Output Stage and power Amplifier

- An important function of the output stage is to provide the amplifier with a low output resistance, so, that it can deliver the output signal to the load without loss of gain.

- The output stage is the final stage of the Amplifier.

- This Amplifier used for obtaining a maximum AC power from the DC power. (high power output)

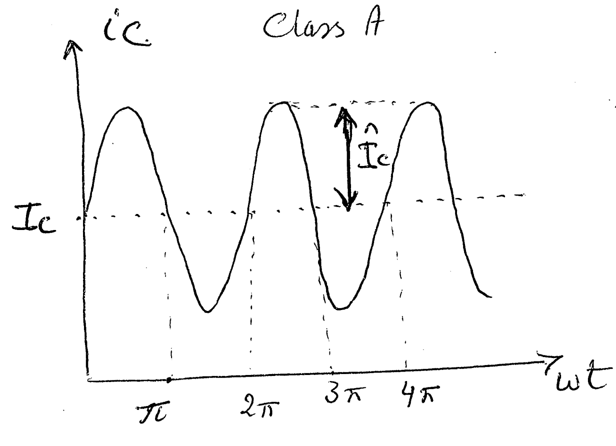
- The power Amplifier is classified into four types:

  1- Class A
  2- Class B
  3- class AB
  4- Class C

- BJTs can handle much larger current than MOSFETs, they are preferred in the design of output stages.

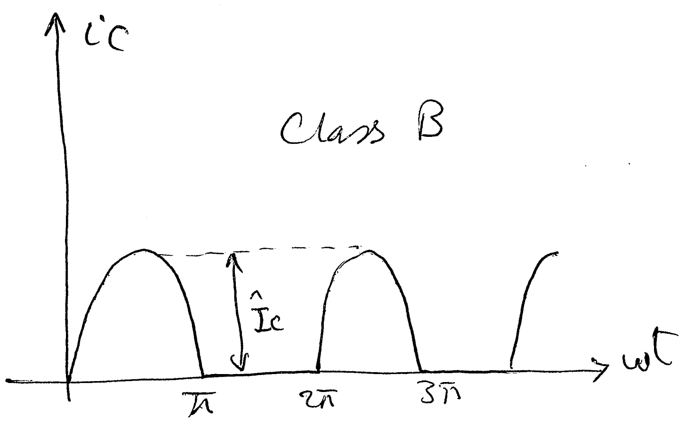
[1] * Class A power Amplifier:

- The class A stage is biased at a current I_C greater than the Amplitude of the signal current ($\hat{I}_c$)
- transistor conduct for the entire cycle of the input signal.
- Conduction Angle = 360°.



[2] Class B power Amplifier

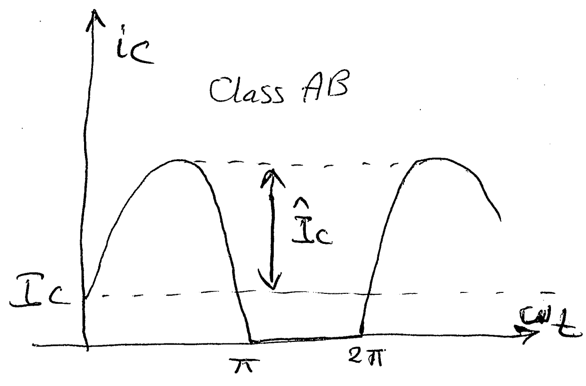
- The class B stage is biased at zero dc current
- The transistor conduct for only half the cycle of the input sinewave.
- Conduction Angle = 180°



[3] * Class AB power Amplifier:

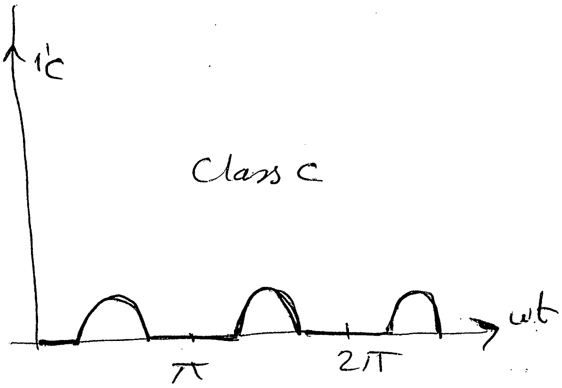
- This Class power Amplifier involve biasing the transistor at a non zero dc Current but Smaller Than the peak Current of the Sine wave Signal.

- The transistor Conduct for interval greater Than half Cycle.
- Conduction Angle > 180°.



[4] * Class C power Amplifier:

- Conduction Angle < 180°
- class C amplifiers are usually employed for radio frequency (RF) power Amplifier.
and tuned-resonator oscillator



Dissipation power:

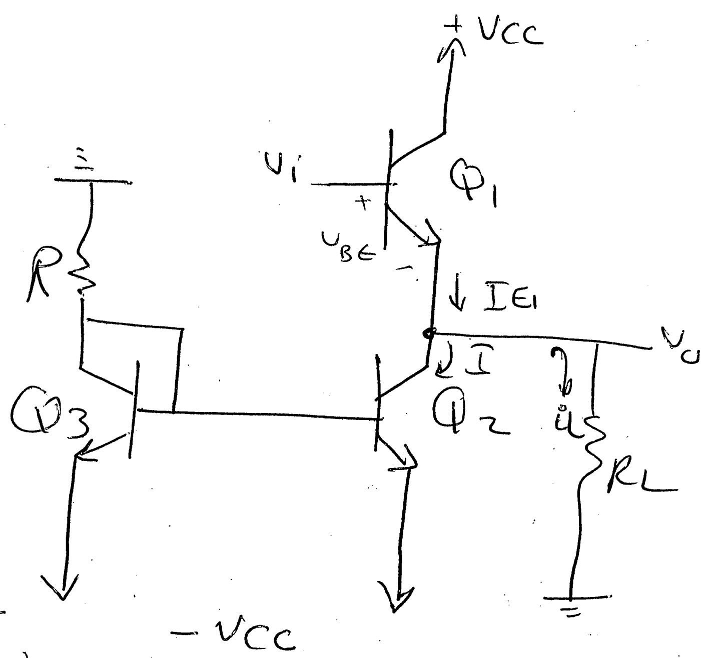
$$P_D = P_S - P_L$$

* Dissipation power in transistor:

$$\boxed{P_{D_Q} = V_{CE} \cdot I_C} \rightarrow \text{instantenous power dissipation in } \underline{Q}$$

Integrated Circuit for class A power Amplifier:

Emitter follower Q_1 is biased with a Constant Current I supplied by transistor Q_2.



