ECE3110 Homework #10 Fall 2005

(Due by Nov. 16 by 6pm in homework locker)

1. (a) The triangular signal of Fig. 1(a) is input to the class A amplifier of Fig. 1(b). The amplifier has the following parameters: V_{CC}=5V, V_{BE}=0.7V (assume constant), $V_{CE,sat}$=0.3V, R_L=2kΩ, and the bias current is designed to be I=V_{CC}/R_L. Sketch the output voltage v_o.

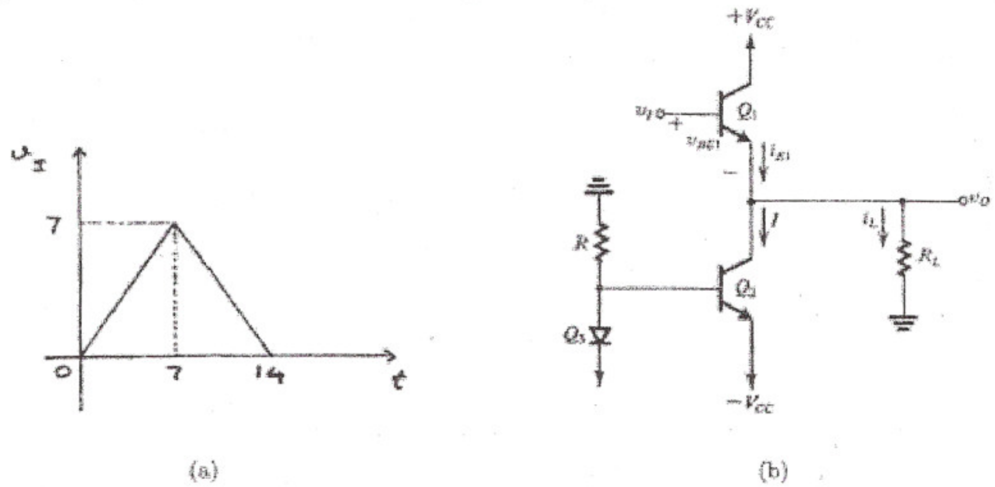
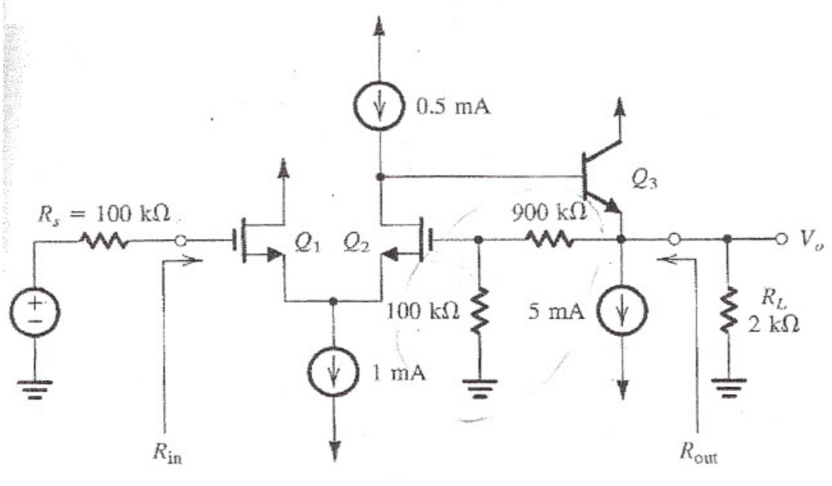


Fig. 1 (a) Input, (b) Output Stage

(b) What type of feedback is employed in the circuit below:



(c) We discussed three types of power amplifiers or output stages in class: **Class A, Class B,** and **Class AB.**

