11.12

$V_{CC} = 5\text{ V}$

For maximum η,

$\hat{V}_o = V_{CC} = 5\text{ V}$

The output voltage that results in maximum device dissipation is given by Eq. (12.20),

$$\hat{V}_o = \frac{2}{\pi}V_{CC}$$

$$= \frac{2}{\pi} \times 5 = 3.18\text{ V}$$

If operation is always at full output voltage, $\eta = 78.5\%$ and thus

$$P_{\text{dissipation}} = (1-\eta)P_s$$

$$= (1-\eta)\frac{P_L}{\eta} = \frac{1-0.785}{0.785}P_L = 0.274P_L$$

$$P_{\text{dissipation/device}} = \frac{1}{2} \times 0.274P_L = 0.137P_L$$

For a rated device dissipation of 1 W, and using a factor of 2 safety margin,

$$P_{\text{dissipation/device}} = 0.5\text{ W}$$

$$= 0.137P_L$$

$$\Rightarrow P_L = 3.65\text{ W}$$

$$3.65 = \frac{1}{2} \times \frac{25}{R_L}$$

$$\Rightarrow R_L = 3.425\ \Omega \text{ (i.e. } R_L \geq 3.425\ \Omega\text{)}$$

The corresponding output power (i.e., greatest possible output power) is 3.65W.

If operation is allowed at $\hat{V}_o = \frac{1}{2}V_{CC} = 2.5\text{ V}$,

$$\eta = \frac{\pi}{4}\frac{\hat{V}_o}{V_{CC}} \text{ (Eq. 12.15)}$$

$$= \frac{\pi}{4} \times \frac{1}{2} = 0.393$$

$$P_{\text{dissipation/device}} = \frac{1}{2}\frac{1-\eta}{\eta}P_L = 0.772P_L$$

$$0.5 = 0.772P_L$$

$$\Rightarrow P_L = 0.647\text{ W}$$

$$= \frac{1}{2}\frac{2.5^2}{R_L}$$

$$\Rightarrow R_L = 4.83\ \Omega \text{ (i.e., } \geq 4.83\ \Omega\text{)}$$

11.13

$$P_L = \frac{1}{2}\frac{\hat{V}_o^2}{R_L}$$

$$100 = \frac{1}{2}\frac{\hat{V}_o^2}{16}$$

$$\hat{V}_o = 56.6\text{ V}$$

$$V_{CC} = 56.6 + 4 = 60.6 \rightarrow 61\text{ V}$$

Peak current from each supply $= \frac{\hat{V}_o}{R_L} = \frac{56.6}{16}$

$$= 3.54\text{ A}$$

$$P_{s+} = P_{s-} = \frac{1}{\pi} \times 3.54 \times 61$$

Thus, $P_s = \frac{2}{\pi} \times 3.54 \times 61$

$$= 137.4\text{ W}$$

$$\eta = \frac{P_L}{P_S} = \frac{100}{137.4} = 73\%$$

Using Eq. (12.22),

$$P_{DN\text{ max}} = P_{DP\text{ max}} = \frac{V_{CC}^2}{\pi^2 R_L} = \frac{61^2}{\pi^2 \times 16}$$

$$= 23.6\text{W}$$

11.14

$$P_L = \frac{\hat{V}_o^2}{R_L}$$

$$P_{S+} = P_{S-} = \frac{1}{2}\left(\frac{\hat{V}_o}{R_L}\right)V_{SS}$$

$$P_S = \frac{\hat{V}_o}{R_L}V_{SS}$$

$$\eta = \frac{P_L}{P_S} = \frac{\hat{V}_o^2/R_L}{\hat{V}_o V_{SS} R_L} = \frac{\hat{V}_o}{V_{SS}}$$

$\eta_{\max} = 1(100\%)$, obtained for $\hat{V}_o = V_{SS}$

$$P_{L\max} = \frac{V_{SS}^2}{R_L}$$

$$P_{\text{dissipation}} = P_S - P_L$$

$$= \frac{\hat{V}_o}{R_L}V_{SS} - \frac{\hat{V}_o^2}{R_L}$$

$$\frac{\partial P_{\text{dissipation}}}{\partial \hat{V}_o} = \frac{V_{SS}}{R_L} - \frac{2\hat{V}_o}{R_L}$$