$$\boxed{I_{E_1} = I + i_L}$$

$$\boxed{v_o = v_i - V_{BE1}}$$

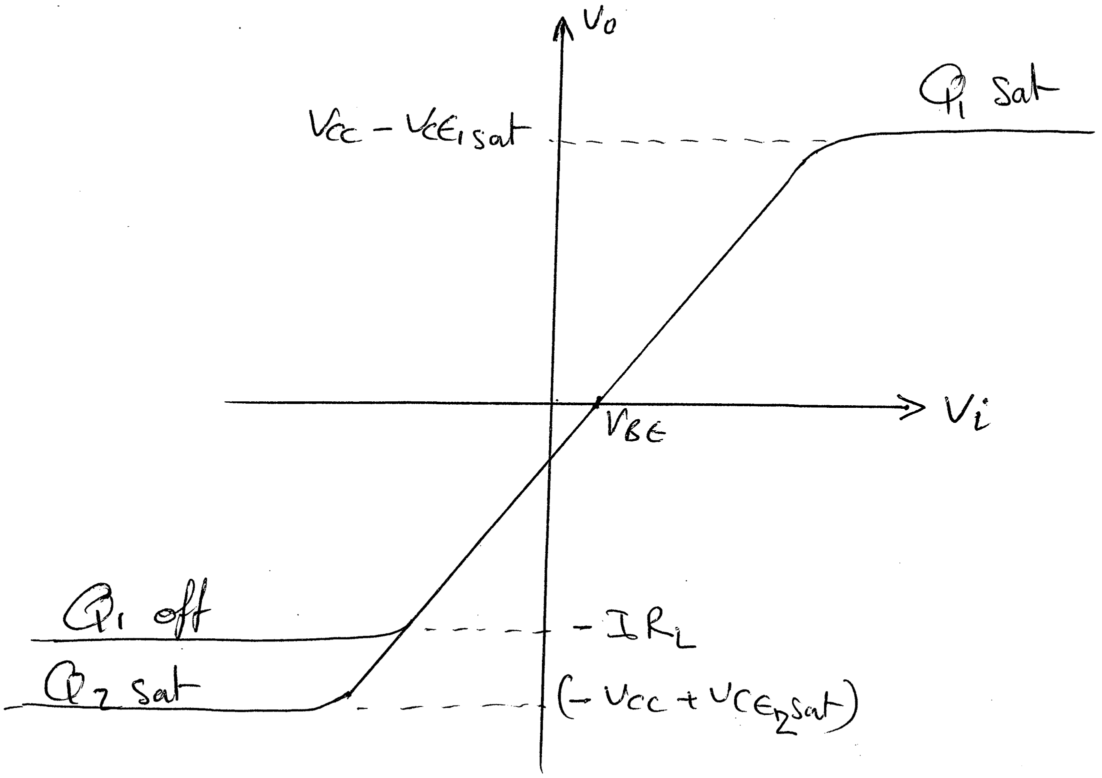
Transfer Characteristic of the emitter follower

$$\boxed{V_o = V_i - V_{BE_1}}$$

where V_{BE} depend on emitter Current I_{E_1} and on the load Current i_L. but we ignore the Small change in V_{BE} ($V_{BE} \simeq$ Constant).

- The positive limit of the linear region is determined by the Saturation of Q_1

$$\therefore \boxed{V_{o\,max} = V_{CC} - V_{CE_1\,sat}}$$



- In the negative direction, depending on the value of I and R_L. The limit of the linear region is determined either by Q_1 turning off.

$$\boxed{v_{omin} = -I R_L} \rightarrow (1) \qquad \boxed{I = -i_L}$$

or by Q_2 Saturating

$$\boxed{v_{omin} = -V_{cc} + V_{CEsat}} \rightarrow (2)$$

from (1), (2)

$$\therefore \; -V_{cc} + V_{CEsat} \leq -I R_L$$

$$\therefore \; I \geq \frac{|-V_{cc} + V_{CEsat}|}{R_L}$$

- That's provide the bias current I is greater than the magnitude of the load current.

* Maximum Swing Case:

$$-V_{cc} + V_{CE_2 sat} \leq V_o \leq V_{cc} - V_{CE_1 sat}$$

At $V_{CE sat} \simeq 0$

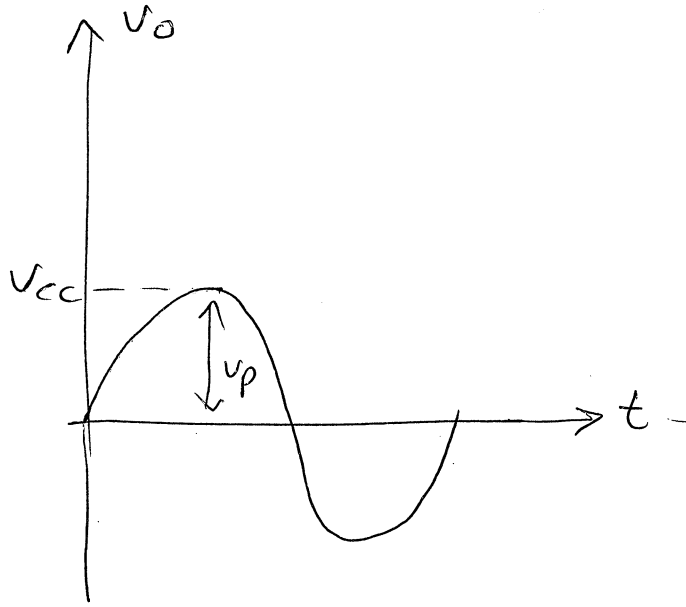
$$\therefore \boxed{-V_{cc} \leq V_o \leq +V_{cc}}$$

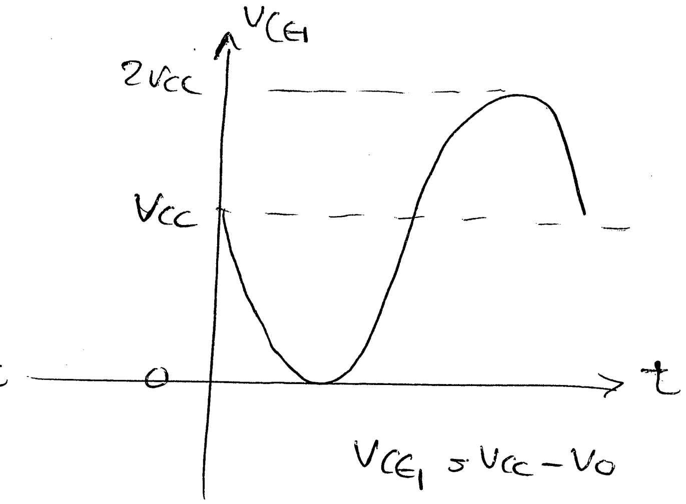
$$\boxed{I \geq \frac{V_{cc}}{R_L}}$$

At $I = \dfrac{V_{cc}}{R_L}$ $\quad \because \; i_L = \dfrac{V_o}{R_L}$

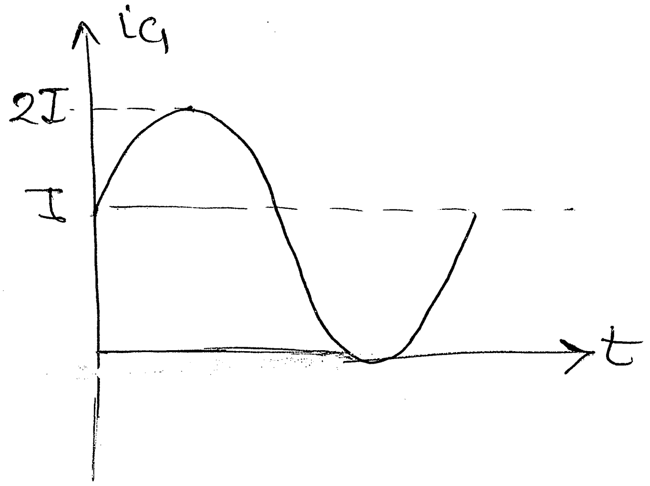
$$\frac{-V_{cc}}{R_L} \leq i_L \leq \frac{V_{cc}}{R_L}$$

