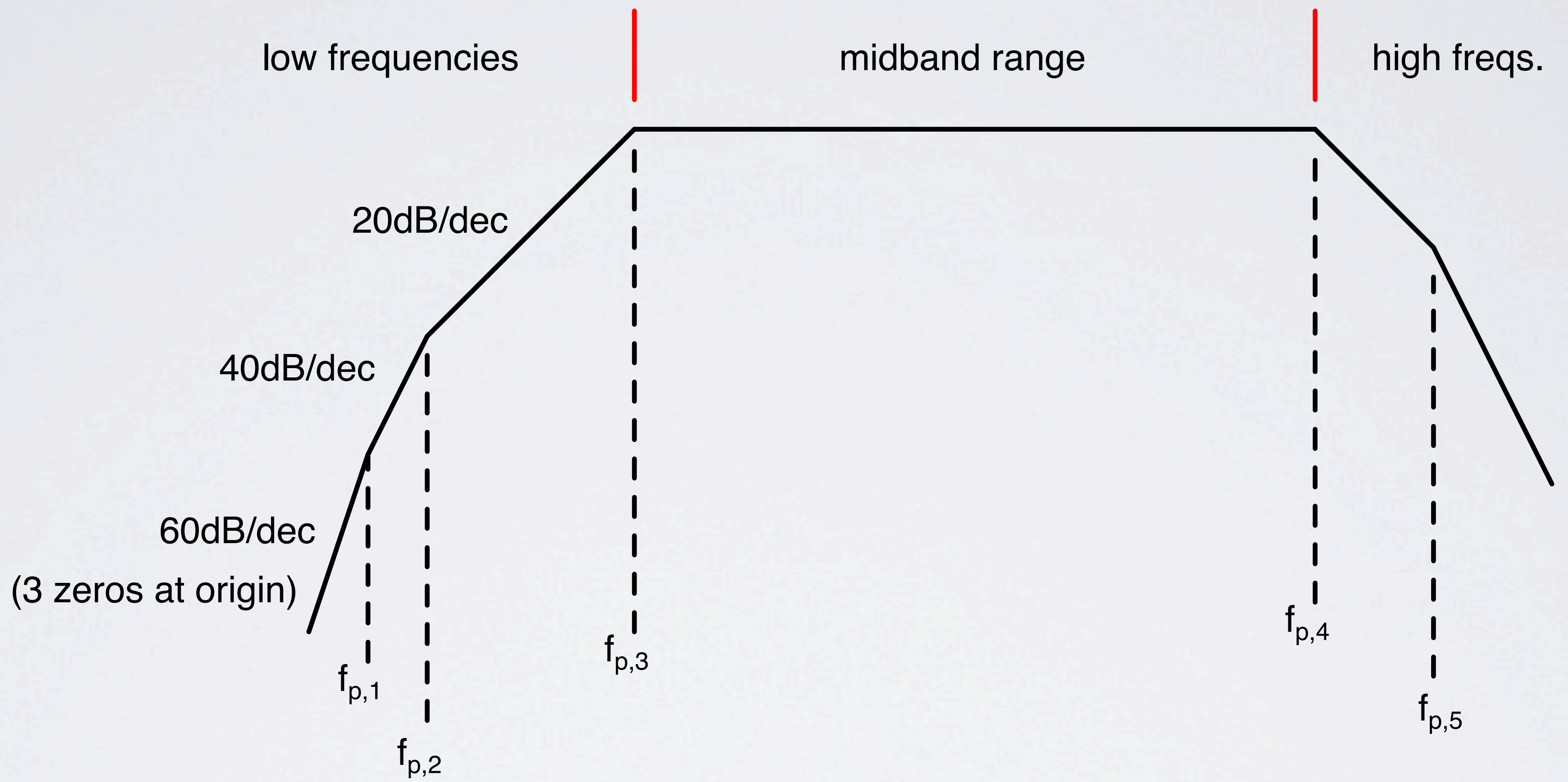
REPASO EXAMEN 1

INEL4202 - Segundo semestre 2012-2013

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

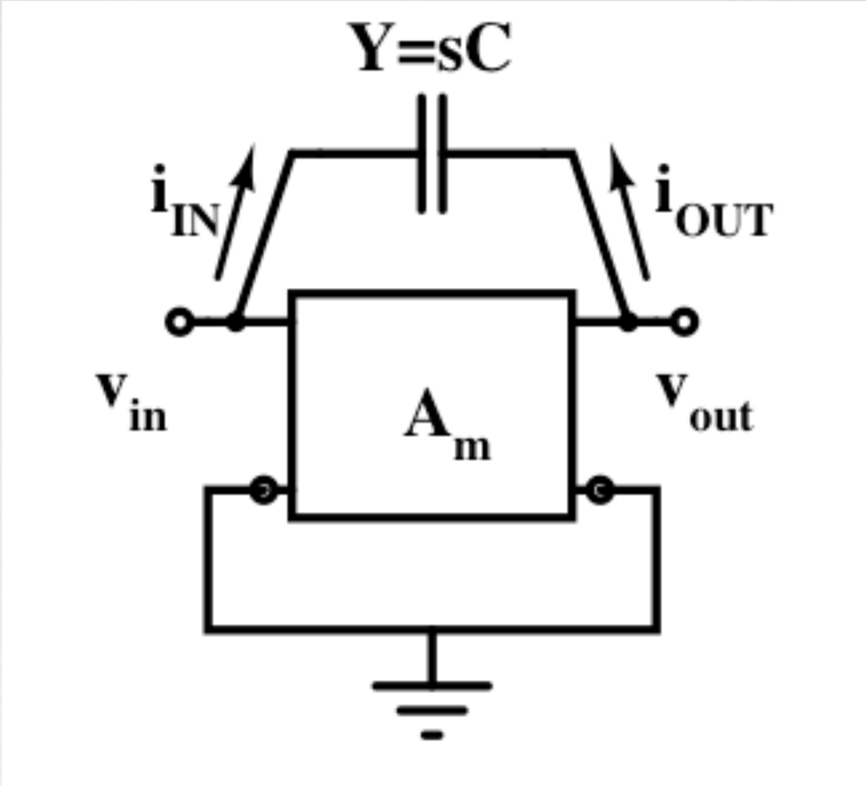
$$f_L = \frac{1}{2\pi R_{EQ} C}$$

  - 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

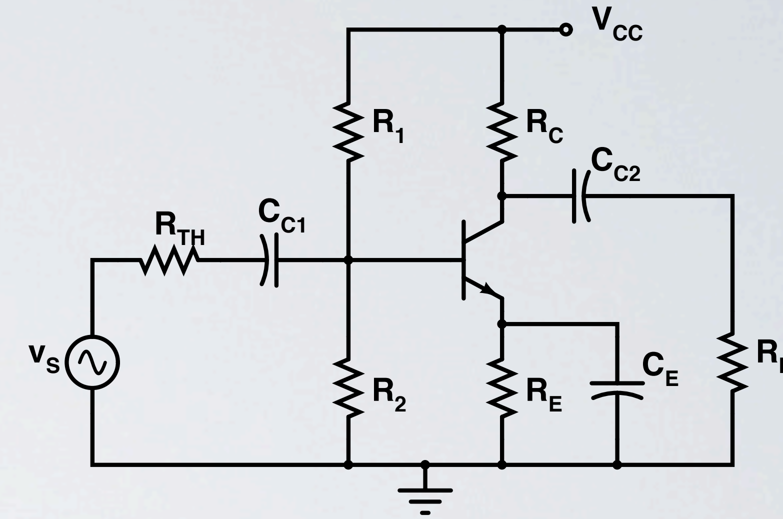
$$\begin{aligned} i_{OUT} &= Y(v_{OUT} - v_{IN}) \\ &= sC\left(1 - \frac{1}{A_M}\right)v_{OUT} \end{aligned}$$