$= 0$ for $\hat{V}_o = \frac{V_{SS}}{2}$

Correspondingly, $\eta = \frac{V_{SS}/2}{V_{SS}} = \frac{1}{2}$ or 50%

11.15

$A_v = \frac{R_L}{R_L + R_{\text{out}}}$ and $R_{\text{out}} = \frac{r_e}{2} = \frac{V_T}{2I_Q}$

Now $A_v \geq 0.98$ for $R_L \geq 100\ \Omega$

$$\therefore 0.98 = \frac{100}{100 + R_{\text{out}}}$$

$$\Rightarrow R_{\text{out}} \simeq 2\ \Omega$$

$$R_{\text{out}} = 2 = \frac{V_T}{2I_Q}$$

(table is for 11.16)

v_o(V)	i_L (mA)	i_N (mA)	i_P (mA)	V_{BEN} (V)	V_{EBR} (V)	V_i (V)	V/V	R_{out} (Ω)	V/V	i_I	R_{in} (Ω)
+10.0	100	100.04	0.04	0.691	0.495	10.1	0.99	0.25	1.00	2	5050
+5.0	50	50.08	0.08	0.673	0.513	5.08	0.98	0.50	1.00	1	5080
+1.0	10	10.39	0.39	0.634	0.552	1.041	0.96	2.32	0.98	0.2	5205
+0.5	5	5.70	0.70	0.619	0.567	0.526	0.95	4.03	0.96	0.1	5260
+0.2	2	3.24	1.24	0.605	0.581	0.212	0.94	5.58	0.95	0.04	5300
+0.1	1	2.56	1.56	0.599	0.587	0.106	0.94	6.07	0.94	0.02	5300
0	0	2	2	0.593	0.593	0	–	6.25	0.94		
−0.1	−1	1.56	2.56	0.587	0.599	−0.106	0.94	6.07	0.94	−0.02	5300
−0.2	−2	1.24	3.24	0.581	0.605	−0.212	0.94	5.58	0.95	−0.04	5300
−0.5	−5	0.70	5.70	0.567	0.619	−0.526	0.95	4.03	0.96	−0.1	5260
−1.0	−10	0.39	10.39	0.552	0.634	−1.041	0.96	2.32	0.98	−0.2	5205
−5.0	−50	0.08	50.08	0.513	0.673	−5.08	0.98	0.50	1.00	−1	5080
−10.0	−100	0.04	100.04	0.495	0.691	−10.1	0.99	0.25	1.00	−2	5050

$$I_Q = \frac{V_T}{4} = \frac{25 \times 10^{-3}}{4} = 6.25\text{ mA}$$

$$V_{BB} = 2V_{BE} = 2\left[0.7 + V_T \ln\left(\frac{6.25}{100}\right)\right]$$

$$= 1.26\text{ V}$$

11.16

The current i_I can be obtained as

$$i_I = \frac{i_N}{\beta_N + 1} - \frac{i_P}{\beta_P + 1} = \frac{i_L}{\beta + 1}$$

$$\therefore \beta_N = \beta_P = \beta = 49$$

Using values of v_I from the table one can evaluate R_{in}

$$\therefore R_{in} = \frac{v_I}{i_I}$$

Using resistance reflection rule

$$R_{in} \cong \beta R_L = 49 \times 100$$

$$= 4900\ \Omega$$

For large input signal the two values of R_{in} are somewhat same. For the small values of v_I, the calculated value in the table is larger.

11.17

$$\frac{v_o}{v_i} = \frac{R_L}{R_L + R_{out}} \text{ and}$$

$$R_{out} = \frac{V_T}{i_P + i_N} = \frac{V_T}{I_Q + I_Q} \text{ at } v_o = 0$$

$$\text{a. } \epsilon = 1 - \left.\frac{v_o}{v_I}\right|_{v_o = 0}$$

$$= 1 - \frac{R_L}{R_L + R_{out}} = 1 - \frac{R_L}{R_L + \dfrac{V_T}{2I_Q}} = \frac{V_T/2I_Q}{R_L + (V_T/2I_Q)}$$

