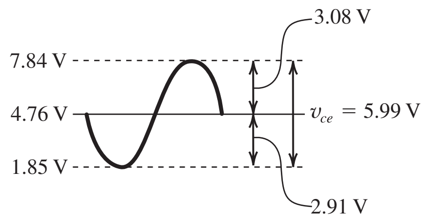
And the collector voltage varies as follows:



7.23 Substituting $v_{gs} = V_{gs} \sin \omega t$ in Eq. (7.28),

$$i_D = \frac{1}{2}k_n(V_{GS} - V_t)^2 + k_n(V_{GS} - V_t)V_{gs} \sin \omega t$$

$$+\frac{1}{2}k_n V_{gs}^2 \sin^2 \omega t$$

$$= \frac{1}{2}k_n(V_{GS} - V_t)^2 + k_n(V_{GS} - V_t)V_{gs} \sin \omega t$$

$$+\frac{1}{2}k_n V_{gs}^2 (\frac{1}{2} - \frac{1}{2} \cos 2\ \omega t)$$

Second-harmonic distortion

$$= \frac{\frac{1}{4}k_n V_{gs}^2}{k_n(V_{GS} - V_t)V_{gs}} \times 100$$

$$= \frac{1}{4}\frac{V_{gs}}{V_{OV}} \times 100 \qquad \text{Q.E.D}$$

For $V_{gs} = 10$ mV, to keep the second-harmonic distortion to less than 1%, the minimum overdrive voltage required is

$$V_{OV} = \frac{1}{4} \times \frac{0.01 \times 100}{1} = 0.25 \text{ V}$$

7.24 $I_D = \frac{1}{2}k_n V_{OV}^2 = \frac{1}{2} \times 10 \times 0.2^2 = 0.2$ mA

$v_{GS} = V_{GS} + v_{gs}$, where $v_{gs} = 0.02$ V

$v_{OV} = 0.2 + 0.02 = 0.22$ V

$$i_D = \frac{1}{2}k_n v_{OV}^2 = \frac{1}{2} \times 10 \times 0.22^2 = 0.242 \text{ mA}$$

Thus,

$i_d = 0.242 - 0.2 = 0.042$ mA

For

$v_{gs} = -0.02$ V, $\quad v_{OV} = 0.2 - 0.02 = 0.18$ V

$$i_D = \frac{1}{2}k_n v_{OV}^2 = \frac{1}{2} \times 10 \times 0.18^2 = 0.162 \text{ mA}$$

Thus,

$i_d = 0.2 - 0.162 = 0.038$ mA

Thus, an estimate of g_m can be obtained as follows:

$$g_m = \frac{0.042 + 0.038}{0.04} = 2 \text{ mA/V}$$

Alternatively, using Eq. (7.33), we can write

$g_m = k_n V_{OV} = 10 \times 0.2 = 2$ mA/V

which is an identical result.

7.25 (a) $I_D = \frac{1}{2}k_n(V_{GS} - V_t^2)$

$$= \frac{1}{2} \times 5(0.6 - 0.4)^2 = 0.1 \text{ mA}$$

$V_{DS} = V_{DD} - I_D R_D = 1.8 - 0.1 \times 10 = 0.8$ V

(b) $g_m = k_n V_{OV} = 5 \times 0.2 = 1$ mA/V

(c) $A_v = -g_m R_D = -1 \times 10 = -10$ V/V

(d) $\lambda = 0.1\ \text{V}^{-1}$, $\quad V_A = \frac{1}{\lambda} = 10$ V

$$r_o = \frac{V_A}{I_D} = \frac{10}{0.1} = 100 \text{ k}\Omega$$

$A_v = -g_m(R_D \parallel r_o)$

$= -1(10 \parallel 100) = -9.1$ V/V

7.26 $A_v = -10 = -g_m R_D = -g_m \times 20$

$g_m = 0.5$ mA/V

To allow for a −0.2-V signal swing at the drain while maintaining saturation-region operation, the minimum voltage at the drain must be at least equal to V_{OV}. Thus