Actúa como un condensador C(1-1/A_M)

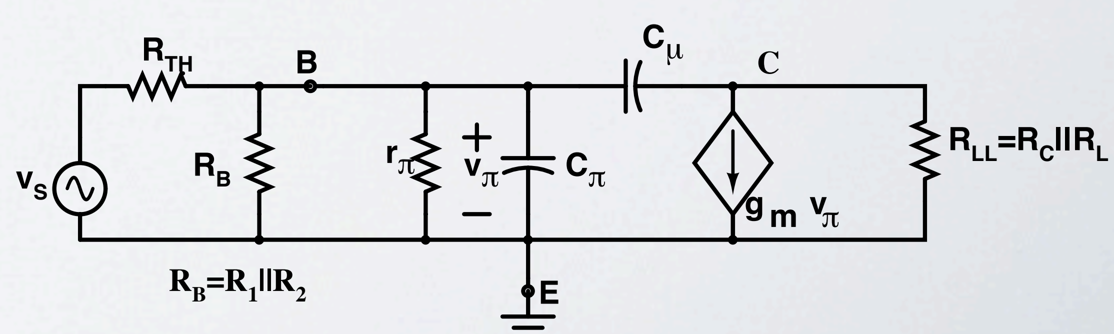
Si A_M <1, Cout ≈ -C/A_M

FRECUENCIAS ALTAS - CE/CS

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

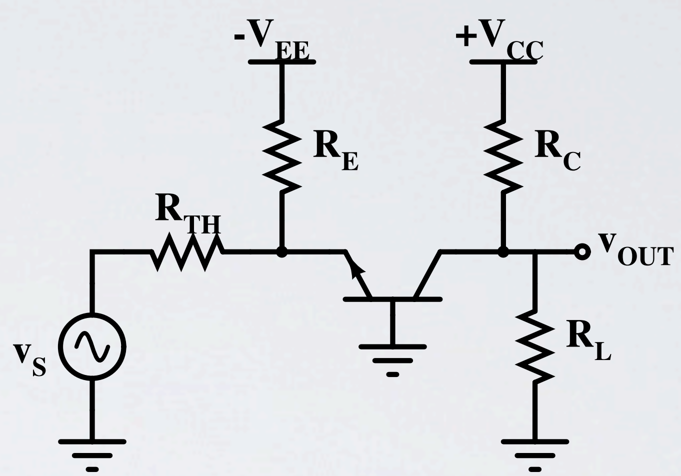


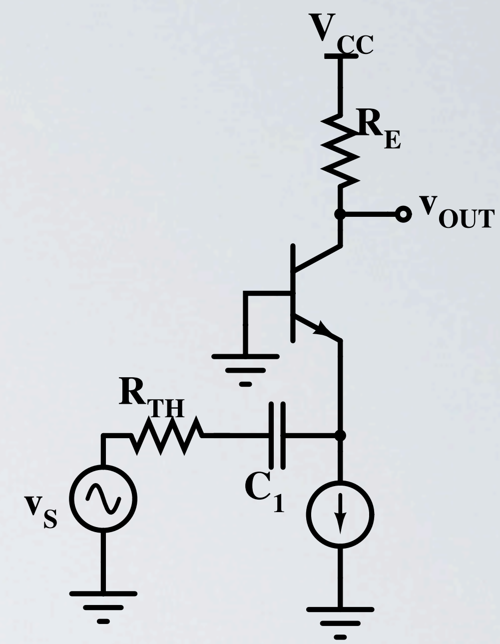
- $C_M = C_\pi + (1 - A_M)C_\mu$
  - A_M es usualmente $-g_m R'_L$ para CE/CS
  - $R'_L = R_L || R_C$ = carga equivalente en ac
- Determine polo de alta frecuencia usando $f_H = \dfrac{1}{2\pi C_M R_{EQ}}$
- R_{EQ} = res. equivalente desde terminales de C_M