$$\epsilon = \frac{V_T/2I_Q}{R_L + (V_T/2I_Q)} = \frac{V_T}{2R_LI_Q + V_T}$$

If $2I_QR_L >> V_T$

$$\epsilon = \frac{V_T}{2I_QR_L}$$

b. Quiescent Power Dissipation $= 2V_{CC}I_Q = P_D$

c. $\epsilon \times$ Quiescent Power Dissipation $=$

$$\frac{V_T}{2I_QR_L} \times 2V_{CC}I_Q = V_T \times \left(\frac{V_{CC}}{R_L}\right)$$

$$\therefore \epsilon P_D = V_T\left(\frac{V_{CC}}{R_L}\right)$$

$$\text{d. } \epsilon P_D = V_T\frac{V_{CC}}{R_L} = 25 \times 10^{-3} \times \frac{15}{100}$$

$$= 3.75\text{ mW}$$

$$P_D = \frac{3.75 \times 10^{-3}}{\epsilon}$$

ϵ	P_D in mW
0.05	75
0.02	187.5
0.01	375

11.18

$I_Q = 1\text{mA}$

For output of -1 V, $i_L = -\frac{1}{100} = -10$ mA

Using Eq. (11.27)

$i_N^2 - i_L i_N - I_Q^2 = 0$

$i_N^2 + 10 i_N - 1 = 0$

$i_N = 0.1\text{mA}$

$i_P = 10.1\text{mA}$

Thus v_{EB_P} increases by $V_T \ln\frac{10.1}{1} = 0.06\text{V}$

and the input step must be -1.06 V

Largest possible positive output from 6 to 10, i.e., 4 V

Largest negative output from 6 to 0, i.e., 6 V

11.19

$R_{out} = r_e/2 = 10\ \Omega$

$\Rightarrow r_e = 20\Omega$

$I_Q = \frac{V_T}{r_e} = \frac{25}{20} = 1.25\text{mA}$

Thus, $\eta = \frac{1.25}{0.1} = 12.5$

11.20

$I_Q \simeq I_{bias} = 0.5$ mA, neglecting the base current of Q_N. More precisely,

$$I_Q = I_{bias} - \frac{I_Q}{\beta + 1}$$

$$\Rightarrow I_Q = \frac{I_{bias}}{1 + \frac{1}{\beta + 1}} \simeq 0.98 \times 0.5 = 0.49 \text{ mA}$$

The largest positive output is obtained when all of I_{bais} flows into the base of Q_N, resulting in

$v_o = (\beta_N + 1) I_{bias} R_L$

$= 51 \times 0.5 \times 100\ \Omega = 2.55$ V

The largest possible negative output voltage is limited by the saturation of

Q_P to $-10 + V_{ECSat} = -10$ V

To achieve a maximum positive output of 10 V without changing I_{bias}, β_N must be

$10 = (\beta_N + 1) \times 0.5 \times 100\ \Omega$

$\Rightarrow \beta_N = 199$

Alternatively, if β_N is held at 50, I_{bias} must be increased so that

$10 = 51 \times I_{bias} \times 100\Omega$

$\Rightarrow I_{bias} = 1.96\text{mA}$

for which,

$$I_Q = \frac{I_{bias}}{1 + \frac{1}{\beta + 1}} = 1.92 \text{ mA}$$

11.21

At 20°C, $I_Q = 1\text{mA} = I_S e^{(0.6/0.025)}$

$\Rightarrow I_S$ (at 20°C) $= 3.78 \times 10^{-11}$ mA

At 70°C, $I_S = 3.78 \times 10^{-11} (1.14)^{50}$

$= 2.64 \times 10^{-8}$ mA

At 70°C, $V_T = 25 \frac{273 + 70}{273 + 20} = 29.3$ mV

Thus, I_Q (at 70°C) $= 2.64 \times 10^{-8} e^{0.6/0.0293}$

$= 20.7$ mA

Additional current $= 20.7 - 1 = 19.7$ mA

Additional power $= 2 \times 20 \times 19.7 = 788$mW

Additional temperature rise$= 10 \times 0.788 = 7.9$°C,

At 77.9°C :

$V_T = \frac{25}{293}(273 + 77.9) = 29.9$ mV

$I_Q = 3.78 \times 10^{-11} \times (1.14)^{57.9} e^{(0.6/0.0299)}$

$= 37.6$ mA

etc., etc.