$V_{DS} = 0.2 + V_{OV}$

Since

$$A_v = -\frac{V_{DD} - V_{DS}}{\frac{1}{2}V_{OV}}$$

$$-10 = -\frac{1.8 - 0.2 - V_{OV}}{0.5V_{OV}}$$

$\Rightarrow V_{OV} = 0.27$ V

The value of I_D can be found from

$$g_m = \frac{2I_D}{V_{OV}}$$

$$0.5 = \frac{2 \times I_D}{0.27}$$

$\Rightarrow I_D = 0.067$ mA

The required value of k_n can be found from

$$I_D = \frac{1}{2}k_n V_{OV}^2$$

$$0.067 = \frac{1}{2}k_n \times 0.27^2$$

$\Rightarrow k_n = 1.83$ mA/V^2

Since $k_n' = 0.2$ mA/V^2, the W/L ratio must be

$$\frac{W}{L} = \frac{k_n}{k_n'} = \frac{1.83}{0.2} = 9.14$$

7.29 Given $\mu_n C_{ox} = 250\ \mu\text{A/V}^2$,

$V_t = 0.5$ V,

$L = 0.5\ \mu$m

For $g_m = 2$ mA/V^2 and $I_D = 0.25$ mA,

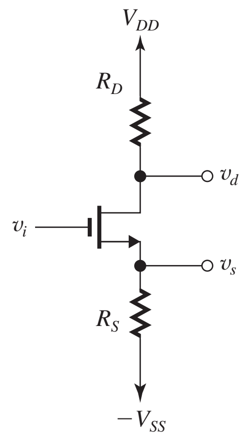
$$g_m = \sqrt{2\mu_n C_{ox}\frac{W}{L}I_D} \Rightarrow \frac{W}{L} = 32$$

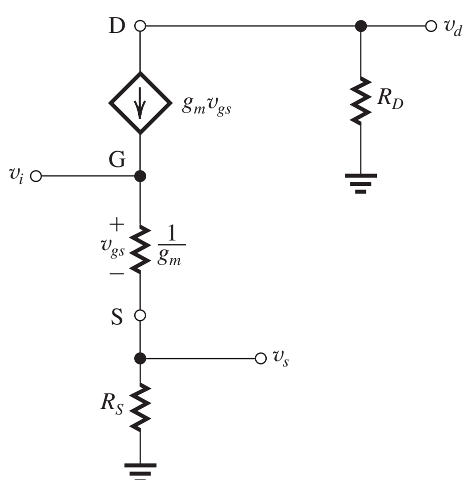
$\therefore W = 16\ \mu$m

$$V_{OV} = \frac{2I_D}{g_m} = 0.25 \text{ V}$$

$\therefore V_{GS} = V_{OV} + V_t = 0.75$ V

7.30





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

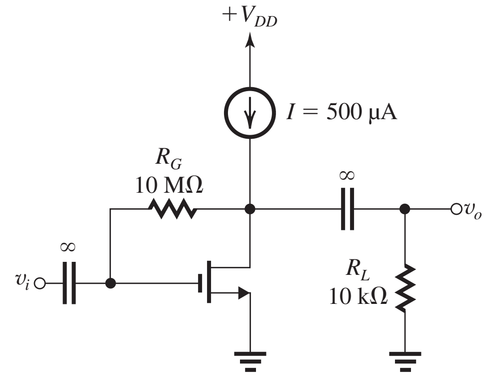
$$v_d = -g_m v_{gs} R_D$$

$$v_s = +g_m v_{gs} R_S$$

$$\therefore \frac{v_s}{v_i} = \frac{R_S}{\frac{1}{g_m} + R_S} = \frac{+g_m R_S}{1 + g_m R_S}$$

$$\frac{v_d}{v_i} = \frac{-R_D}{\frac{1}{g_m} + R_S} = \frac{-g_m R_D}{1 + g_m R_S}$$

7.31



$V_t = 0.5$ V

$V_A = 50$ V

Given $V_{DS} = V_{GS} = 1$ V. Also, $I_D = 0.5$ mA.

$$V_{OV} = 0.5 \text{ V}, \ g_m = \frac{2I_D}{V_{OV}} = 2 \text{ mA/V}$$

$$r_o = \frac{V_A}{I_D} = 100 \text{ k}\Omega$$

$$\frac{v_o}{v_i} = -g_m\,(R_G \parallel R_L \parallel r_o) = -18.2 \text{ V/V}$$

For $I_D = 1$ mA:

V_{OV} increases by $\sqrt{\frac{1}{0.5}} = \sqrt{2}$ to

$\sqrt{2} \times 0.5 = 0.707$ V.