Which type has the worst distortion? ________________

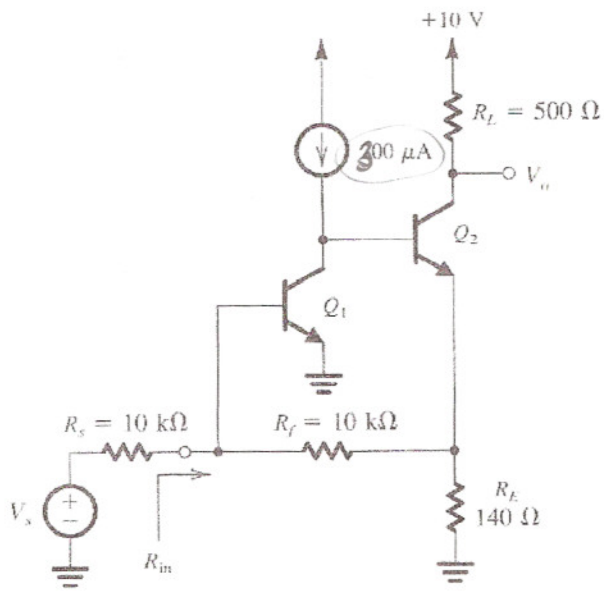
Which type has the highest power efficiency? ____________________

Which type has the lowest power efficiency? ____________________

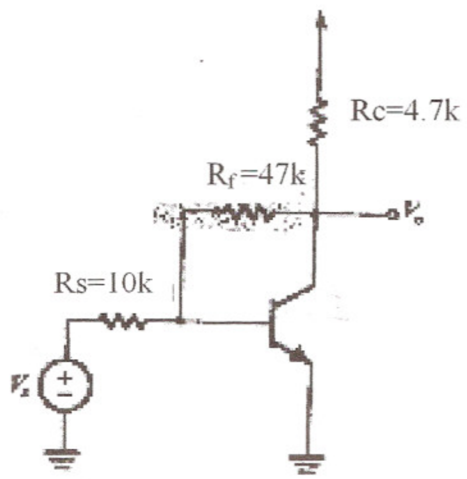
(d) If we put a square wave into a feedback amplifier, and the output shows too much ringing for our application, is the phase margin too high or too low? ________________

2. An amplifier has a dc gain of 10^5 and high-frequency poles at 10^5 Hz, $3.16\text{x}10^5$ Hz, and 10^6Hz. For a phase margin of 45° find the value of β and the corresponding closed-loop gain.

3. Consider the amplifier below. When the source voltage Vs has zero dc component, the output dc voltage is Vo=5V. Let both BJTs have β=50, and assume constant V_{BE}=0.7V for both BJTs. Determine the dc voltages at all nodes and the dc emitter currents of Q_1 and Q_2. Use feedback analysis to find Vo/Vs and Rin.



4. Consider the circuit shown below. The transistor has β=100, and is biased so that the dc operating point is I_B=0.015mA, I_C=1.5mA, and Vo=4.7V. Determine the small-signal loop gain.



5. Consider a feedback amplifier for which the open-loop gain A(s) is given by

$$A(s) = \frac{1000}{(1 + s/10^4)(1 + s/10^5)^2}$$

If the feedback factor β is independent of frequency, find the frequency at which the phase shift is 180°, and find the critical value of β at which oscillations will commence. (Hint: A good initial guess for the desired frequency is 10^5 rad/sec.)

6. The datasheet of the PN2222A bipolar transistor contains the following information:

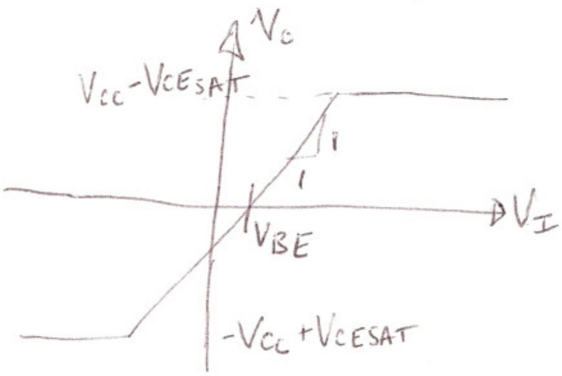
Maximum allowable junction temperature $T_{Jmax} = 150°C$
Maximum power dissipation $P_{Dmax} = 625$ mW at ambient temperature $T_A = 25°C$
Junction-to-case thermal resistance $\theta_{JC} = 80°C/W$