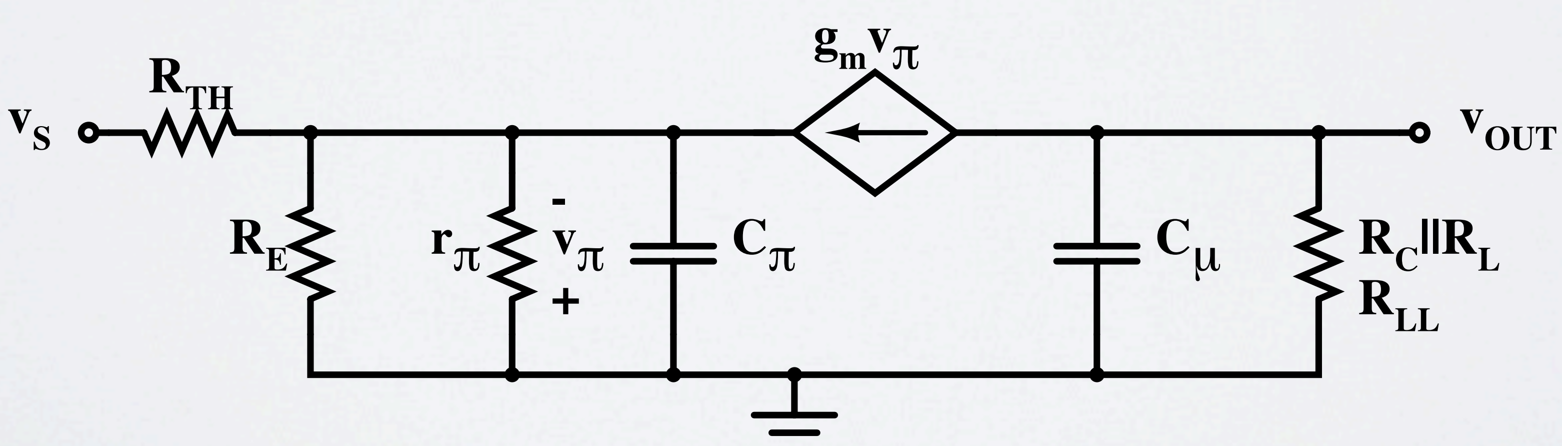
Common-base/-gate

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

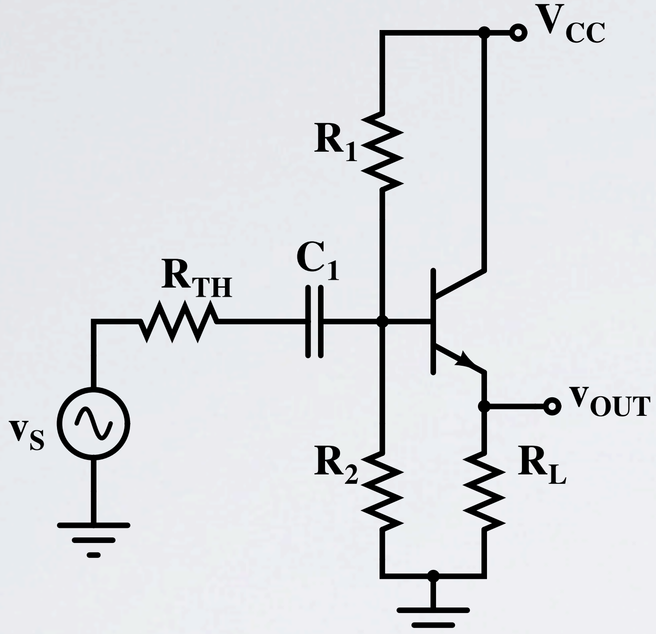


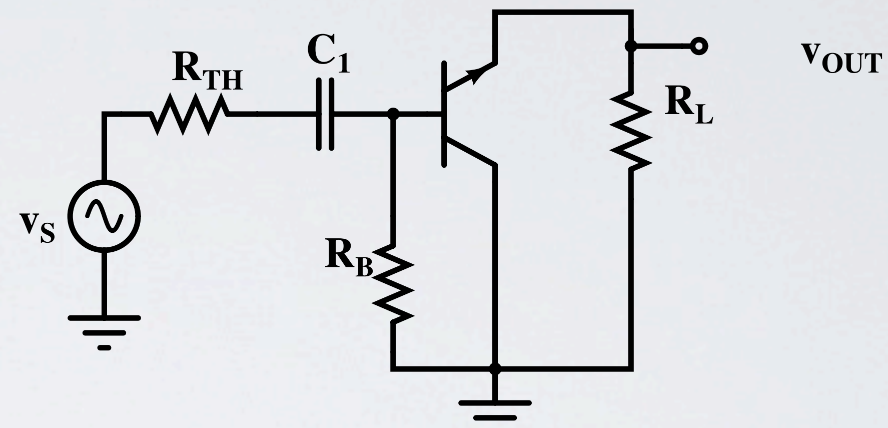


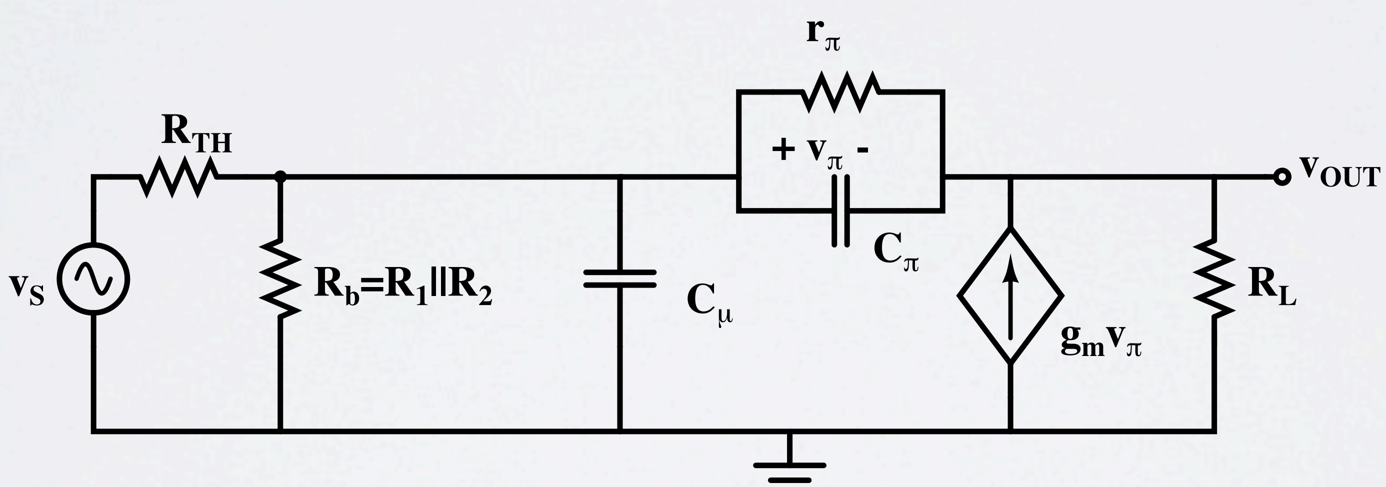
$$f_{H1} = \frac{1}{2\pi C_\mu R_{EQ,1}} \qquad f_{H2} = \frac{1}{2\pi C_\pi R_{EQ,2}}$$



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:

$$\begin{aligned} f_t &= \frac{\beta}{2\pi r_\pi \left(C_\pi + C_\mu\right)} = \frac{g_m}{2\pi \left(C_\pi + C_\mu\right)} \\ C_\pi &= \frac{\beta}{2\pi r_\pi f_t} - C_\mu = \frac{g_m}{2\pi f_t} - C_\mu \end{aligned}$$