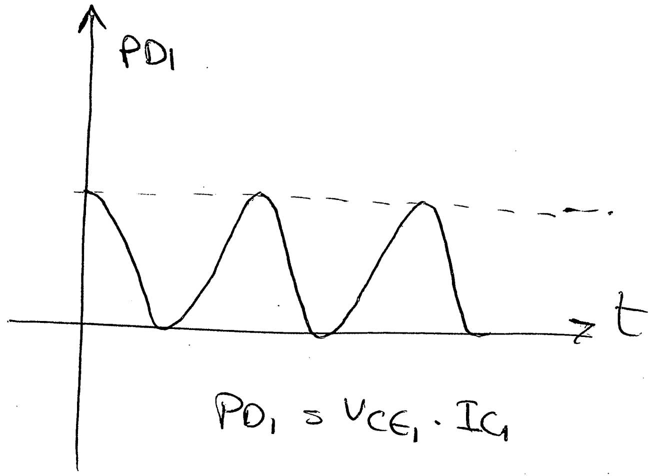
$$\boxed{-I \leq i_L \leq I}$$





$V_{CE_1} = V_{cc} - V_o$
$= V_{cc} - V_p \sin\omega t$





$P_{D_1} = V_{CE_1} \cdot I_{C_1}$

* Supply power (P_S) :

$$P_S = P_{+V_{CC}} + P_{-V_{CC}}$$

$$= V_{CC}\, I_{av}(Q_1) + V_{CC}\, I_{av}(Q_2)$$

$$I_{av}(Q_1) = I_{C_1}(av) = I$$

$$I_{av}(Q_2) = I \text{ (Constant)}$$

$$\therefore \boxed{P_S = 2 V_{CC}\, I}$$

Load power (P_L):

$$P_L = V_{orms} * I_{orms} = \frac{V_{orms}^2}{R_L}$$

$$\boxed{P_L = \frac{V_p^2}{2R_L}}$$

* Efficiency (η):

$$\eta = \frac{P_L}{P_S} = \frac{V_p^2}{4 I V_{cc} R_L} = \frac{1}{4}\left(\frac{V_p}{I R_L}\right)\cdot\left(\frac{V_p}{V_{cc}}\right)$$

At $V_p = V_{cc} = I R_L$

$\therefore$ $\boxed{\eta_{max} = 25\%}$ max η of class A

* Dissipation power (P_D)

$$P_{DQ_1} = V_{CE_1} \cdot I_{C_1} = (V_{cc} - V_o)(I + i_L)$$

$$P_{DQ_2} = V_{CE_2} \cdot I_{C_2} = (V_o + V_{cc})\, I$$

$\therefore$ $\boxed{P_D = P_{DQ_1} + P_{DQ2}}$

or $\boxed{P_D = P_S - P_L}$

End

Example: for the previous Emitter follower

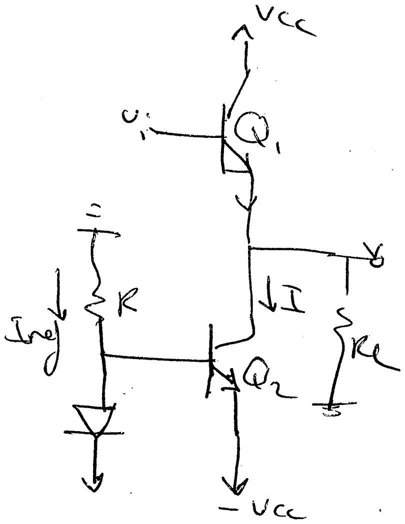
$V_{CC} = 15V$, $V_{CEsat} = 0.2V$ and β very high.

- Find the value of R that will establish a bias current sufficiently large to allow the largest possible output signal swing for $R_L = 1K\Omega$
- Determine the resulting output signal swing and the minimum and maximum emitter currents of Q_1.

Sol.

$$\because \quad I \geq \frac{|-V_{CC} + V_{CEsat}|}{R_L}$$

$$\therefore \quad \boxed{I = 14.8\,mA}$$



for max output swing

$$-V_{CC} + V_{CEsat} \leq V_o \leq V_{CC} - V_{CEsat}$$

$$\boxed{-14.8 \leq V_o \leq 14.8}$$

$I = I_{ref}$

$$I_{ref} = \frac{0 - (0.7 + (-15))}{R} = 14.8\,mA$$

$\therefore \boxed{R = 0.97\,K\Omega}$

$$I_{E_{max}} = I + i_{L_{max}}$$

$$= I + I = 2I$$

$\therefore \boxed{I_{E_{max}} = 29.6\,mA}$

$$I_{E_{mi}} = I + i_{L_{min}}$$

$$= I - I = 0$$

$$\boxed{0 \leq I_{E_1} \leq 29.6\,mA}$$

Sheet (3)
power Amplifier
Class A

14.1 A class A emitter follower, biased using the circuit shown in Fig. 14.2, uses $V_{CC} = 5$ V, $R = R_L = 1$ kΩ, with all transistors (including Q_3) identical. Assume $V_{BE} = 0.7$ V, $V_{CEsat} = 0.3$ V, and β to be very large. For linear operation, what are the upper and lower limits of output voltage, and the corresponding inputs? How do these values change if the emitter–base junction area of Q_3 is made twice as big as that of Q_2? Half as big?

$V_{CC} = 5V$

$R = R_L = 1k\Omega$

$V_{BE} = 0.7\ V$

$V_{CEsat} = 0.3V$

$\beta \gg$

what is V_{omax}, V_{omin}, V_{imax}, V_{imin}

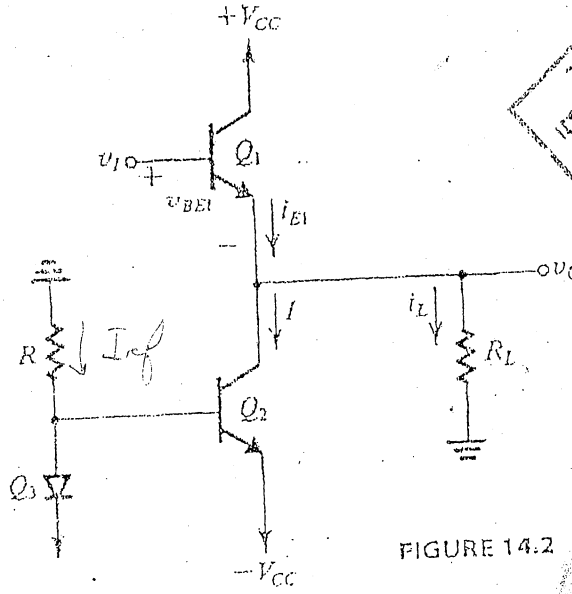


FIGURE 14.2

for linear operation

$$V_{omax} = V_{CC} - V_{CEsat} = 5 - 0.3 = 4.7\ V$$

$$V_{imax} = V_{BE} + V_{omax} = 0.7 + 4.7 = 5.4\ V$$

$V_{omin} = -I R_L$

<u>OR</u>

$V_{omin} = V_{CEsat} - V_{CC}$

$\therefore \quad I = I_{ref} = \dfrac{V_{CC} - V_{BE}}{R} = \dfrac{5 - 0.7}{1k} = 4.3\,mA$