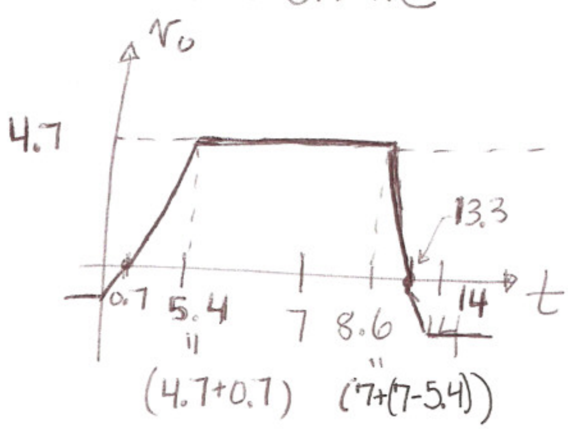
(a) Draw an equivalent electrical circuit for this thermal system. Label all components as well as the junction temperature T_J, the case temperature T_C, and the ambient temperature T_A. (Note that we are not using a heat sink in this problem.)
(b) Find the case-to-ambient thermal resistance θ_{CA}.
(c) Assuming an ambient temperature of 25°C, what is the case temperature T_C when the transistor dissipates 500 mW?

7. Exercises 12.31 and 13.18

HW #10 sol'n

1\. a. Class A amplifier transfer characteristic





b. Series-shunt

c. worst distortion: Class B

highest power efficiency: Class $\underline{\underline{B}}$ (or AB is almost the same)

lowest power efficiency: Class A.

d. too low

2\. $$A(s) = \frac{10^5}{\left(\frac{s}{10^5}+1\right)\left(\frac{s}{3.16\times10^5}+1\right)\left(\frac{s}{10^6}+1\right)}$$

$$pm = 45^\circ \Rightarrow \tan^{-1}\left(\frac{f}{10^5}\right) + \tan^{-1}\left(\frac{f}{3.16\times10^5}\right) + \tan^{-1}\left(\frac{f}{10^6}\right) = 135^\circ$$

$$\therefore \quad f \cong 3.16\times10^5 \text{ Hz}$$

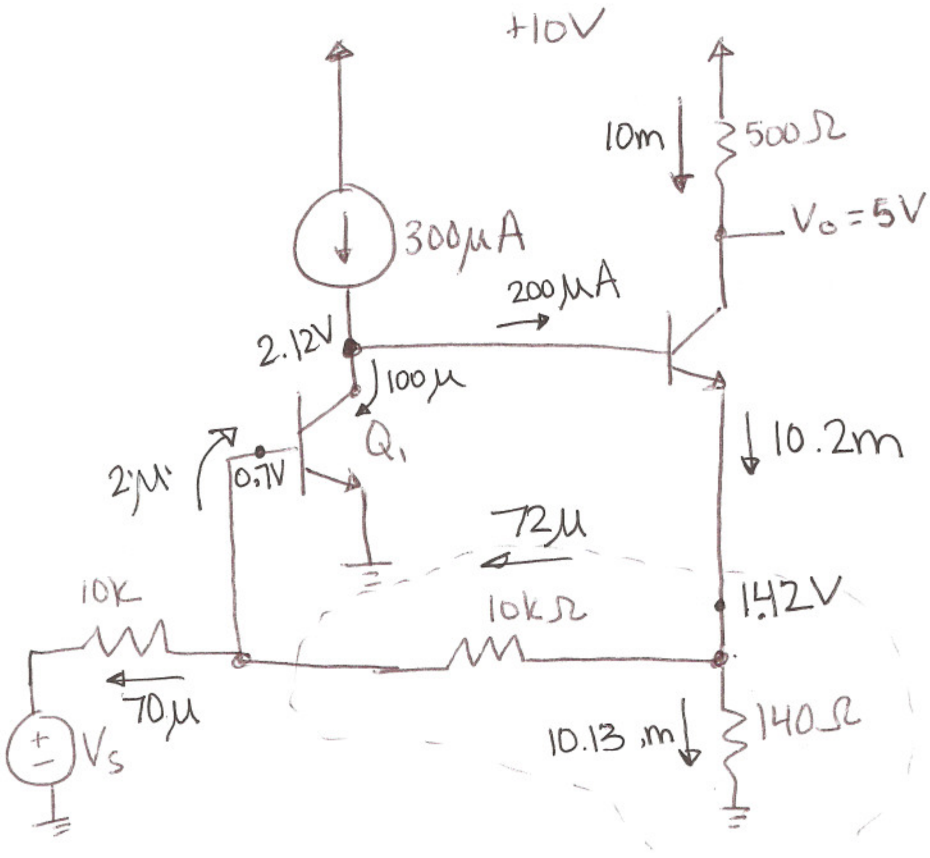
$$|A\cdot\beta| = 1 = \frac{10^5\cdot\beta}{\sqrt{\left(\frac{3.16\times10^5}{10^5}\right)^2+1^2}\ \sqrt{2}\ \sqrt{\left(\frac{3.16\times10^5}{10^6}\right)^2+1^2}}$$