$V_{GS} = V_{DS} = 1.207$ V

$g_m = 2.83$ mA/V, $r_o = 50$ kΩ and

$$\frac{v_o}{v_i} = -23.6 \text{ V/V}$$

7.32 For the NMOS device:

$$I_D = 100 = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{OV}^2$$

$$= \frac{1}{2} \times 400 \times \frac{10}{0.5} \times V_{OV}^2$$

$$\Rightarrow V_{OV} = 0.16 \text{ V}$$

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.1 \text{ mA}}{0.16} = 1.25 \text{ mA/V}$$

$$V_A = 5L = 5 \times 0.5 = 2.5 \text{ V}$$

$$r_o = \frac{V_A}{I_D} = \frac{2.5}{0.1} = 25 \text{ k}\Omega$$

For the PMOS device:

$$I_D = 100 = \frac{1}{2}\mu_p C_{ox}\frac{W}{L}V_{OV}^2$$

$$= \frac{1}{2} \times 100 \times \frac{10}{0.5} \times V_{OV}^2$$

$$\Rightarrow V_{OV} = 0.316 \text{ V}$$

$$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.1}{0.316} = 0.63 \text{ mA/V}$$

$$V_A = 6L = 6 \times 0.5 = 3 \text{ V}$$

$$r_o = \frac{V_A}{I_D} = \frac{3}{0.1} = 30 \text{ k}\Omega$$

7.33 (a) Open-circuit the capacitors to obtain the bias circuit shown in Fig. 1, which indicates the given values.

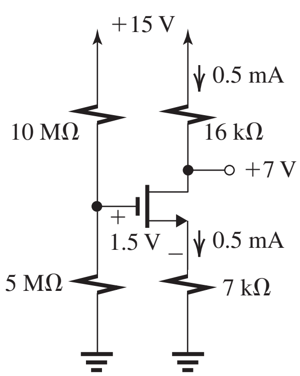


Figure 1

From the voltage divider, we have

$$V_G = 15\frac{5}{10+5} = 5 \text{ V}$$

From the circuit, we obtain

$$V_G = V_{GS} + 0.5 \times 7$$

$$= 1.5 + 3.5 = 5 \text{ V}$$

which is consistent with the value provided by the voltage divider.

Since the drain voltage (+7 V) is higher than the gate voltage (+5 V), the transistor is operating in saturation.

From the circuit

$V_D = V_{DD} - I_D R_D = 15 - 0.5 \times 16 = +7$ V, as assumed

Finally,

$V_{GS} = 1.5$ V, thus $V_{OV} = 1.5 - V_t = 1.5 - 1 = 0.5$ V

$$I_D = \frac{1}{2}k_n V_{OV}^2 = \frac{1}{2} \times 4 \times 0.5^2 = 0.5 \text{ mA}$$

which is equal to the given value. Thus the bias calculations are all consistent.

(b) $g_m = \dfrac{2I_D}{V_{OV}} = \dfrac{2 \times 0.5}{0.5} = 2$ mA/V

$$r_o = \frac{V_A}{I_D} = \frac{100}{0.5} = 200 \text{ k}\Omega$$

(c) See Fig. 2 below.

(d) $R_{\text{in}} = 10 \text{ M}\Omega \parallel 5 \text{ M}\Omega = 3.33 \text{ M}\Omega$

$$\frac{v_{gs}}{v_{\text{sig}}} = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} = \frac{3.33}{3.33 + 0.2}$$

$$= 0.94 \text{ V/V}$$

$$\frac{v_o}{v_{gs}} = -g_m(200 \parallel 16 \parallel 16)$$

$$= -2 \times 7.69 = -15.38 \text{ V/V}$$

$$\frac{v_o}{v_{\text{sig}}} = \frac{v_{gs}}{v_{\text{sig}}} \times \frac{v_o}{v_{gs}} = -0.94 \times 15.38$$

$$= -14.5 \text{ V/V}$$

7.34 (a) Using the exponential characteristic:

$$i_c = I_C e^{v_{be}/V_T} - I_C$$

giving $\dfrac{i_c}{I_C} = e^{v_{be}/V_T} - 1$

(b) Using small-signal approximation:

$$i_c = g_m v_{be} = \frac{I_C}{V_T} \cdot v_{be}$$

This figure belongs to Problem 7.33, part (c).