$\therefore \quad V_{omin} = -I R_L = -4.3mA * 1k = -4.3\,V$

$V_{omin} = V_{CEsat} - V_{CC} = 0.3 - 5 = -4.7\,V$

$\therefore \quad \therefore \quad \boxed{V_{omin} = -4.3V}$

$\therefore \quad V_{imin} = V_{BE} + V_{omin} = 0.7 - 4.3 = -3.6\,V$

$\therefore \quad \boxed{V_{imin} = -3.6V}$

* if Base-emitter junction of Q_3 is twice than Q_2

$A_{Q_3} = 2\, A_{Q_2}$

$I_3 = 2\, I_2$

$I_2 = I$

$I_3 \simeq I_{ref}$

$\therefore I_{ref} = 2I \quad \therefore \boxed{I = \frac{1}{2} I_{ref}}$

$\therefore I = \frac{1}{2}(4.3\,mA) = 2.15\,mA$

$\therefore V_{o\,min} = -I R_L = -2.15\,V$

$V_{i\,min} = V_{BE} + V_{o\,min} = 0.7 - 2.15$

$= -1.45\,V$

$\therefore$

---

* For Area of Emitter-Base Junction of Q_3 is half of Q_2

$\therefore I_3 = \frac{1}{2} I_2$

$I_{ref} = \frac{1}{2} I \quad \therefore I = 2 I_{ref}$

$\therefore I = 2(4.3) = 8.6\,mA$

$V_{o\,min} = -I R_L = -8.6\,V$ OR $V_{o\,min} = -V_{CC} + V_{CE\,sat}$ $= -4.7\,V$

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$V_{i\,min} = V_{BE} + V_{om} = +0.7 - 4.7\,V$

$= \boxed{-4 \quad Volt}$

✓D14.3 Using the follower configuration shown in Fig. 14.2 with ±9-V supplies, provide a design capable of ±7-V outputs with a 1-kΩ load, using the smallest possible total supply current. You are provided with four identical, high-β BJTs and a resistor of your choice.

$V_{CC} = 9V$

Provide a design ?!

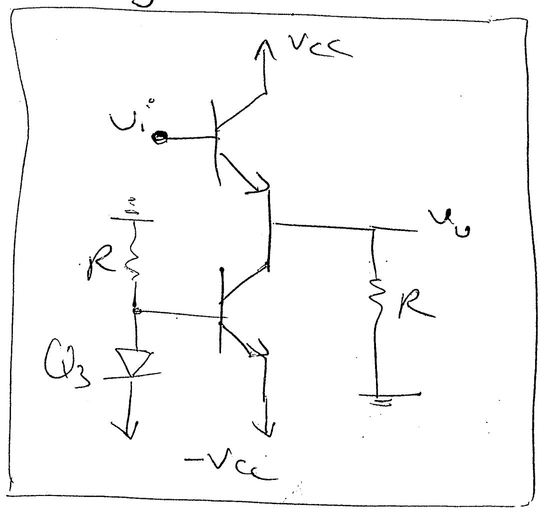
To get $V_o = \pm 7V$

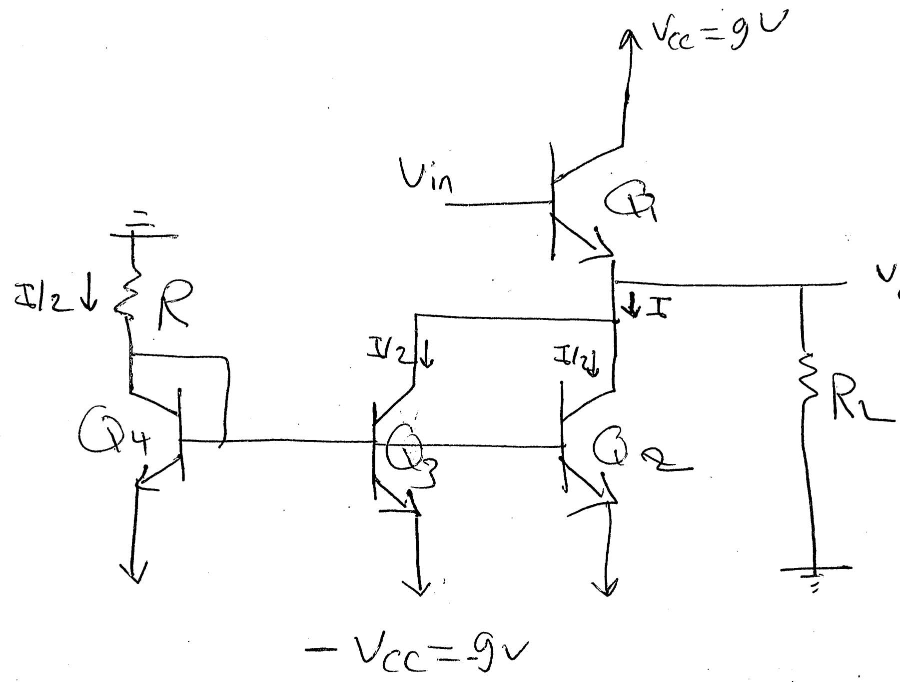
$R_L = 1k\Omega$

using the Smallest possible total Supply Current.

Provided by 4-transistor BJT and R (choice).

Fig 14.2





To Calculate The value of $\underline{\underline{R}}$

$$V_{o\,min} = -7\,V$$
$$= -I R_L$$

$$\therefore \quad I = 7\,mA$$

$$\therefore \quad I_{ref} = \frac{I}{2} = 3.5\,mA$$

$$\therefore \quad I_{ref} = \frac{\overset{9\,volt}{V_{CC}} - \overset{0.7\,V}{V_{BE}}}{R} = 3.5\,mA$$

$$\therefore \quad R = \frac{9 - 0.7}{3.5} = 2.37\,k\Omega$$

$$\therefore \quad \boxed{R\ choice = 2.37\,k\Omega}$$

T

D14.4 An emitter follower using the circuit of Fig. 14.2, for which the output voltage range is ±5 V, is required using $V_{CC} = 10$ V. The circuit is to be designed such that the current variation in the emitter-follower transistor is no greater than a factor of 10, for load resistances as low as 100 Ω. What is the value of R required? Find the incremental voltage gain of the resulting follower at $v_O = +5$, 0, and −5 V, with a 100-Ω load. What is the percentage change in gain over this range of v_O?