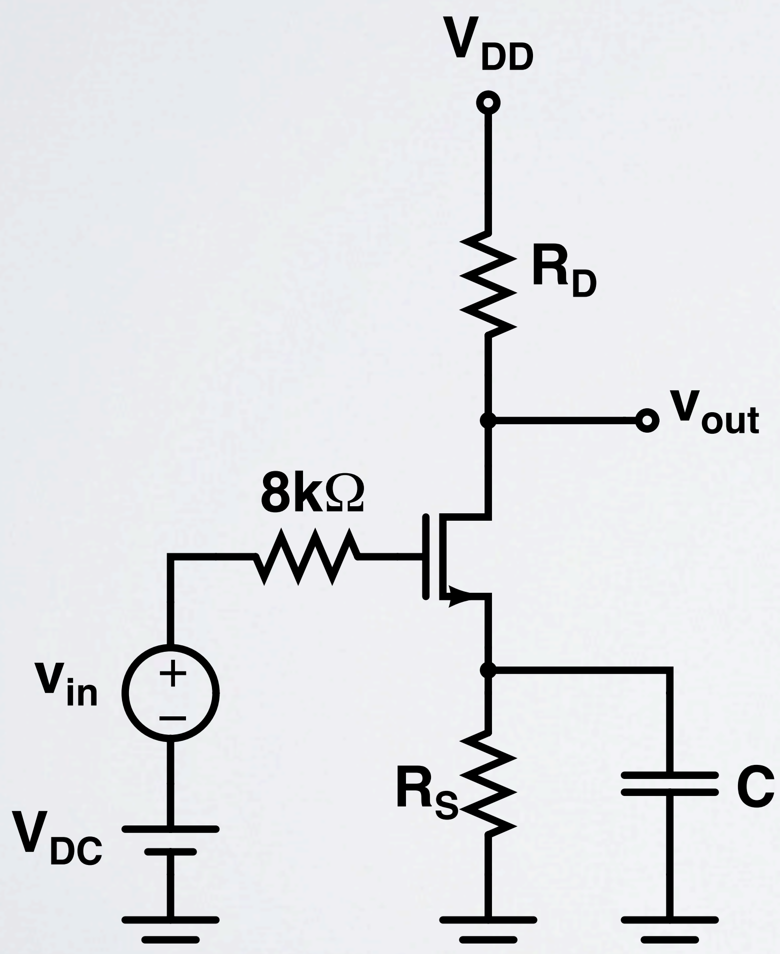
- Para el mosfet, use

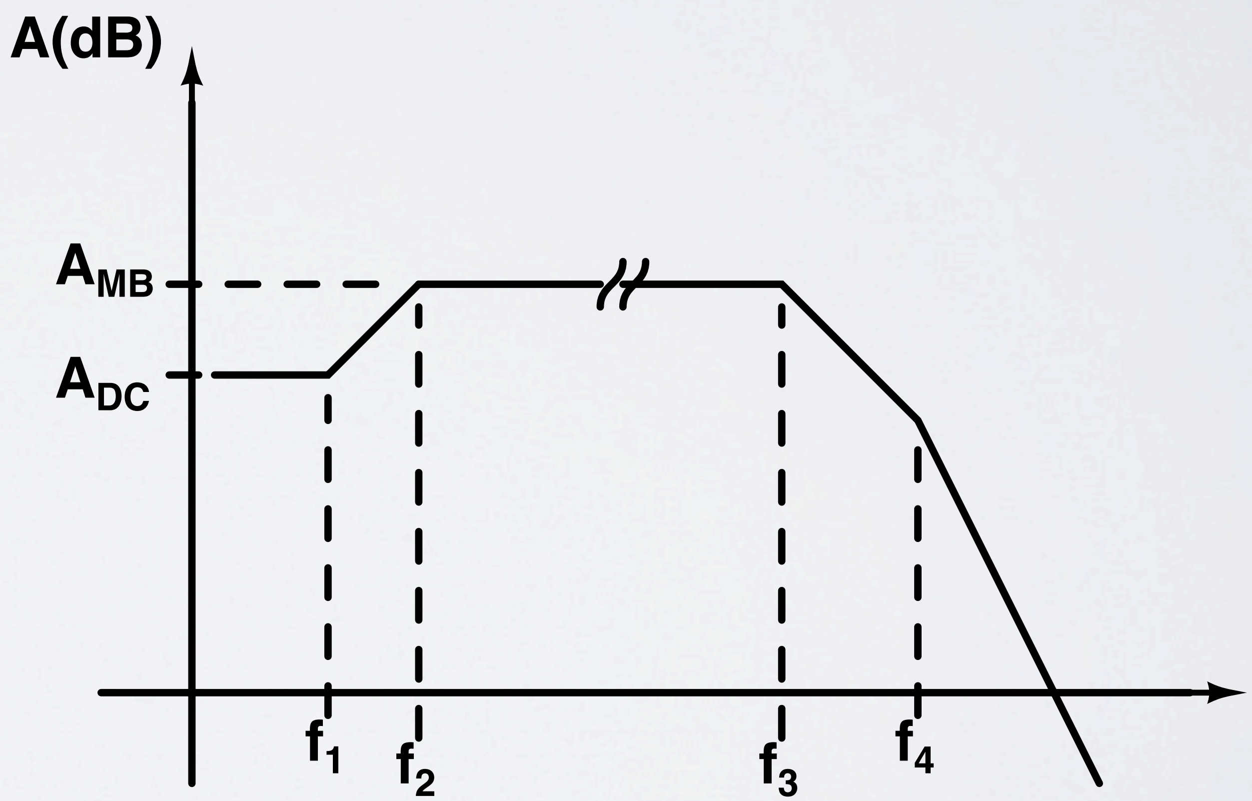
$$f_t = \frac{g_m}{2\pi \left(C_{gs} + C_{gd}\right)}$$

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*,

$$\begin{aligned} \tau_p &= R_{os}C \\ \tau_z &= R_S C \end{aligned}$$

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

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

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

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

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

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

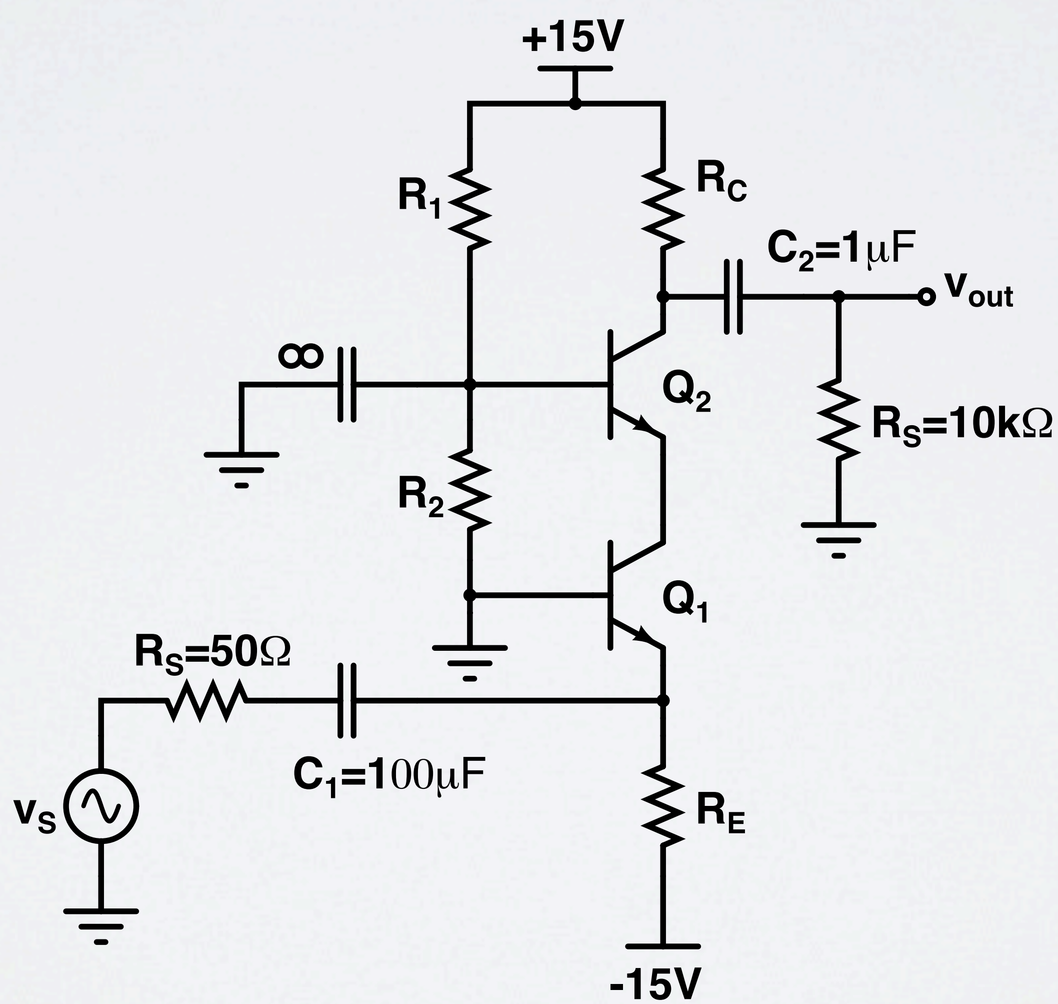
$$C_{gs} + 101 \times 0.15pF = \frac{1}{2\pi \times 8k\Omega \times 10^6} = 19.9pF = C_{gs} + 15.15pF$$

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

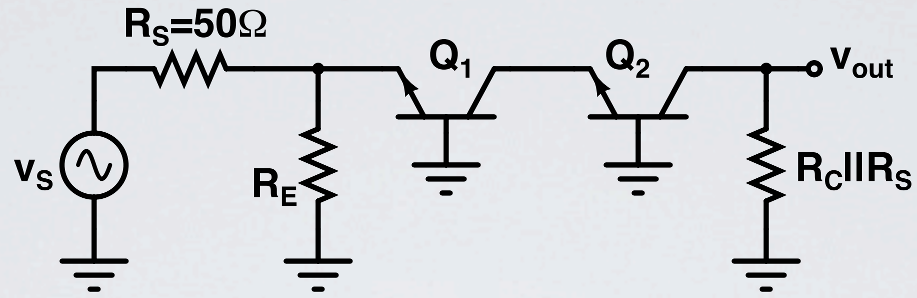
EJEMPLO

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}),

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

$$\begin{aligned} I_{CQ1} &= \frac{14.3V}{14.3k\Omega} = 1mA \simeq I_{CQ2} \\ g_{m1} &\simeq g_{m2} = 40mA/V \\ r_{\pi 1} &= r_{\pi 2} = 2.5k\Omega \end{aligned}$$

$$\begin{aligned} A_v &= \frac{14.3k\Omega \| \frac{2.5k}{101}}{14.3k\Omega \| \frac{2.5k}{101} + 50}(40mA/V \times \frac{2.5k}{101})(40mA/V \times 3.33k\Omega) \\ &\simeq \frac{24.75}{74.75}(1)(133.2) = \boxed{44.1V/V} \end{aligned}$$