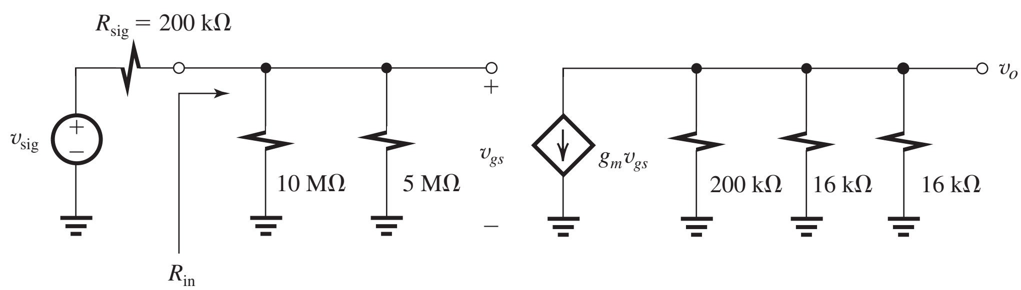


Figure 2

Substituting $g_m = 20$ mA/V results in

$R_C = 7.7$ kΩ

The overall voltage gain achieved is

$$\frac{v_o}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} \times g_m R_C$$

$$= \frac{50}{50+50} \times 20 \times 7.7$$

$$= 77 \text{ V/V}$$

7.58 Refer to Fig. P7.58. Since β is very large, the dc base current can be neglected. Thus the dc voltage at the base is determined by the voltage divider,

$$V_B = 5\frac{100}{100+100} = 2.5 \text{ V}$$

and the dc voltage at the emitter will be

$$V_E = V_B - 0.7 = 1.8 \text{ V}$$

The dc emitter current can now be found as

$$I_E = \frac{V_E}{R_E} = \frac{1.8}{3.6} = 0.5 \text{ mA}$$

and

$$I_C \simeq I_E = 0.5 \text{ mA}$$

Replacing the BJT with the T model of Fig. 7.26(b) results in the following equivalent circuit model for the amplifier.

$$i_e = \frac{v_i}{R_E + r_e}$$

$$v_{o1} = i_e R_E = v_i \frac{R_E}{R_E + r_e}$$

$$\frac{v_{o1}}{v_i} = \frac{R_E}{R_E + r_e} \qquad \text{Q.E.D.}$$

$$v_{o2} = -\alpha i_e R_C = -\alpha \frac{v_i}{R_E + r_e} R_C$$

$$\frac{v_{o2}}{v_i} = -\frac{\alpha R_C}{R_E + r_e} \qquad \text{Q.E.D.}$$

For $\alpha \simeq 1$,

$$r_e = \frac{V_T}{I_E} = \frac{25 \text{ mV}}{0.5 \text{ mA}} = 50\ \Omega$$

$$\frac{v_{o1}}{v_i} = \frac{3.6}{3.6 + 0.05} = 0.986 \text{ V/V}$$

$$\frac{v_{o2}}{v_i} = -\frac{3.3}{3.6 + 0.05} = 0.904 \text{ V/V}$$

If v_{o1} is connected to ground, R_E will in effect be short-circuited at signal frequencies, and v_{o2}/v_i will become

$$\frac{v_{o2}}{v_i} = -\frac{\alpha R_C}{r_e} = -\frac{3.3}{0.05} = -66 \text{ V/V}$$

7.59 See figure on next page.

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_{vo} \frac{R_L}{R_L + R_o}$$

$$= \frac{100}{100+20} \times 100 \times \frac{2}{2+0.1}$$

$$= 79.4 \text{ V/V}$$

$$i_o = \frac{v_o}{R_L}$$

$$i_i = \frac{v_{sig}}{R_{sig} + R_{in}}$$

$$\frac{i_o}{i_i} = \frac{v_o}{v_{sig}} \frac{R_{sig} + R_{in}}{R_L}$$

$$= G_v \frac{R_{sig} + R_{in}}{R_L}$$

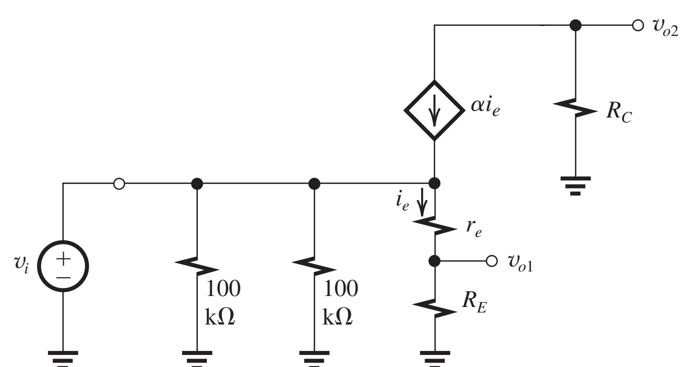
$$= 79.4 \times \frac{20+100}{2} = 4762 \text{ A/A}$$