$V_o = \pm 5V$, $V_{CC} = 10V$

Current variation in $I_E = 10$

$R_L = 100\ \Omega$

find $\underline{\underline{R}}$?, VG at $V_o = 5V$, $0V$, $-5V$

<u>Sol!</u>

$$\frac{I_{Emax}}{I_{Emin}} = 10$$

$$I_E = I + i_L = I + \frac{V_o}{R_L}$$

$$I_{Emax} = I + i_L = I + \frac{5}{100\,\Omega}$$

$$= \boxed{I + 50\,mA}$$

$$I_{Emin} = I - i_L = \boxed{I - 50\,mA}$$

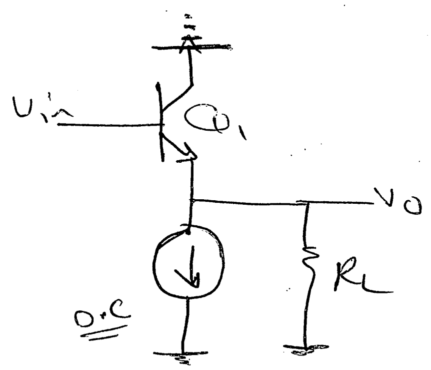
$$\therefore \quad \frac{I + 50\,mA}{I - 50\,mA} = 10$$

$$\therefore \quad \boxed{I = 61.1\ mA}$$

$$\therefore \quad R = \frac{V_{CC} - V_{BE}}{I} = \frac{10 - 0.7}{61.1}$$

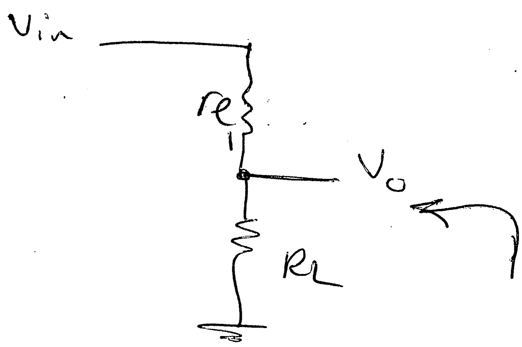
$$\therefore \quad \boxed{R = 152\ \Omega}$$

To find $A_V = \frac{V_o}{V_{in}}$



$$r_{e_1} = \frac{V_T}{I_{E_1}} = \frac{0.025}{I_{E_1}}$$

when $V_o = 5\,V$



AC equivalent circuit

$$\therefore \quad I_{E_1} = I + i_L = 61.6 + 50$$
$$= 111.1\,mA$$

$$\boxed{r_{e_1} = 0.225\ \Omega}$$

$$A_V = \frac{V_o}{V_i} = \frac{R_L}{R_L + r_{e_1}} = 0.998$$

for $V_o = 0$

$I_{E_1} = 61.1 + 0 = 61.1\,mA$

$r_{e_1} = 0.409\,\Omega$

$A_v = 0.996\ V/V$

for $V_o = -5V$

$I_{E_1} = 61.1 - 50 = 11.1\,mA$

$r_{e_1} = 2.25\,\Omega$

$A_v = 0.978$

∴ Change in gain $0.978 < A_v < 0.998$

∴ percentage Change in Gain $= (A_{v_1} - A_{v_2})\,\%$

$= (0.998 - 0.978) \times 100$

$= (0.02) \times 100$

$= 2\,\%$

*14.5 Consider the operation of the follower circuit of Fig. 14.2 for which $R_L = V_{CC}/I$, when driven by a square wave such that the output ranges from $+V_{CC}$ to $-V_{CC}$ (ignoring V_{CEsat}). For this situation, sketch the equivalent for v_O, i_{C1}, and p_{D1}. Repeat for a square-wave output that has peak levels of $\pm V_{CC}/2$. What is the average power dissipation in Q_1 in each case? Compare these results to those for sine waves of peak amplitude V_{CC} and $V_{CC}/2$, respectively.

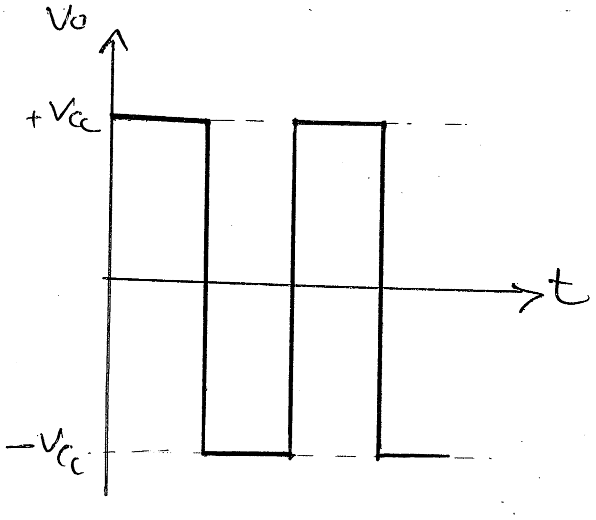
$R_L = \frac{V_{CC}}{I}$ $\quad \therefore \quad V_o = V_{CC}$

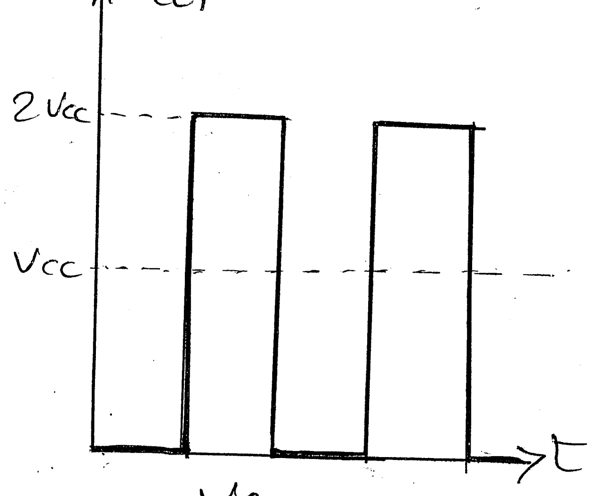
$-V_{CC} < V_o < V_{CC}$

$\boxed{V_{CEsat} = 0}$

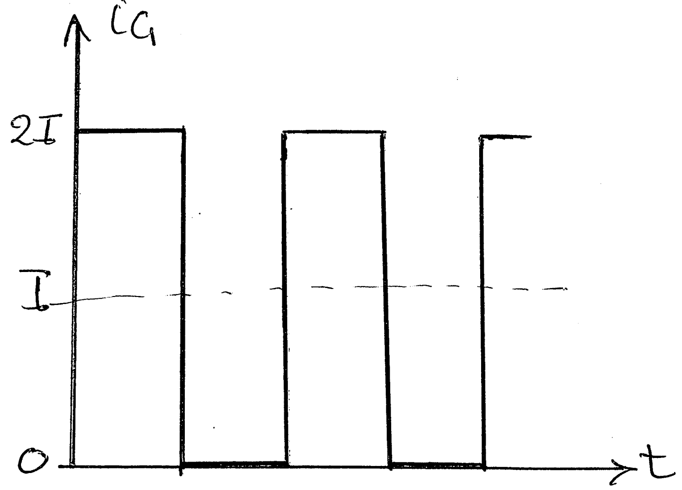
Sketch V_o, i_{C1}, P_{D1}
when the circuit driven by square wave

i) for $\pm V_{CC}$ output:

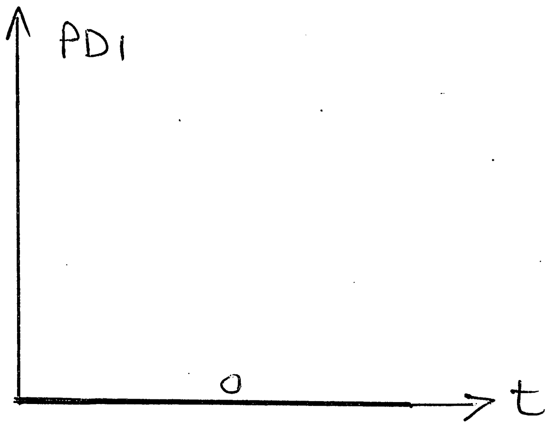




$V_{CE_1} = V_{CC} - V_o$

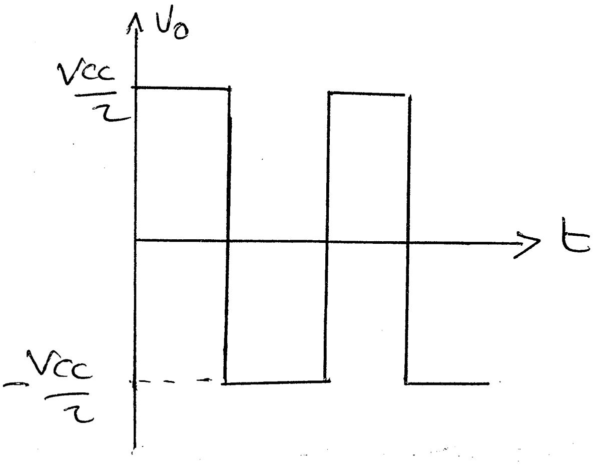


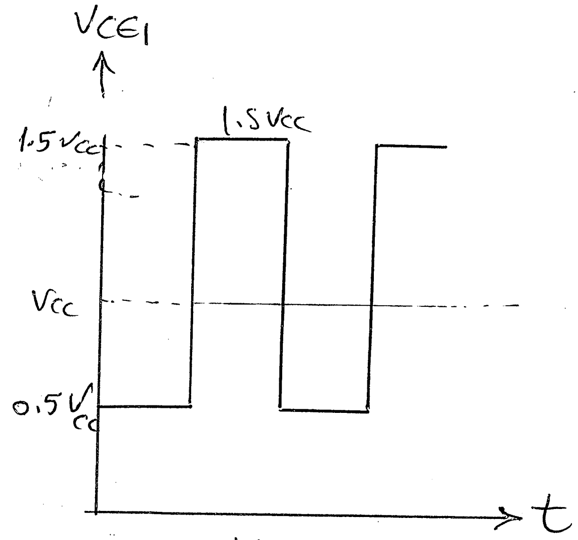
$i_{C_1} = I + i_L$



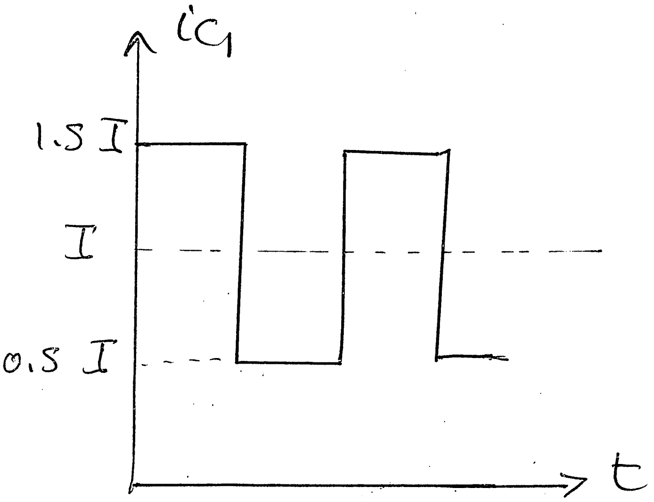
$P_{D_1} = i_{C_1} V_{CE_1} = 0$
$= P_{av_1}$