$$\Rightarrow \beta \cong \boxed{49\mu}$$

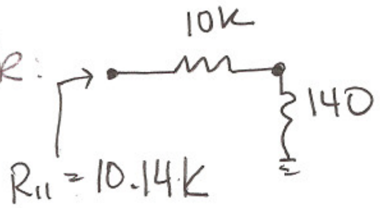
$$A_f = \frac{10^5}{1+(10^5)(49\mu)} \cong \boxed{17K}$$

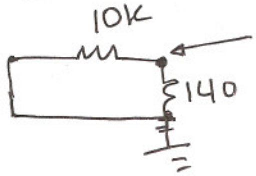
3.

shunt-series



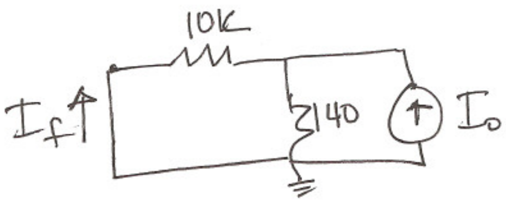
feedback:





$R_{22} = 10K \| 140 \cong 138$

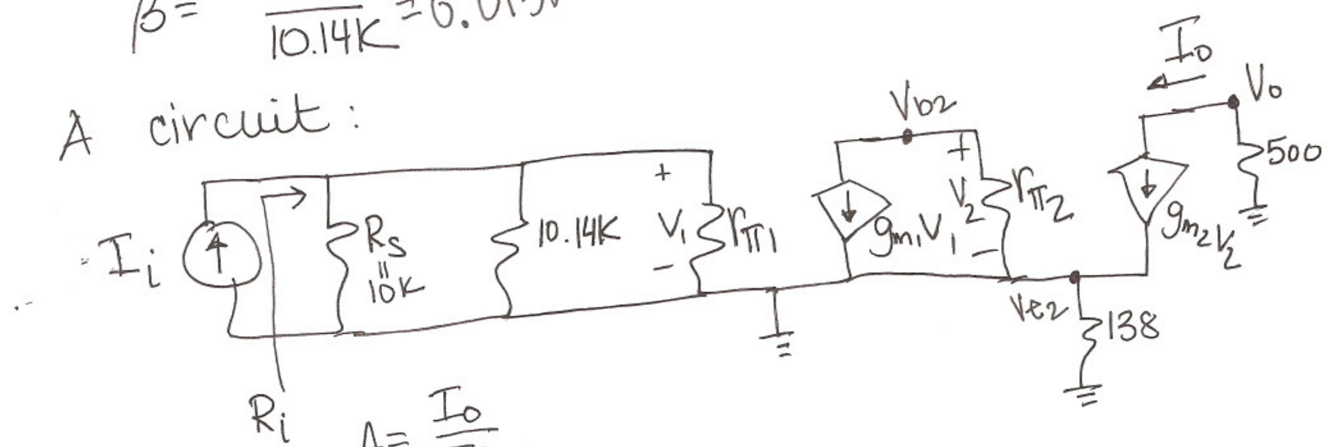
$\beta \equiv \dfrac{I_f}{I_o}$



$\therefore\ I_f = \dfrac{-I_o\, 140}{10.14K}$

$\beta = \dfrac{-140}{10.14K} \cong 0.0138$

A circuit:



$A \equiv \dfrac{I_o}{I_i}$

3. (cont.)

$$g_{m_1} = \frac{I_{C1}}{V_T} = \frac{100\mu}{25m} = 4m\ A/V \Rightarrow r_{\pi_1} = \frac{\beta}{g_{m1}} = \frac{50}{4m} = 12.5K\Omega$$

$$g_{m2} = \frac{I_{C2}}{V_T} = \frac{10m}{25m} = 400m\ A/V \Rightarrow r_{\pi_2} = \frac{50}{400m} = 20\Omega$$

$$I_o = g_{m2} V_2$$

$$V_2 = \underbrace{-g_{m_1} V_1 \left(r_{\pi_2} + 138(\beta+1)\right)}_{V_{b2}} \underbrace{- g_{m2} V_2 \left(138 \| \frac{r_{\pi 2}}{(\beta+1)}\right)}_{V_{e2}}$$

$$V_2 = -28.152\, V_1 - 0.16 V_2 \Rightarrow \quad V_2 \triangleq -24.4 V_1$$

$$V_1 = I_i \left(10K \| 10.14K \| r_{\pi_1}\right) \cong (3589) I_i$$

$$A \equiv \frac{I_o}{I_i} = 400m(-24.4)(3589) \cong -35K\ A/A$$

$$A_f = \frac{A}{1+A\beta} = \frac{-35K}{1+(-35K)(-0.0138)} \cong \boxed{-73\ A/A}$$

$$V_o = -I_o(500) \quad \text{and} \quad I_s = \frac{V_s}{10K}$$

$$\frac{V_o}{V_s}: \quad \frac{I_o}{I_s} = \frac{-V_o}{500} \cdot \frac{10K}{V_s} \Rightarrow \quad \frac{V_o}{V_s} = 73 \cdot \frac{500}{10K} \cong \boxed{3.65\ V/V}$$

$$R_i = (10K \| 10.14K \| r_{\pi}) \approx 3589$$

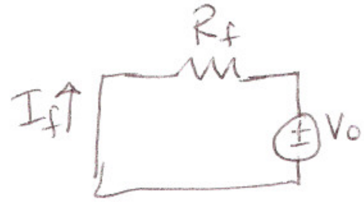
$$R_{if} = \frac{R_i}{1+A\beta} \approx \boxed{6.4\Omega}$$

4. shunt-shunt configuration:

· feedback $\Rightarrow$

$R_{11} = R_{22} = R_f = 47K$

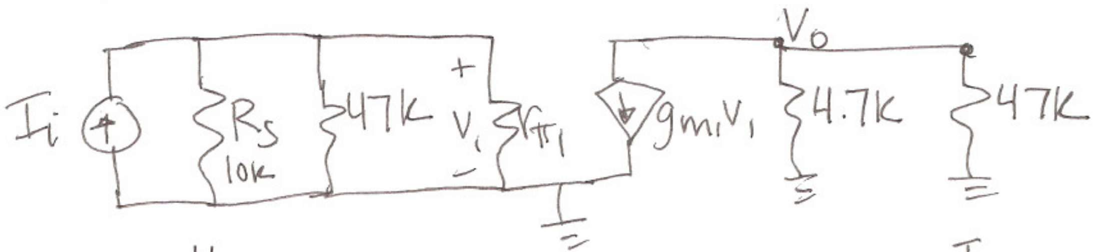
$\beta \equiv \dfrac{I_f}{V_o}$



$V_o = -I_f \cdot R_f$

$\therefore \beta = -\dfrac{1}{R_f} = -\dfrac{1}{47K}$

A-circuit



$A \equiv \dfrac{V_o}{I_i}$

$V_o = -g_{m_1} V_1 \,(4.7K \| 47K)$

$V_1 = I_i \,(10K \| 47K \| r_{\pi_1})$

$g_{m_1} = \dfrac{I_{C_1}}{V_T} = \dfrac{1.5m}{25m} = 60m$

$r_{\pi_1} = \dfrac{\beta}{g_{m_1}} = \dfrac{100}{60m} \cong 1.7K$

$A \equiv \dfrac{V_o}{I_i} \cong -60m\,(4.3K)(1410) = -363{,}780$

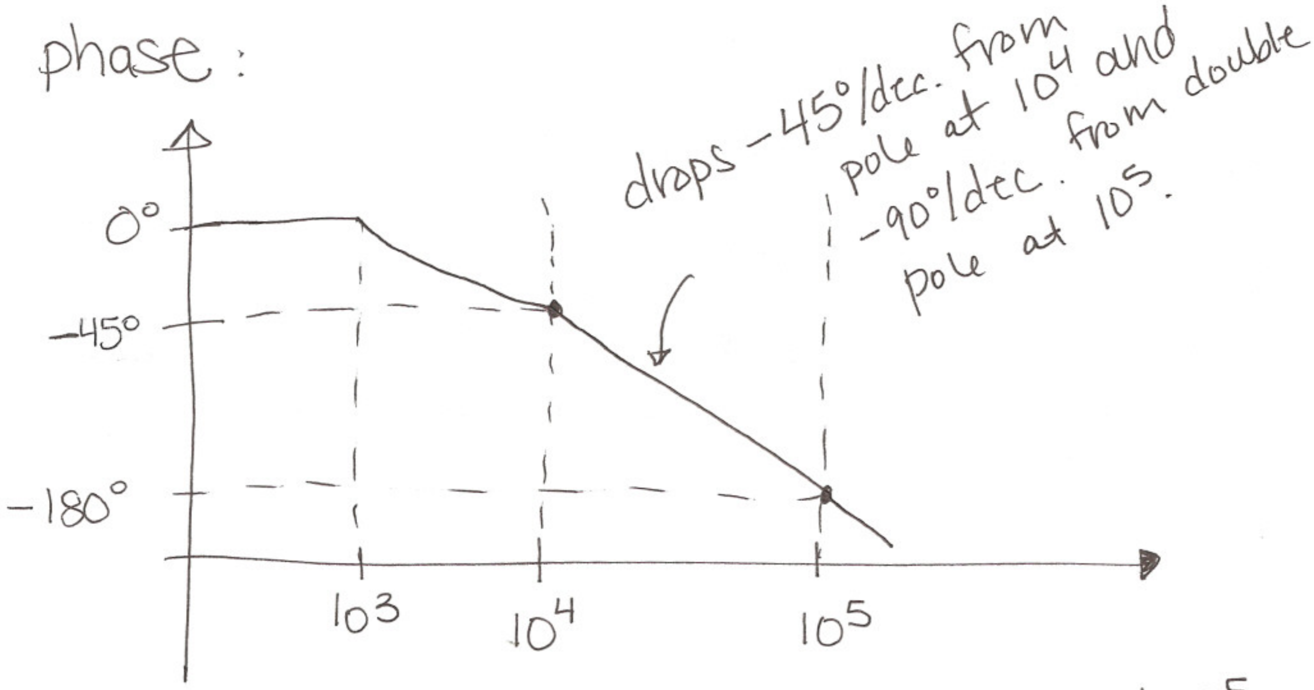
$\dfrac{V_o}{I_s} = A_f = \dfrac{-363{,}780}{1 + (-363{,}780)\left(-\frac{1}{47K}\right)} \cong \boxed{-42K \;V/A}$

converting to $V_s \Rightarrow$

$I_s = \dfrac{V_s}{10K} \Rightarrow \quad -42K = \dfrac{V_o}{I_s} = \dfrac{V_o \cdot 10K}{V_s}$