7.60 (a) $\dfrac{R_{in}}{R_{in} + R_{sig}} = 0.95$

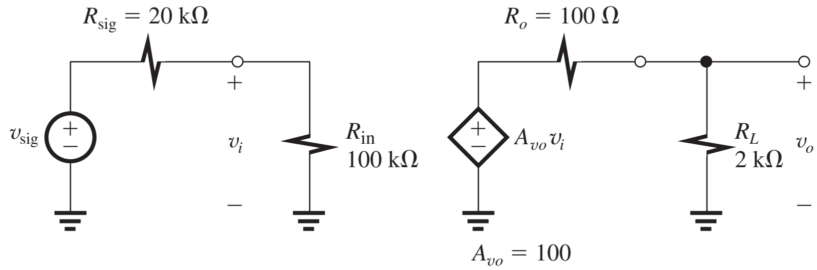
$$\frac{R_{in}}{R_{in} + 100} = 0.95$$

$$\Rightarrow R_{in} = 1.9 \text{ M}\Omega$$

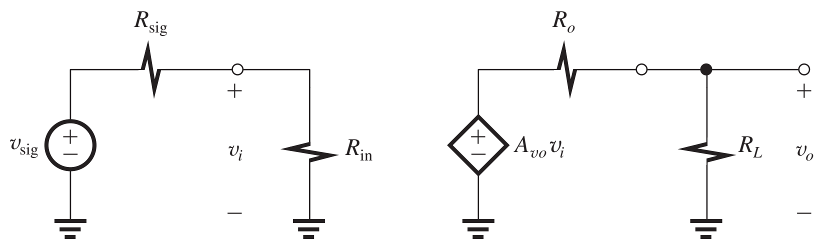
This figure belongs to Problem 7.58.



This figure belongs to Problem 7.59.



This figure belongs to Problem 7.60.



(b) With $R_L = 2\ \text{k}\Omega$,

$$v_o = A_{vo}v_i\frac{2}{2+R_o}$$

With $R_L = 1\ \text{k}\Omega$,

$$v_o = A_{vo}v_i\ \frac{1}{1+R_o}$$

Thus the change in v_o is

$$\Delta v_o = A_{vo}v_i\left[\frac{2}{2+R_o} - \frac{1}{1+R_o}\right]$$

To limit this change to 5% of the value with $R_L = 2\ \text{k}\Omega$, we require

$$\left[\frac{2}{2+R_o} - \frac{1}{1+R_o}\right]\Big/\left(\frac{2}{2+R_o}\right) = 0.05$$

$$\Rightarrow R_o = \frac{1}{9}\ \text{k}\Omega = 111\ \Omega$$

(c) $G_v = 10 = \dfrac{R_{in}}{R_{in}+R_{sig}}A_{vo}\dfrac{R_L}{R_L+R_o}$

$$= \frac{1.9}{1.9+0.1} \times A_{vo} \times \frac{2}{2+0.111}$$

$$\Rightarrow A_{vo} = 11.1\ \text{V/V}$$

The values found about are limit values; that is, we require

$R_{in} \geq 1.9\ \text{M}\Omega$

$R_o \leq 111\ \Omega$

$A_{vo} \geq 11.1\ \text{V/V}$

7.61 The circuit in Fig. 1(b) (see figure on next page) is that in Fig. P7.61, with the output current source expressed as $G_m v_i$. Thus, for equivalence, we write

$$G_m = \frac{A_{vo}}{R_o}$$

To determine G_m (at least conceptually), we short-circuit the output of the equivalent circuit in Fig. 1(b). The short-circuit current will be

$$i_o = G_m v_i$$

Thus G_m is defined as

$$G_m = \left.\frac{i_o}{v_i}\right|_{R_L=0}$$

and is known as the short-circuit transconductance. From Fig. 2 on next page,

$$\frac{v_i}{v_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}}$$

$$v_o = G_m v_i(R_o \parallel R_L)$$

Thus,

$$\frac{v_o}{v_{sig}} = \frac{R_{in}}{R_{in}+R_{sig}}G_m(R_o \parallel R_L)$$

7.62

$$G_{vo} = \left.\frac{v_o}{v_{sig}}\right|_{R_L=\infty}$$

Now, setting $R_L = \infty$ in the equivalent circuit in Fig. 1(b), we can determine G_{vo} from

This figure belongs to Problem 7.63.