11.22

Since the peak positive output current is 200 mA, the base current of Q_N can be as high as

$\frac{200}{\beta_N + 1} = \frac{200}{51} \simeq 4$ mA. We select

$I_{bias} = 5$ mA, thus providing the multiplier with a minimum current of 1 mA.

Under quiescent conditions ($v_o = 0$ and $i_L = 0$) the base current of Q_N can be neglected.

Selecting $I_R = 0.5$ mA leaves $I_{C1} = 4.5$ mA. To obtain a quiescent current of 2 mA in the output transistors, V_{BB} should be

$$V_{BB} = 2V_T \ln\frac{2 \times 10^{-3}}{10^{-15}} = 1.19 \text{ V}$$

Thus

$$R_1 + R_2 = \frac{V_{BB}}{I_R} = \frac{1.19}{0.5} = 2.38 \text{ k}\Omega$$

At a collector current of 4.5 mA, Q_1 has

$$V_{BEL} = V_T \ln\frac{4.5 \times 10^{-3}}{10^{-14}} = 0.671 \text{ V}$$

The value of R_1 can now be determined as

$R_1 = \frac{0.671}{0.5} = 1.34$ kΩ and

$R_2 = 2.58 - 1.34 = 1.04$ kΩ

11.23

(a) $V_{BE} = 0.7$ V at 1 mA

At 0.5 mA,

$V_{BE} = 0.7 + 0.025 \ln\frac{0.5}{1} = 0.683$ V

Thus $R_1 = \frac{0.683}{0.5} = 1.365\ \text{k}\Omega$

and $R_2 = 1.365\ \text{k}\Omega$

(b) For $I_{\text{bias}} = 2\ \text{mA}$, I_C increases to nearly 1.5 mA for which

$$V_{BE} = 0.7 + 0.025\ \ln\frac{1.3}{1} = 0.710\ \text{V}$$

Note that $I_R = \frac{0.710}{1.365} = 0.52$ mA is very nearly equal to the assumed value of 0.50 mA, Thus no further iterations are required.

$$V_{BB} = 2V_{BE} = 1.420\ \text{V}$$

(c) For $I_{\text{bias}} = 10\ \text{mA}$, assume that I_R remains constant at 0.5 mA, thus $I_{C1} = 9.5$ mA

and $V_{BE} = 0.7 + 0.025\ \ln\frac{9.5}{1} = 0.756\ \text{V}$

at which

$$I_R = \frac{0.755}{1.365} = 0.554\ \text{mA}$$

Thus,

$$I_{C1} = 10 - 0.554 = 9.45\ \text{mA}$$

and $V_{BE} = 0.7 + 0.025\ \ln\frac{9.45}{1} = 0.756\ \text{V}$

Thus $V_{BB} = 2 \times 0.756 = 1.512\ \text{V}$

(d) Now for $\beta = 100$,

$$I_{R1} = \frac{0.756}{1.365} = 0.554\ \text{mA}$$

$$I_{R2} = 0.554 + \frac{9.45}{101} = 0.648\ \text{mA}$$

$$I_C = 10 - 0.648 = 9.352\ \text{mA}$$

Thus, $V_{BE} = 0.7 + 0.025\ \ln\frac{9.352}{1} = 0.756\ \text{V}$

$$V_{BB} = 0.756 + I_{R2}\,R_2$$
$$= 0.756 + 0.648 \times 1.365$$
$$= 1.641\ \text{V}$$

11.24

a. From Figure 11.17

$$R_{\text{out}} = R_{\text{OQN}} \parallel R_{\text{OQP}}$$

$$R_{\text{OQM}} = \frac{1}{g_{mN}} \parallel r_{ON} \simeq \frac{1}{g_{mN}}$$

$$R_{\text{OQP}} = \frac{1}{g_{mP}} \parallel r_{OP} \simeq \frac{1}{g_{mP}}$$

$$R_{\text{out}} = \frac{1}{g_{mN}} \parallel \frac{1}{g_{mP}} = \frac{\frac{1}{g_{mN}} \times \frac{1}{g_{mP}}}{\frac{1}{g_{mN}} + \frac{1}{g_{mP}}} = \frac{1}{g_{mN} + g_{mP}}$$