$\dfrac{V_o}{V_s} = \boxed{-4.2 \;V/V}$

5. phase :



∴ phase shift at 180° should be around 10^5 ⇒

$$\angle A(j\omega) = \tan^{-1}\left(\frac{\omega}{10^4}\right) - 2\tan^{-1}\left(\frac{\omega}{10^5}\right) = -180^\circ$$

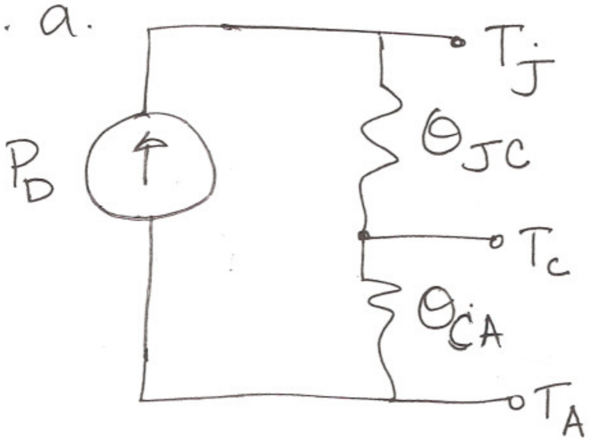
$$\omega \approx \boxed{1.1 \times 10^5 \text{ rad/sec.}}$$

· Oscillations commence when $|A\beta| = 1$ and the phase from A is at 180°

$$\therefore \quad \frac{1{,}000 \cdot \beta}{\sqrt{\left(1+\left(\frac{1.1\times10^5}{10^4}\right)^2\right)\left[1+\left(\frac{1.1\times10^5}{10^5}\right)^2\right]}} \geq 1$$

$$\beta \geq \boxed{0.0244}$$

6. a.



b. at $T_A = 25°C$ then $P_D = 625mW$

$\theta_{JC} = 80° C/W$

$T_J = 150° C$

$\therefore \quad P_D(\theta_{JC} + \theta_{CA}) = T_J - T_A$

$$\theta_{CA} = \frac{T_J - T_A}{P_D} - \theta_{JC} = \frac{(150-25)}{625m} - 80° C/W$$

$\theta_{CA} = \boxed{120° C/W}$

OR $\quad T_J - T_c = P_D(\theta_{JC}) \Rightarrow T_c = 150° - 625m(80°) = 100°$

$T_c - T_A = P_D(\theta_{CA}) \Rightarrow \frac{100-25}{625m} = \theta_{CA} = 120° C/W$

C. $P_D = 500mW \Rightarrow$

$T_c = T_A + P_D(\theta_{CA}) = 25 + 500m(120°) = 85°$

(6)

12.31

From Eq (12.96) & (12.97)

$C_3 = C_4 = \omega_0 T_c C$

$= 2\pi 10^4 \times \frac{1}{200\times10^3} \times 20$

$= \underline{\underline{6.283\ pF}}$

From Eq. (12.99)

$C_5 = \frac{C_4}{Q} = \frac{6.283}{20} = \underline{\underline{0.314\ pF}}$

From EQ (12.100)

Centre-frequency gain $= \frac{C_6}{C_5} = 1$

$C_6 = C_5 = \underline{\underline{0.314 pF}}$

13.18

To obtain a triangular waveform with 10-V peak-to-peak amplitude we should have

$V_{TH} = -V_{TL} = 5V$

But $V_{TL} = -L_+ \frac{R_1}{R_2}$

Thus $-5 = -10 \times 10/R_2$

$R_2 = \underline{\underline{20k\Omega}}$

For 1kHz frequency, T= 1ms.

Thus,

$T/2 = 0.5\times10^{-3} = CR\ \frac{V_{TH} - V_{TL}}{L_+}$

$= 0.01 \times 10^{-6} \times R \times 10/10$

$R = \underline{\underline{50\ k\Omega}}$