ii) $\pm \frac{V_{CC}}{2}$ output

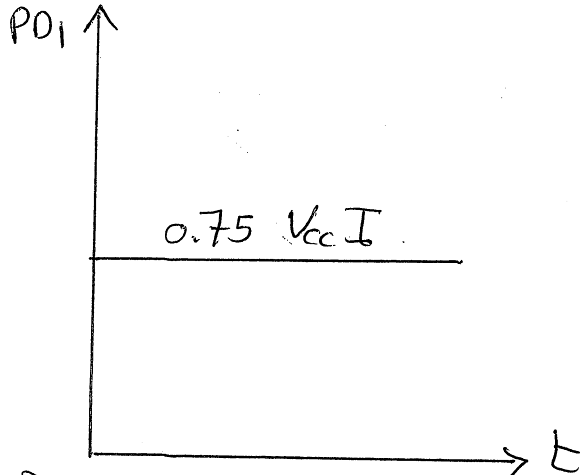




$V_{CE_1} = V_{CC} - V_o$



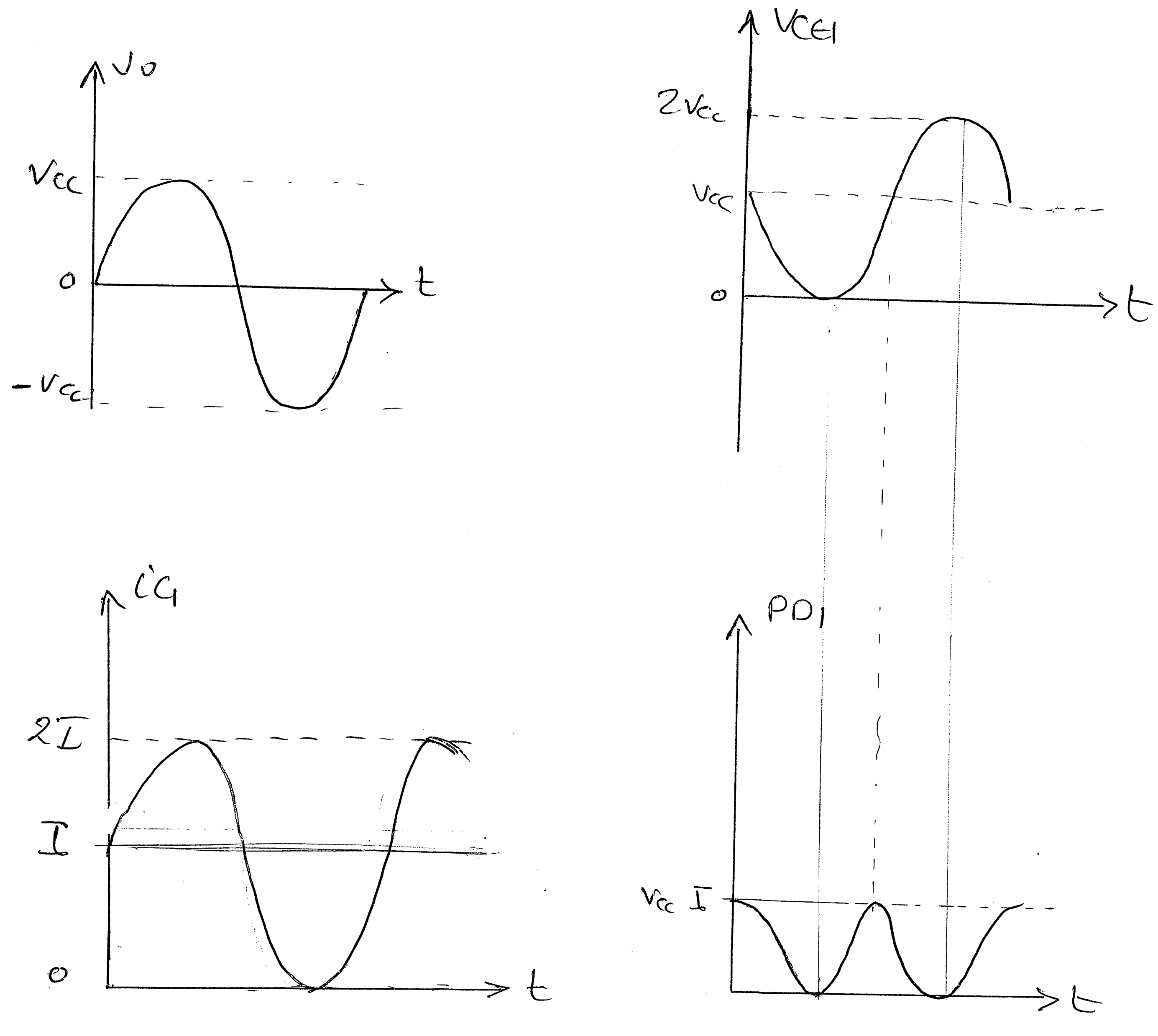
$i_C = I + i_L$



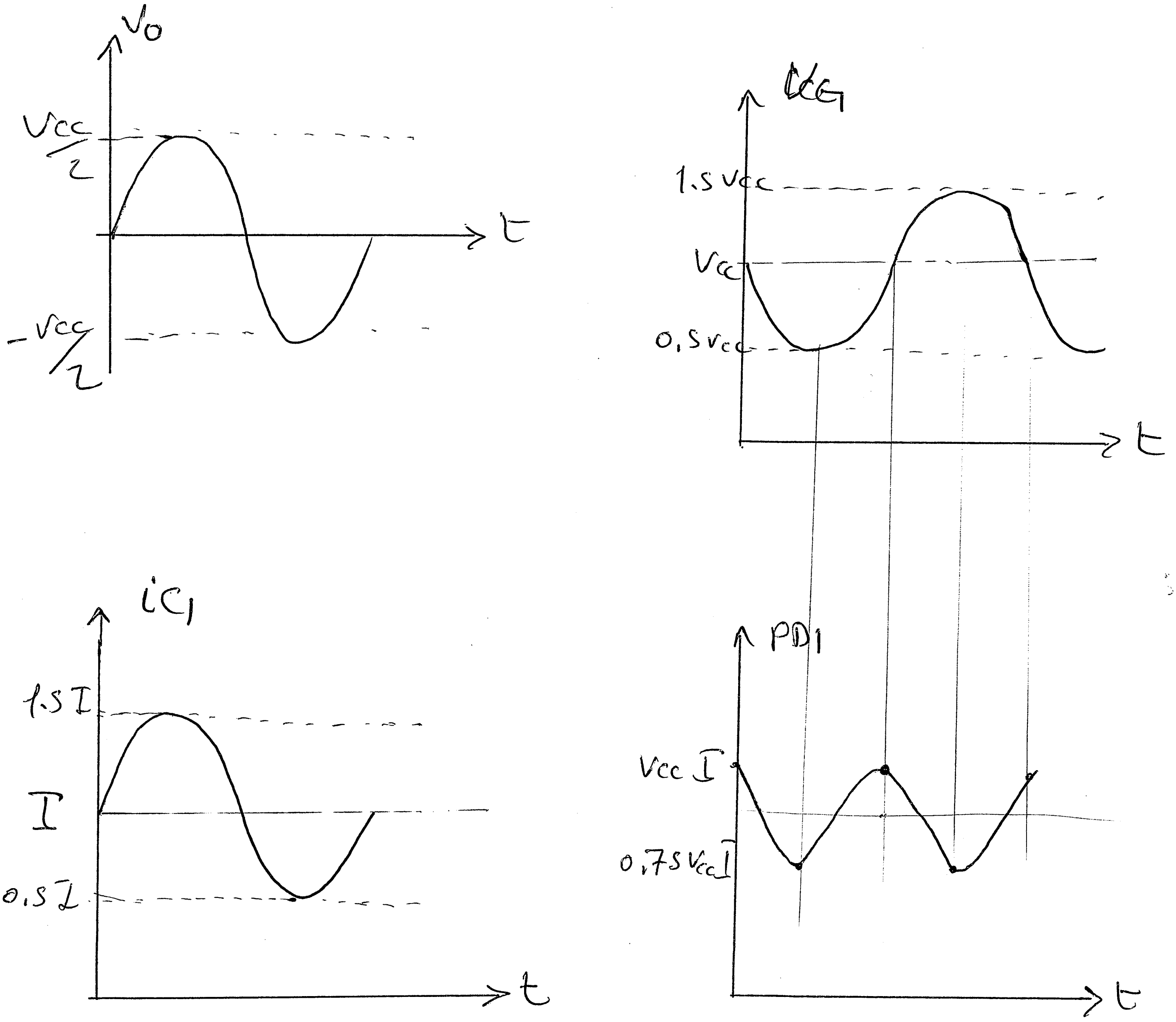
$P_{D_1} = i_{C_1} \cdot V_{CE_1}$

for sine-wave:

i) $\pm V_{cc}$ output



ii) $\pm \frac{V_{cc}}{2}$ output:



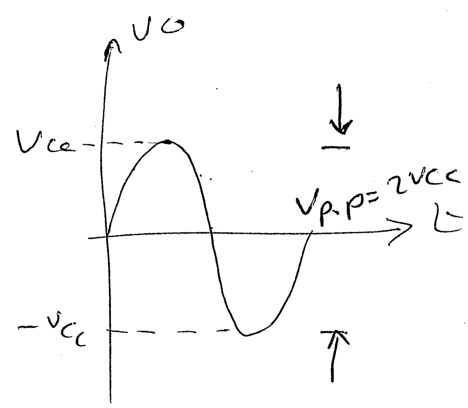
14.6 Consider the situation described in Problem 14.5. For square-wave outputs having peak-to-peak values of $2V_{CC}$ and V_{CC}, and for sine waves of the same peak-to-peak values, find the average power loss in the current-source transistor Q_2.