$= \frac{1}{2g_m}$ for matched devices $g_{mN} = g_{mP} = g_m$

b. $R_{\text{out}} = 10 = \frac{1}{2g_m} \Rightarrow g_m = \frac{1}{20}$

$$g_m = \frac{2I}{V_{ov}} = \frac{2}{V_{ov}} \times \frac{1}{2}\,k'\left(\frac{W}{L}\right)V_{ov}^2 = k'\left(\frac{W}{L}\right)V_{ov}$$

$$\therefore \frac{1}{20} = k'\left(\frac{W}{L}\right)V_{ov} = 200 \times 10^{-3} \times V_{ov}$$

$$\Rightarrow V_{ov} = 0.25\ \text{V}$$

But $V_{ov} = V_{GS} - V_t$

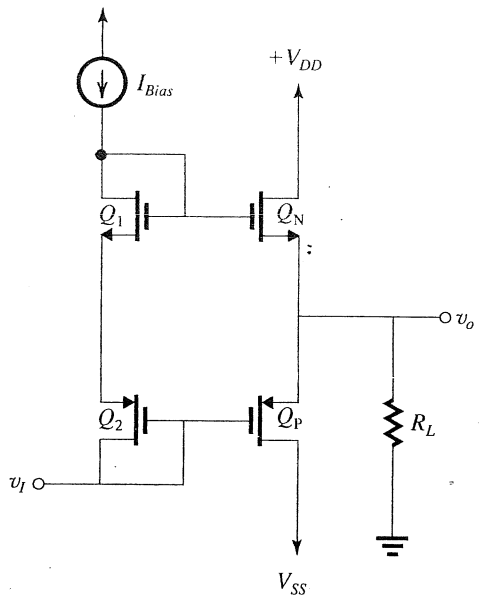
$0.25 = V_{GS} - 0.7$

So $V_{GS} = 0.95$ V

$V_{GG} = V_{GS1} + V_{GS2} = 2\,V_{GS}$

$= 1.9$

11.25



a. under quiescent condition

$$\text{Voltage gain} = \frac{v_O}{v_i} = \frac{R_L}{R_L + R_{\text{out}}}$$

As shown in problem 11.24, for matched transistors

$$R_{\text{out}} = \frac{1}{2g_m}$$

Substitute for R_{out} above for $\frac{v_O}{v_i}$

$$\frac{v_O}{v_i} = \frac{R_L}{R_L + \frac{1}{2g_m}}$$

b. Voltage gain $= 0.98 = \frac{R_L}{R_L + \frac{1}{2g_m}}$

$$0.98 = \frac{1000}{1000 + \frac{1}{2g_m}}$$

$$\Rightarrow g_m = 24.5\ \text{mA/V}$$

For Q_1, $I_{\text{Bias}} = I_D$

$$\therefore 0.1 = \frac{1}{2}k_1 V_{OV}^2$$

$$0.1 = \frac{1}{2} \times 20 \times V_{OV}^2$$

$$\Rightarrow V_{OV} = 0.1\text{ V}$$

For Q_N

$$g_m = k_n V_{OV}$$

$$24.5 = k_n \times 0.1$$

$$k_n = 245\text{ mA/V}^2$$

$$n = \frac{k_n}{k_1} = \frac{245}{20}$$

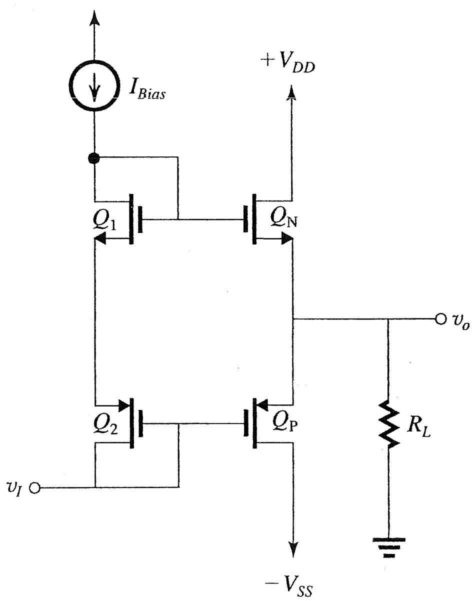
$$= 12.25$$

and $I_Q = nI_{\text{bias}}$

$$= 12.25 \times 0.1$$

$$= 1.225\text{ mA}$$

11.26



a. Equation 11.43

$$I_Q = \text{I}_{\text{Bias}} \frac{(W/L)_n}{(W/L)_1}$$

$$1 = 0.1 \frac{(W/L)_n}{(W/L)_1}$$

$$\frac{(W/L)_n}{(W/L)_1} = 10$$

$$Q_1: I_{\text{Bias}} = \frac{1}{2} k_n' \left(\frac{W}{L}\right)_1 V_{ov}^2$$

$$0.1 = \frac{1}{2} \times 0.250 \times \left(\frac{W}{L}\right)_1 \times (0.2)^2$$

$$\Rightarrow \left(\frac{W}{L}\right)_1 = 20$$

$$Q_2: 0.1 = \frac{1}{2} \times 0.100 \times \left(\frac{W}{L}\right)_2 \times (0.2)^2$$

$$\Rightarrow \left(\frac{W}{L}\right)_2 = 50$$

