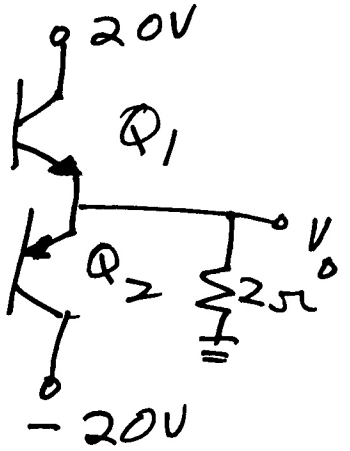
Problem #4 Solutions: Electronics

2013 PhD Qualifying Exam

(1) Maximum instantaneous C-E voltage = 40V.



Q_1 Near cutoff

Q_2 Near saturation

$V_{CE1} = V_{C1} - V_{E1}$

$V_{C1} \downarrow +20V$ $\quad V_{E1} \downarrow -20V$

With 50% factor of safety

$$\boxed{\text{Voltage rating} \geq 40(1.5) = 60V}$$

(2) $I_{C,max} = \frac{20V}{2\Omega} = 10A$ = max. instantaneous collector current.

With 50% factor of safety

$$\boxed{I_{C,max} \geq (10)(1.5) = 15A}$$

(3) $\langle P_C \rangle = \frac{\langle P_{CC} \rangle - \langle P_L \rangle}{2}$ = average power dissipated in a BJT

$\langle P_{cc} \rangle$ = average power provided by 20 V supplies

$$P_{cc}(t) = V_{cc} I_c(t) \qquad 0 < t < T/4$$

$$I_c(t) = \frac{V_p}{R_L}\left[t/(T/4)\right]$$

$$\langle P_{cc} \rangle = \frac{4}{T}\int_0^{T/4} \frac{V_{cc} V_p}{R_L} \frac{4}{T} t\, dt = \frac{V_{cc} V_p}{2R_L}$$

$\langle P_L \rangle$ = average power dissipated in R_L

$$P_L(t) = \left\{\frac{V_p\, t}{[T/4]}\right\}^2 \frac{1}{R_L} \qquad 0 < t < \frac{T}{4}$$

$$\langle P_L \rangle = \frac{4}{T}\int_0^{T/4} \frac{V_p^2}{(T/4)^2 R_L} t^2\, dt = \frac{V_p^2}{3R_L}$$

$$2\langle P_c \rangle = \frac{V_{cc} V_p}{2R_L} - \frac{V_p^2}{3R_L}$$

$$2\frac{d\langle P_c \rangle}{dV_p} = 0 = \frac{V_{cc}}{2} - \frac{2}{3}V_p \;;\; V_p = \frac{3V_{cc}}{4}$$

$$\langle P_c \rangle\Big|_{max} = \frac{1}{2}\left\{\frac{V_{cc}}{2R_L} \times \frac{3V_{cc}}{4} - \frac{1}{3R_L}\left(\frac{3V_{cc}}{4}\right)^2\right.$$

$$\langle P_C \rangle\Big|_{max} = \frac{3V_{CC}^2}{16R_L} - \frac{9V_{CC}^2}{96R_L}$$

$$\langle P_C \rangle\Big|_{max} = \frac{3V_{CC}^2}{16R_L}\left(1 - \frac{3}{6}\right) = \frac{3V_{CC}^2}{32R_L}$$

Put in numbers

$$\langle P_C \rangle\Big|_{max} = \frac{3}{32}\frac{(20)^2}{2} = \frac{1200}{64} = \boxed{18.75\,W}$$

(4) At max signal swing $V_p = V_{CC}$

$$\langle P_{CC} \rangle = \frac{(20)^2}{(2)(2)} = \frac{400}{4} = 100\,W$$

$$\langle P_L \rangle = \frac{(20)^2}{(3)(2)} = \frac{400}{6} = 66.7\,W$$

$$\boxed{\eta\Big|_{max} = \frac{66.7}{100} = 66.7\%}$$

(5) $T_{J,max} = \langle P_C \rangle\Big|_{max} R_{\theta,ja} + 35^\circ C$

$= (18.75)(5) + 35 = 94 + 35$

$$\boxed{T_{J,max} = 129^\circ C}$$