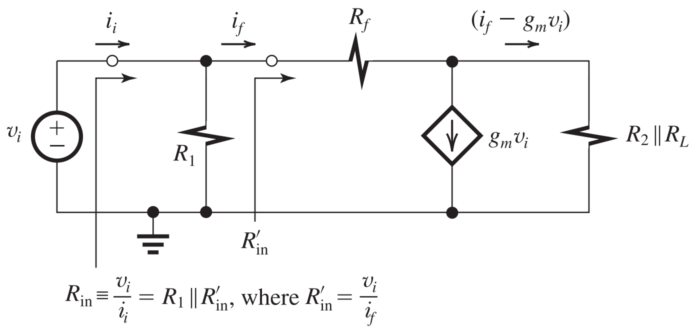


Figure 1

Thus,

$$v_i[1 + g_m(R_2 \| R_L)] = i_f[R_f + (R_2 \| R_L)]$$

$$R'_{in} \equiv \frac{v_i}{i_f} = \frac{R_f + (R_2 \| R_L)}{1 + g_m(R_2 \| R_L)}$$

and

$$R_{in} = R_1 \| R'_{in}$$

$$= R_1 \| \left[\frac{R_f + (R_2 \| R_L)}{1 + g_m(R_2 \| R_L)} \right] \qquad \text{Q.E.D.}$$

To determine A_{vo}, we open-circuit R_L and use the circuit in Fig. 2, where

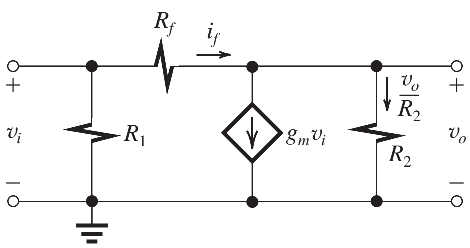


Figure 2

$$i_f = g_m v_i + \frac{v_o}{R_2}$$

$$v_i = i_f R_f + v_o = \left(g_m v_i + \frac{v_o}{R_2}\right) R_f + v_o$$

$$v_i(1 - g_m R_f) = v_o\left(1 + \frac{R_f}{R_2}\right)$$

Thus,

$$A_{vo} \equiv \frac{v_o}{v_i} = \frac{1 - g_m R_f}{1 + \frac{R_f}{R_2}}$$

which can be manipulated to the form

$$A_{vo} = -g_m R_2 \frac{1 - 1/g_m R_f}{1 + (R_2/R_f)} \qquad \text{Q.E.D.}$$

Finally, to obtain R_o we short-circuit v_i in the circuit of Fig. P7.63. This will disable the controlled source $g_m v_i$. Thus, looking between the output terminals (behind R_L), we see R_2 in parallel with R_f,

$$R_o = R_2 \| R_f \qquad \text{Q.E.D.}$$

For $R_1 = 100\ \text{k}\Omega,\ R_f = 1\ \text{M}\Omega,\ g_m = 100\ \text{mA/V}$

$R_2 = 100\ \Omega$ and $R_L = 1\ \text{k}\Omega$

$$R_{in} = 100 \| \frac{1000 + (0.1 \| 1)}{1 + 100(0.1 \| 1)} = 100 \| 99.1$$

$$= 49.8\ \text{k}\Omega$$

Without R_f present (i.e., $R_f = \infty$), $R_{in} = 100\ \text{k}\Omega$ and

$$A_{vo} = -100 \times 0.1 \frac{1 - (1/100 \times 1000)}{1 + \frac{0.1}{1000}}$$

$$\simeq -10\ \text{V/V}$$

Without R_f, $-A_{vo} = 10$ V/V and

$$R_o = 0.1 \| 1000 \simeq 0.1\ \text{k}\Omega = 100\ \Omega$$

Without R_f, $R_o = 100\ \Omega$.