$$Q_N: 1 = \frac{1}{2} \times 0.250 \times \left(\frac{W}{L}\right)_N \times (0.2)^2$$

$$\Rightarrow \left(\frac{W}{L}\right)_N = 200$$

$$Q_P: 1 = \frac{1}{2} \times 0.100 \times \left(\frac{W}{L}\right)_P \times (0.2)^2$$

$$\left(\frac{W}{L}\right)_P = 500$$

b. From the circuit we get $-v_I + V_{GSP} + v_o = 0$

Since $v_o = 0$

$v_I = V_{GSP}$

$$V_{SGP} = |V_{ov}| + |V_t|$$

$$= 0.2 + 0.45$$

$$= -0.65\text{ V}$$

$$\therefore v_I = V_{GSP} = -0.65\text{ V}$$

c. Using equation 11.4

$$v_{o\max} = V_{DD} - V_{ov}|_{\text{Bias}} - V_{\text{GSN}}$$

To find V_{GSN},

$$i_{\text{DNmax}} = \frac{1}{2} k_n' \frac{W}{L} (V_{\text{GSN}} - V_t)^2$$

$$10 = \frac{1}{2} \times 0.250 \times 200\,(V_{\text{GSN}} - V_t)^2$$

$$\Rightarrow V_{\text{GSN}} - V_t = 0.63\text{ V}$$

$$V_{\text{GSN}} = V_t + 0.63 = 0.45 + 0.63 \simeq 1.1\text{ V}$$

$$\therefore v_{o\max} = 2.5 - 0.2 - 1.1 = 1.2\text{ V}$$

11.27

Refer to Figure 11.19

$I_Q = 3$ mA, $|V_{ov}| = 0.15$ V

$$g_{mn} = g_{mp} = \frac{2I_D}{V_{ov}} = \frac{2 \times 3}{0.15} = 0.04\text{ A/V}$$

$$= 40\text{ mA/V}$$

Using equation 11.57

$$R_{\text{out}} = \frac{1}{\mu(g_{mp} + g_{mn})} = \frac{1}{5(0.04 + 0.04)}$$

$$= 2.5\ \Omega$$

11.28

a. From equation 11.68

$$|\text{Gain Error}| = \frac{1}{2\mu g_m R_L}$$

From equation 11.57

$$R_{\text{out}} \simeq \frac{1}{\mu(g_{mp} + g_{mp})}$$

$$= \frac{1}{2\mu g_m} \text{ when } g_{mp} = g_{mn} = g_m$$

$$\therefore |\text{Gain Error}| = \frac{1}{2\mu g_m} \times \frac{1}{R_L}$$

$$= \frac{R_{\text{out}}}{R_L}$$

b. Again equation 11.68

$$|\text{Gain Error}| = \frac{1}{2\mu g_m R_L}$$

$$0.05 = \frac{1}{2 \times 10 \times g_m \times 100}$$

$g_m = 0.01$ A/V = 10 mA/V

Equation 11.67

$$g_m = \frac{2I_Q}{V_{ov}}$$

$$V_{ov} = \frac{2I_Q}{g_m} = \frac{2 \times 1}{10}$$

$V_{ov} = 0.2$ V

11.29

a. $I_Q = \frac{1}{2} k_n' \frac{W}{L} V_{ov}^2$

$$1.5 \times 10^{-3} = \frac{1}{2} \times 100 \times 10^{-6} \left(\frac{W}{L}\right)_P (0.15)^2$$