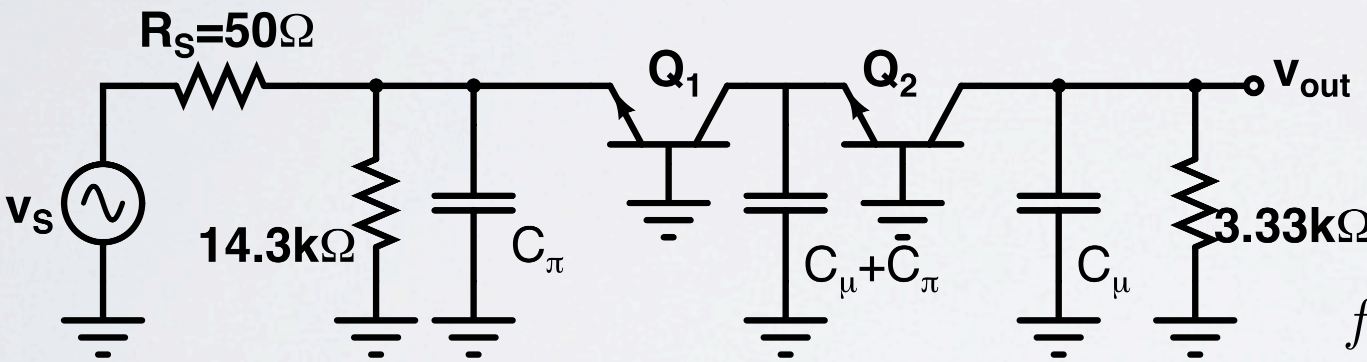
frecuencias de los polos de baja frecuencia, y
Respuesta:

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

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

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,



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

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

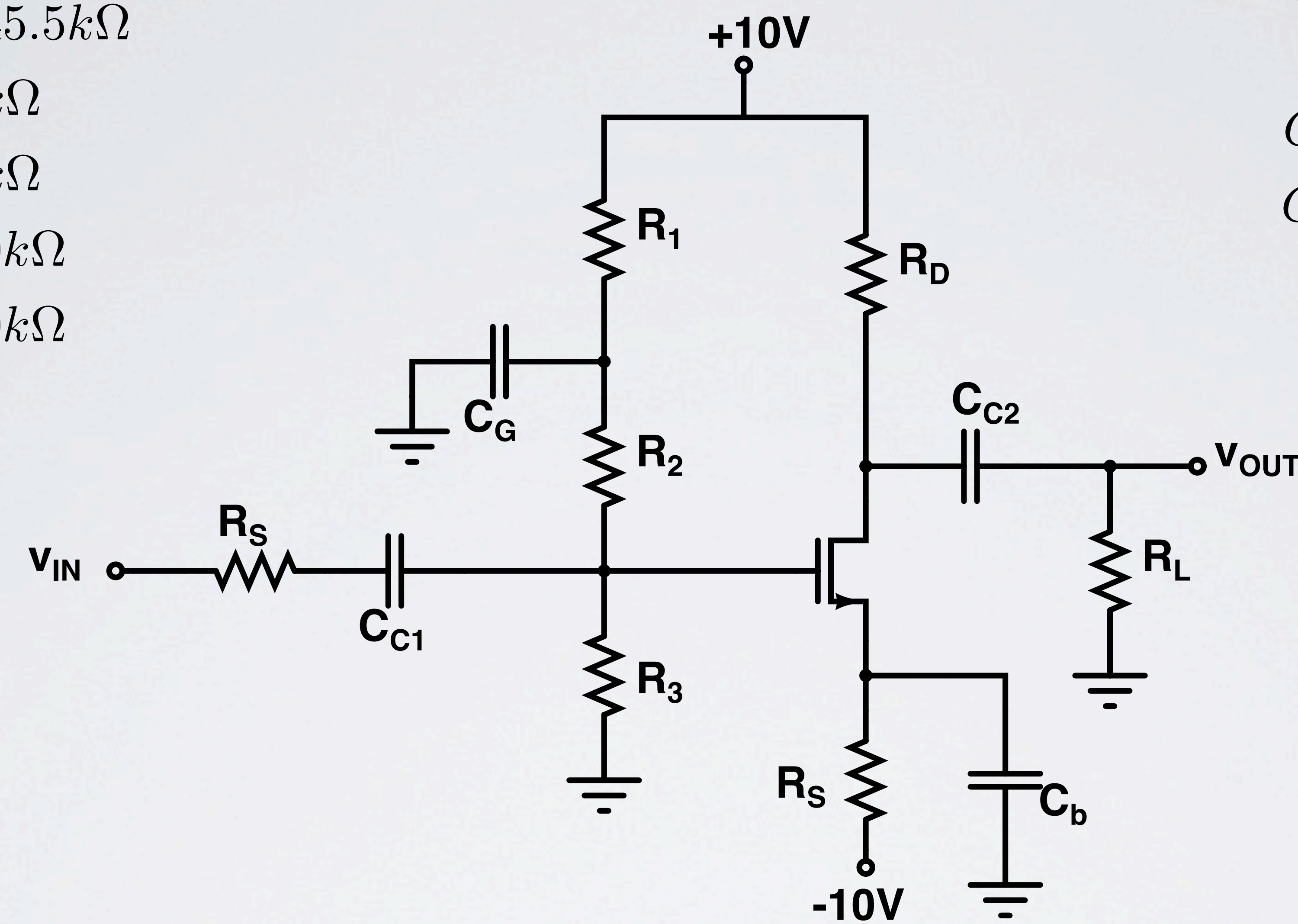
y

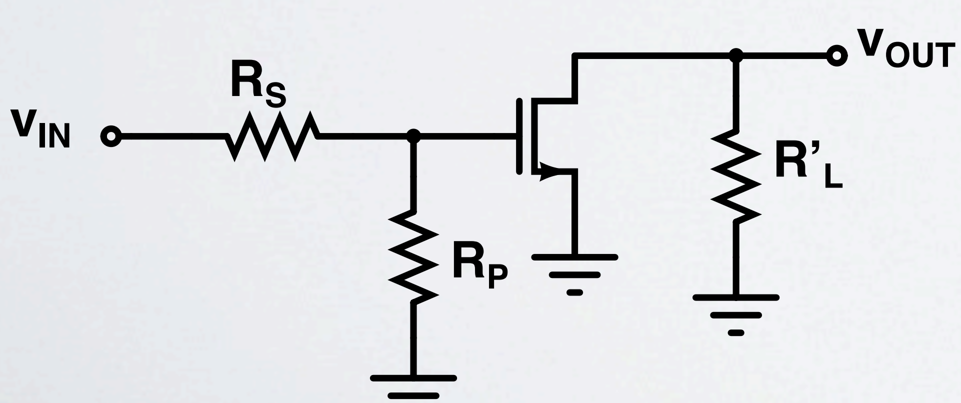
$$f_{H3} = \frac{1}{2\pi C_\mu \times 3333\Omega} = \boxed{95.5MHz}$$