Thus the only parameter that is significantly affected by the presence of R_f is R_{in}, which is reduced by a factor of 2!

$$G_v = \frac{R_{in}}{R_{in} + R_{sig}} A_{vo} \frac{R_L}{R_L + R_o}$$

With R_f,

$$G_v = \frac{49.8}{49.8 + 100} \times -10 \times \frac{1}{1 + 0.1}$$

$$= -3\ \text{V/V}$$

Without R_f,

$$G_v = \frac{100}{100 + 100} \times -10 \times \frac{1}{1 + 0.1} = -4.5\ \text{V/V}$$

7.64 $R_{sig} = 1\ \text{M}\Omega,\ R_L = 10\ \text{k}\Omega$

$g_m = 2\ \text{mA/V},\ R_D = 10\ \text{k}\Omega$

$G_v = -g_m(R_D \parallel R_L)$

$= -2(10 \parallel 10) = -10 \text{ V/V}$

7.65 $R_{\text{in}} = \infty$

$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}V_{OV}^2$

$320 = \frac{1}{2} \times 400 \times 10 \times V_{OV}^2$

$\Rightarrow V_{OV} = 0.4 \text{ V}$

$g_m = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.32}{0.4} = 1.6 \text{ mA/V}$

$A_{vo} = -g_m R_D = -1.6 \times 10 = -16 \text{ V/V}$

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

$G_v = A_{vo}\frac{R_L}{R_L + R_o}$

$= -16 \times \frac{10}{10+10} = -8 \text{ V/V}$

Peak value of $v_{\text{sig}} = \frac{0.2 \text{ V}}{8} = 25 \text{ mV}$.

7.66 $R_D = 2R_L = 30 \text{ k}\Omega$

$V_{OV} = 0.25 \text{ V}$

$G_v = -g_m(R_D \parallel R_L)$

$-10 = -g_m(30 \parallel 15)$

$\Rightarrow g_m = 1 \text{ mA/V}$

$g_m = \frac{2I_D}{V_{OV}}$

$1 = \frac{2 \times I_D}{0.25}$

$\Rightarrow I_D = 0.125 \text{ mA} = 125 \ \mu\text{A}$

If R_D is reduced to $15 \text{ k}\Omega$,

$G_v = -g_m(R_D \parallel R_L)$

$= -1 \times (15 \parallel 15) = -7.5 \text{ V/V}$

7.67 (a) See figure below.

(b) $g_{m1} = g_{m2} = \frac{2I_D}{V_{OV}} = \frac{2 \times 0.3}{0.2} = 3 \text{ mA/V}$

$R_{D1} = R_{D2} = 10 \text{ k}\Omega$

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

$G_v = \frac{v_{gs2}}{v_{gs1}} \times \frac{v_o}{v_{gs2}}$

$= -g_{m1}R_{D1} \times -g_{m2}(R_{D2} \parallel R_L)$

$= 3 \times 10 \times 3 \times (10 \parallel 10)$

$= 450 \text{ V/V}$

7.68 $g_m = \frac{I_C}{V_T} = \frac{0.5 \text{ mA}}{0.025 \text{ V}} = 20 \text{ mA/V}$

$r_\pi = \frac{\beta}{g_m} = \frac{100}{20 \text{ mA/V}} = 5 \text{ k}\Omega$

$R_{\text{in}} = r_\pi = 5 \text{ k}\Omega$

$R_o = R_C = 10 \text{ k}\Omega$

$A_{vo} = -g_m R_C = -20 \times 10 = -200 \text{ V/V}$

$A_v = A_{vo}\frac{R_L}{R_L + R_o} = -200 \times \frac{10}{10+10}$

$= -100 \text{ V/V}$

$G_v = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}}A_v$

$= \frac{5}{5+10} \times -100$

$= -33.3 \text{ V/V}$

For $\hat{v}_\pi = 5 \text{ mV}$, $\hat{v}_{\text{sig}}$ can be found from

$\hat{v}_\pi = \hat{v}_{\text{sig}} \times \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} = \hat{v}_{\text{sig}} \times \frac{5}{5+10}$

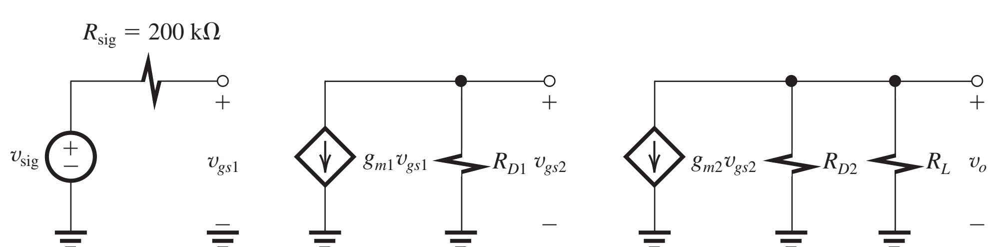
$\Rightarrow \hat{v}_{\text{sig}} = 15 \text{ mV}$

Correspondingly, $\hat{v}_o$ will be

$\hat{v}_o = G_v \hat{v}_{\text{sig}}$

$= 15 \times 33.3 = 500 \text{ mV} = 0.5 \text{ V}$

This figure belongs to Problem 7.67.