$$\Rightarrow \left(\frac{W}{L}\right)_P \simeq 1333.3$$

$$\left(\frac{W}{L}\right)_N = \frac{(W/L)_P}{(k_n'/k_{Q_p}')} = \frac{1333.3}{(250/100)}$$

$= 533.3$

b. $g_m = \frac{2I_Q}{V_{ov}} = \frac{2 \times 1.5}{0.15} = 20$ mA/V

$= 0.02$ A/V

$$R_{out} = \frac{1}{2\mu g_m} \quad g_{mp} = g_{mn} = g_m$$

$$2.5 = \frac{1}{2\mu \times 0.02}$$

$$\mu = \frac{1}{2.5 \times 2 \times 0.02}$$

$\mu = 10$

c. $\text{Gain Error} = -\frac{V_{ov}}{4\mu I_Q R_L}$

$$= -\frac{0.15}{4 \times 10 \times 1.5 \times 10^{-3} \times 50}$$

$= -0.05$

Gain Error = 5%

d. In the quiescant state $v_o = 0$

The voltage at the output of each amplifier will be $= \mu (v_o - v_I) = -\mu v_I$

e. Q_N turn off when the voltage at its gate drops from quiescent value of -1.85 V to -2V, at which point $V_{GSN} = V_{tN}$, and an equal change of -0.15 V appear at the output of the top amplifier.

$$i_P = \frac{1}{2} k_P \left(\frac{W}{L}\right)_P (0.3)^2$$

$$= \frac{1}{2} \times 0.100 \times 1333.3 \times 0.3^2$$

$i_P = 6$ mA

$v_o = 6 \times 10^{-3} \times 50\ \Omega = 0.3$ V

So for $v_o > 0.3$ V, Q_P conducts all the current.

f. the situation at $v_o = v_{omax}$ will occur when Q_P will go from saturation to triode region and it will be approximatly 2 V.

Linear range of v_o from 2 to -2 V

11.30

$$\text{Power rating} = \frac{130 - 30}{2} = 50 \text{ W}$$

$$I_{Cav} \leq \frac{50}{20} = 2.5 \text{ A}$$

11.31

$$\theta_{JA} = \frac{150 - 25}{0.2} = 625°\text{C/W} = 0.625°\text{C/mW}$$

At 70°C, Power rating

$$= \frac{150 - 70}{0.625} = 128 \text{ mW}$$

$$T_J = 50 + 0.625 \times 100 = 112.5°\text{C}$$

11.32

$T_J \leq 50 + 3 \times 30 = 140°$C

$V_{BE} = 800 - 2 \times (140 - 25) = 570$ mV

$= 0.57$ V

It will reduce thermal resistance and maximum power dissipation.

11.33

(a) $\theta_{JA} = \frac{T_{Jmax} - T_{AO}}{P_{DO}}$

$$= \frac{100 - 25}{2} = 37.5° \text{ C/W}$$

(b) At $T_A = 50°$C

$$P_{Dmax} = \frac{T_{Jmax} - T_A}{\theta_{JA}}$$

$$= \frac{100 - 50}{37.5} = 1.33 \text{ W}$$

(c) $T_J = 25° + 37.5 \times 1 = 62.5°$C

11.34

$T_C - T_A = \theta_{CA} P_D$

$= (\theta_{CS} + \theta_{SA}) P_D$

$$\Rightarrow P_D = \frac{T_C - T_A}{\theta_{CS} + \theta_{SA}} = \frac{90 - 30}{0.5 + 0.1} = 100 \text{ W}$$

$T_J - T_C = \theta_{JC} P_D$

$130 - 90 = \theta_{JC} \times 100$

$\Rightarrow \theta_{JC} = 0.4°$ C/W