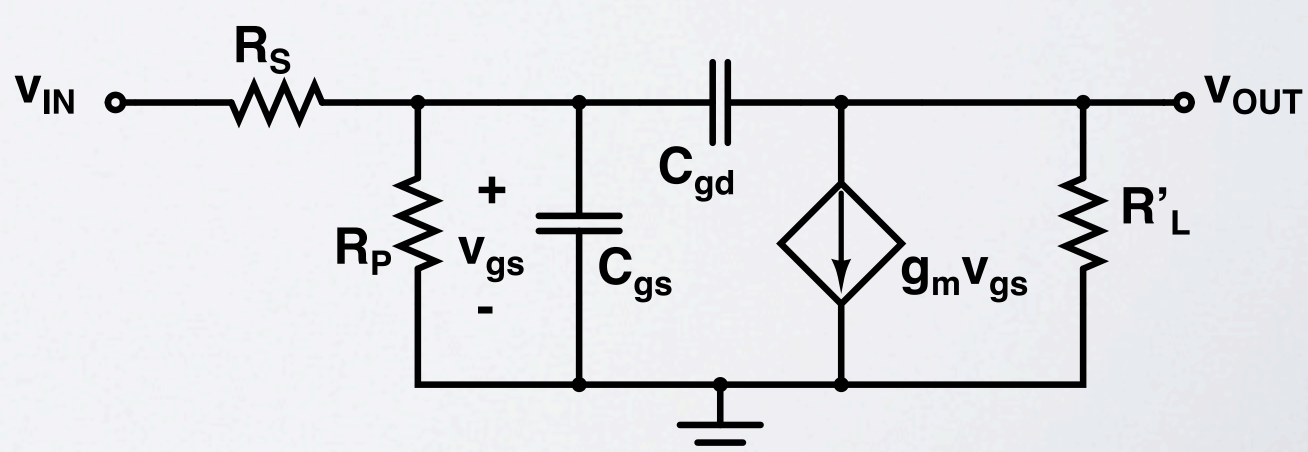
Ejemplo

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

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







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

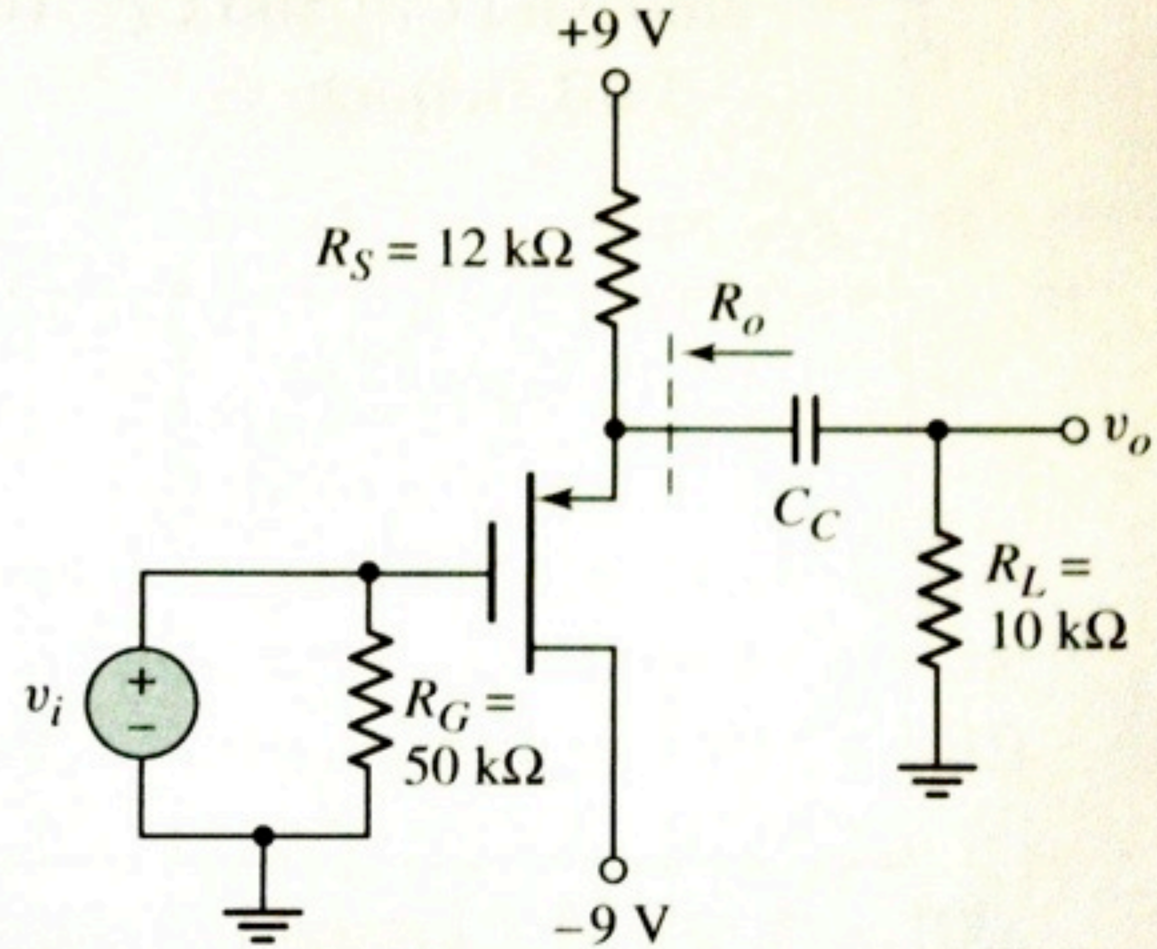


Figure P7.16

*D7.16 The transistor in the circuit in Figure P7.16 has parameters $K_p = 0.5$ mA/V^2, $V_{TP} = -2$ 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.

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

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

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

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

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

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

b. $\underline{r = \left(R_0+R_L\right)C_C}$

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

$$C_C = \frac{r}{R_o+R_L} = \frac{7.96\times10^{-3}}{(0.923+10)\times10^3} \Rightarrow \underline{C_C = 0.729\ \mu\text{F}}$$