7.69 $|G_v| = \dfrac{R'_L}{(R_{sig}/\beta) + (1/g_m)}$

$R'_L = 10\text{ k}\Omega,\ R_{sig} = 10\text{ k}\Omega,\ g_m = \dfrac{I_C}{V_T}$

$= \dfrac{1}{0.025} = 40\text{ mA/V}$

Nominal $\beta = 100$

(a) Nominal $|G_v| = \dfrac{10}{(10/100) + 0.025}$

$= 80\text{ V/V}$

(b) $\beta = 50,\ |G_v| = \dfrac{10}{(10/50) + 0.025}$

$= 44.4\text{ V/V}$

$\beta = 150,\ |G_v| = \dfrac{10}{(10/150) + 0.025}$

$= 109.1\text{ V/V}$

Thus, $|G_v|$ ranges from 44.4 V/V to 109.1 V/V.

(c) For $|G_v|$ to be within ±20% of nominal (i.e., ranging between 64 V/V and 96 V/V), the corresponding allowable range of β can be found as follows:

$$64 = \frac{10}{(10/\beta_{min}) + 0.025}$$

$\Rightarrow \beta_{min} = 76.2$

$$96 = \frac{10}{(10/\beta_{max}) + 0.025}$$

$\Rightarrow \beta_{max} = 126.3$

(d) By varying I_C, we vary the term $1/g_m$ in the denominator of the $|G_v|$ expression. If β varies in the range 50 to 150 and we wish to keep $|G_v|$ within ±20% of a new nominal value of $|G_v|$ given by

$$|G_v|_{nominal} = \frac{10}{(10/100) + (1/g_m)}$$

then

$$0.8\,|G_v|_{nominal} = \frac{10}{(10/50) + (1/g_m)}$$

That is,

$$\frac{8}{0.1 + (1/g_m)} = \frac{10}{0.2 + (1/g_m)}$$

$\Rightarrow \dfrac{1}{g_m} = 0.3$ or $g_m = 3.33\text{ mA/V}$

$$|G_v|_{nominal} = \frac{10}{0.1 + 0.3} = 25\text{ V/V}$$

$$|G_v|_{min} = \frac{10}{0.2 + 0.3}$$

$= 20\text{ V/V}$ (−20% of nominal)

We need to check the value obtained for $\beta = 150$,

$$|G_v|_{max} = \frac{10}{10/150 + 0.3} = 27.3\text{ V/V}$$

which is less than the allowable value of $1.2\,|G_v|_{nominal} = 30\text{ V/V}$. Thus, the new bias current is

$I_C = g_m \times V_T = 3.33 \times 0.025 = 0.083\text{ mA}$

$|G_v|_{nominal} = 25\text{ V/V}$

7.70 (a) See figure below.

(b) $R_{C1} = R_{C2} = 10\text{ k}\Omega \quad R_{sig} = 10\text{ k}\Omega$

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

$$g_{m1} = g_{m2} = \frac{I_C}{V_T} = \frac{0.25\text{ mA}}{0.025\text{ V}} = 10\text{ mA/V}$$

$$r_{\pi1} = r_{\pi2} = \frac{\beta}{g_m} = \frac{100}{10} = 10\text{ k}\Omega$$

$$\frac{v_{\pi1}}{v_{sig}} = \frac{r_{\pi1}}{r_{\pi1} + R_{sig}} = \frac{10}{10 + 10} = 0.5\text{ V/V}$$

$$\frac{v_{\pi2}}{v_{\pi1}} = -g_{m1}(R_{C1} \parallel r_{\pi2}) = -10(10 \parallel 10)$$

$= -50\text{ V/V}$

$$\frac{v_o}{v_{\pi2}} = -g_{m2}(R_{C2} \parallel R_L)$$

$= -10(10 \parallel 10) = -50\text{ V/V}$

This figure belongs to Problem 7.70.