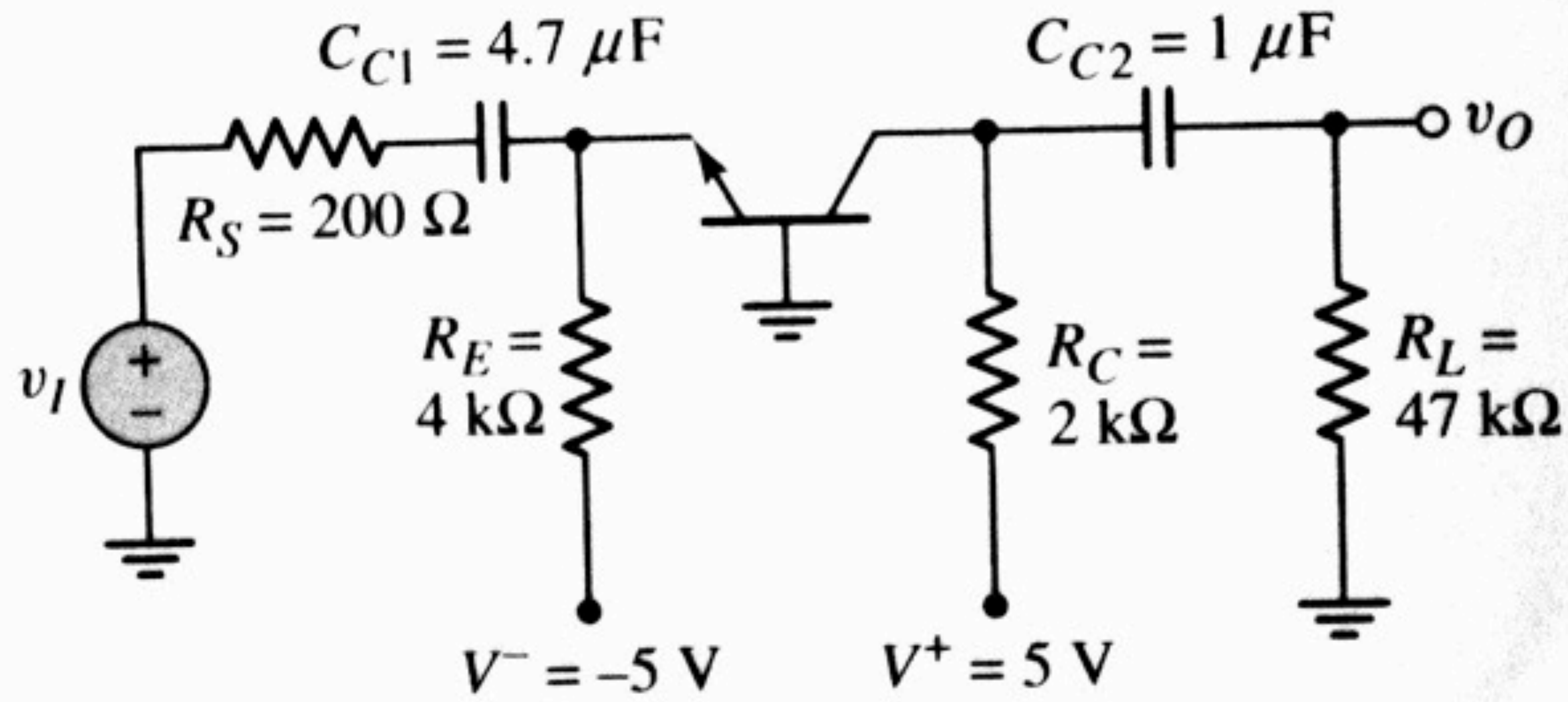


Figure P7.18

7.18 The parameters of the transistor in the circuit in Figure P7.18 are $V_{BE}(\text{on}) = 0.7$ 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)

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

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

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

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

(c) $$f_1 = \frac{1}{2\pi\tau_1} = \frac{1}{2\pi\left(1.053\times10^{-3}\right)} \Rightarrow \underline{f_1 = 151 \text{ Hz}}$$

7.20 The parameters of the transistor in the circuit in Figure P7.20 are $K_p = 1\ \text{mA/V}^2$, $V_{TP} = -1.5$ 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.

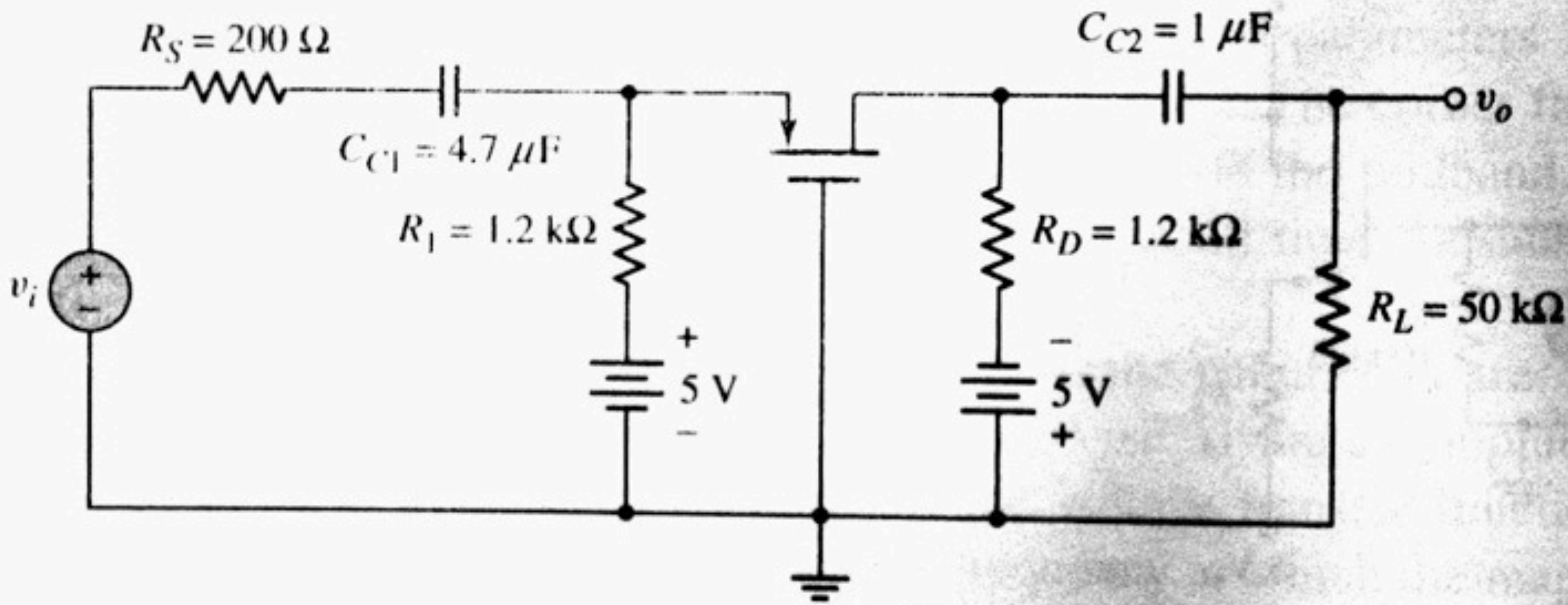


Figure P7.20

7.20

(a)

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

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

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

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

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

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

$$r_o=\infty$$

(b)

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

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

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

For $C_{C2}, \tau_{s2}=\left(1.2x10^3+50\times 10^3\right)\left(10^{-6}\right)=51.2\ ms$

(c)

C_{C2} dominates,

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

Error: C_{C1} dominates

*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 $C_B \rightarrow \infty$.

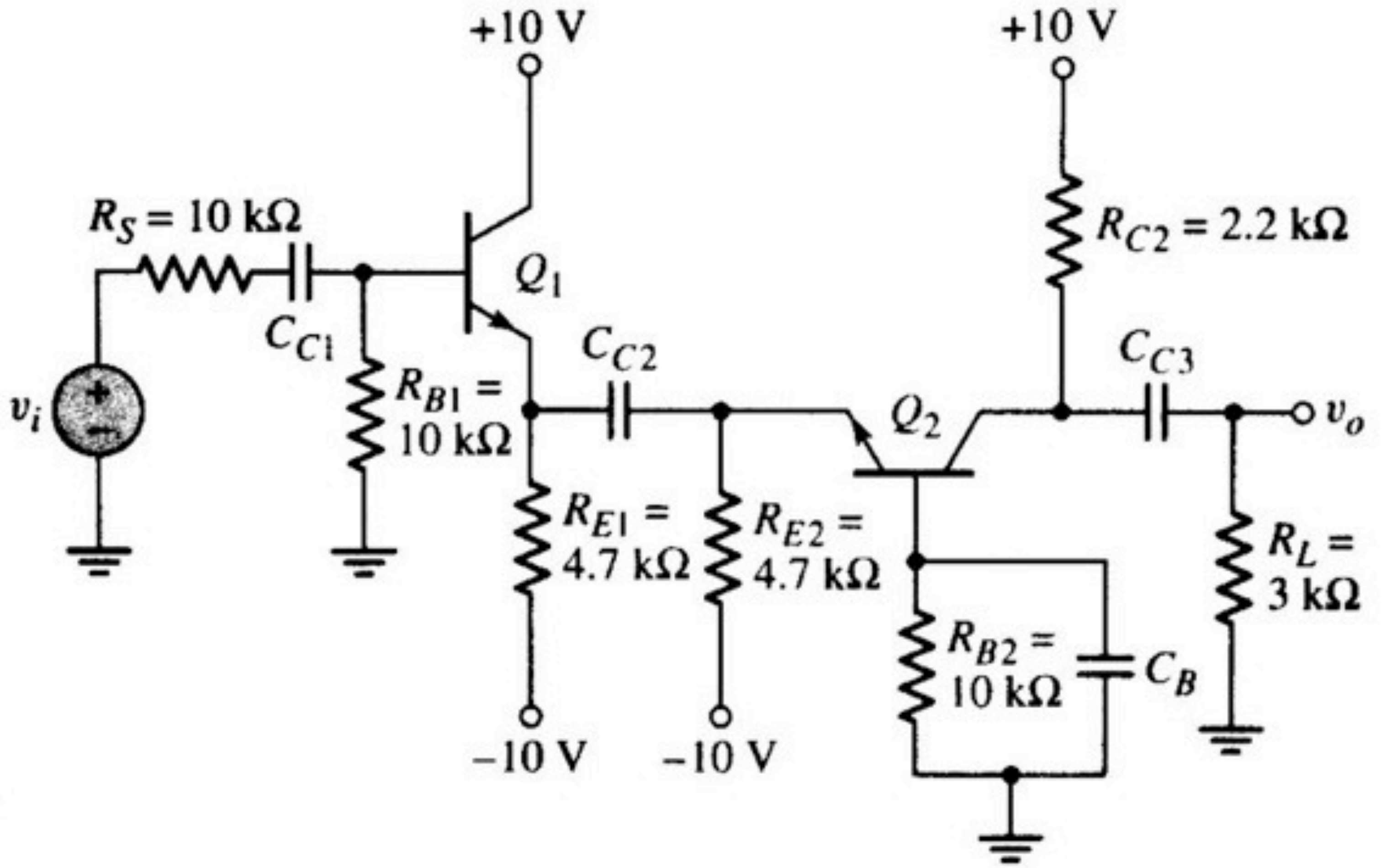


Figure P7.37

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 $I_{CQ} = 1$ mA and has parameters $C_\pi =$ 10 pF, $C_\mu = 2$ pF, and $\beta_o = 120$. Determine f_β and f_T.

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

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

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

$$f_T = \frac{38.46\times10^{-3}}{2\pi\left(10+2\right)\times10^{-12}}$$

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

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

*7.63 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: $\beta_o = 120$, $V_A = \infty$, $V_{BE}(\text{on}) = 0.7$ V, $C_\pi = 12$ pF, and $C_\mu = 2$ 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 $C_L = 15$ pF is connected to the output, determine if the upper 3 dB frequency is dominated by the load capacitance or by the transistor characteristics.

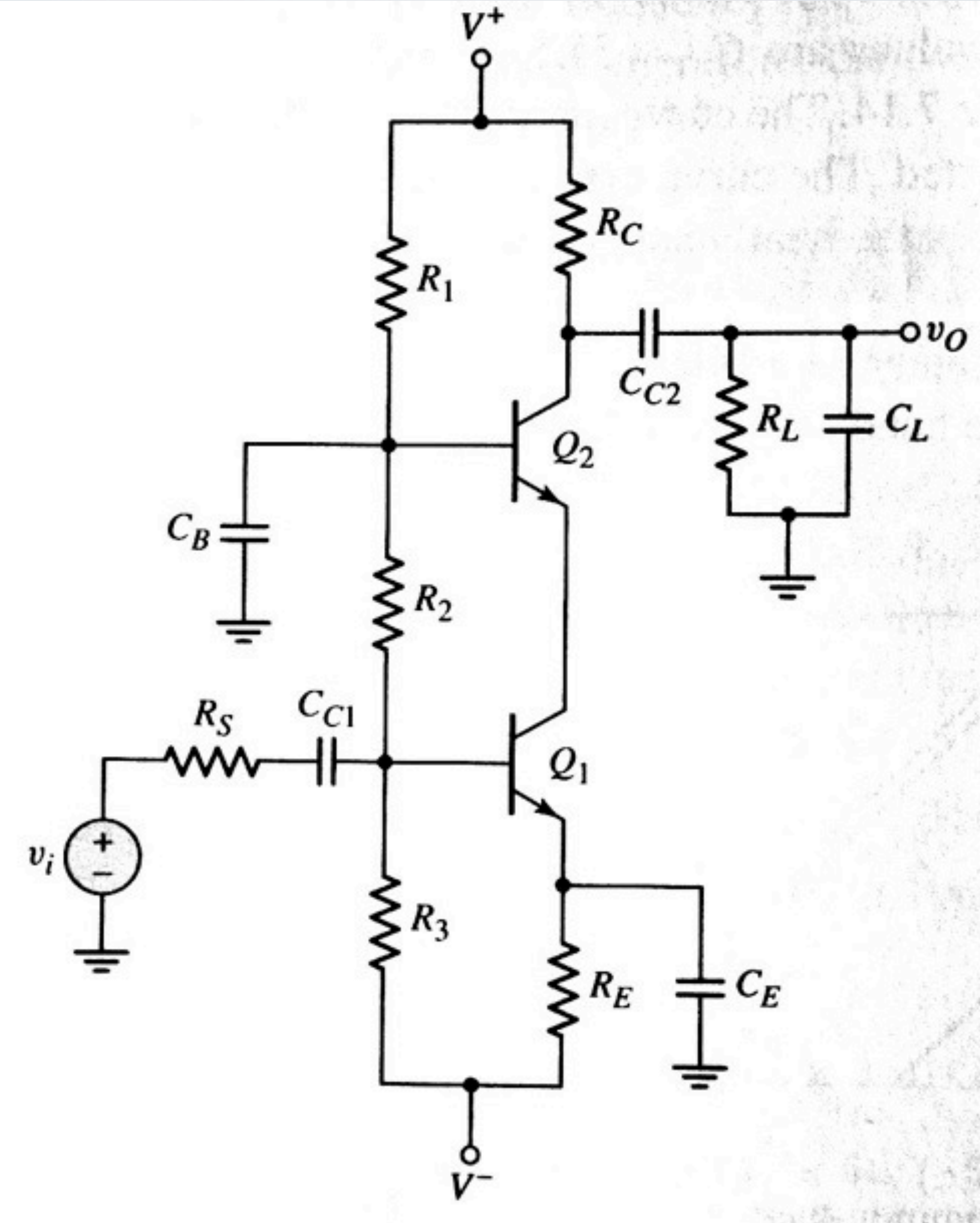


Figure 7.66 Cascode circuit

7.63

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

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

a.

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

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

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

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

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

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

$$r_\mu = \left(R_C \| R_L\right) C_\mu$$

$$= \left(15 \| 10\right)\times 10^3 \times 2\times 10^{-12}$$

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

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

b.

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

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

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

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