Square wave output

$V_{p.p} = 2\,V_{CC}$

Sine wave output

$V_{p.p} = 2\,V_{CC}$



find Pav in Q_2 (which has I)

$$\therefore\ PD_{max} = V_{CE_{2\,max}} \cdot I = (\overset{V_{CC}}{V_o} + V_{CC})\, I = 2V_{CC} I$$

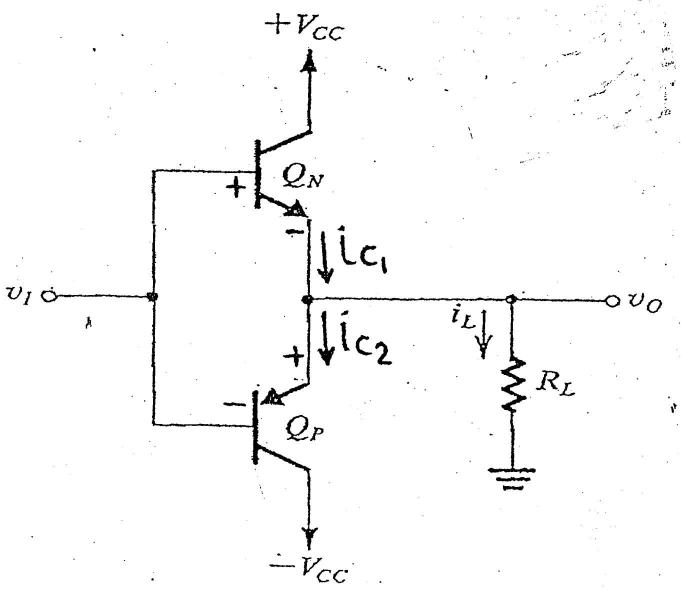
$$PD_{min} = V_{CE_{2\,min}} \cdot I = (\overset{-V_{CC}}{V_o} + V_{CC})\, I = 0$$

$$\therefore\ PD_{av} = \frac{PD_{max} + PD_{min}}{2} = V_{CC}\, I$$

$PD_{av} = V_{CC}\, I$ for (all Cases Sine & Square)

Class B power Amplifier

- It Consists of a Complementary pair of transistors (an npn and a pnp) Connected in Such a way That both Can't Conduct at The Same time.



Circuit operation:

- when V_i (input voltage) $= 0$

  ∴ both transistors are Cut off and $V_o = 0$

* $V_i \geq 0.5V \Rightarrow Q_N$ Conduct
  Q_P off

$\therefore \quad V_o = V_i - V_{BE_N}$

$i_L = i_{C_1}$

* $V_i \leq 0.5V \Rightarrow Q_P$ Conduct
  Q_N off

$\therefore \quad V_o = V_i + V_{EB_P}$

$i_L = -i_{C_2}$

Note: the transistors in class B are biased at Zero Current and Conduct only when the input signal is present.

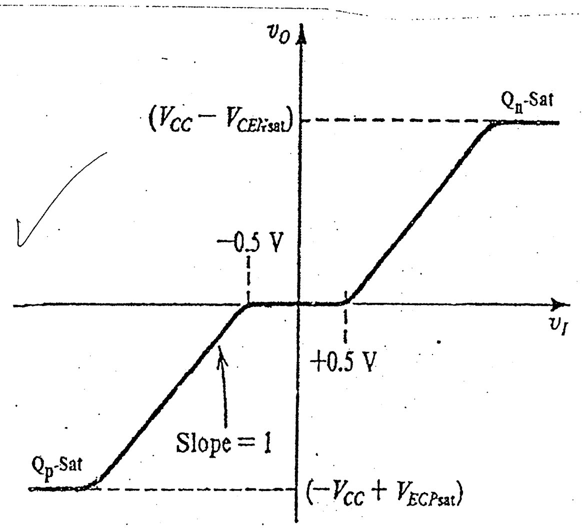
- the Circuit operate in a push-pull Amplifier
  Q_N push Current into the load when Vin is positive
  Q_P pull Current from the load when Vin is Negative

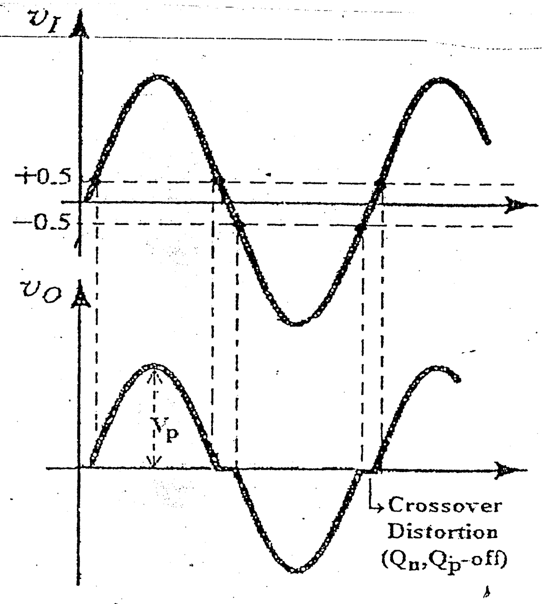
Push → يدفع
Pull → يسحب

* Transfer characteristics:

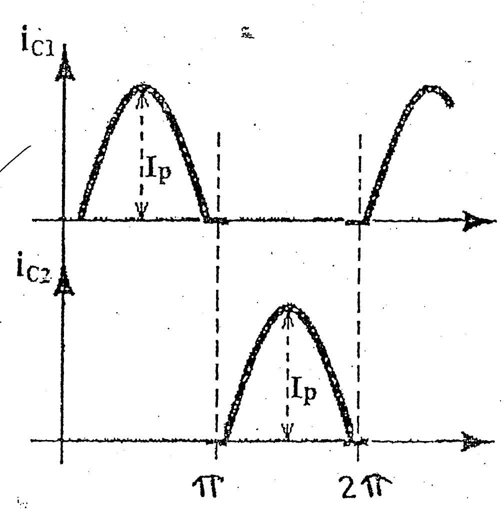
The dead band is region That both transistors are cut off. The dead band result in the Crossover distortion.

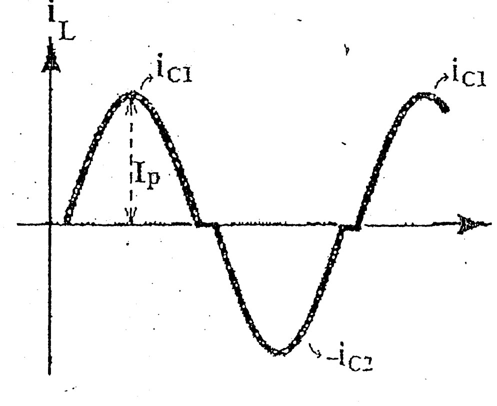
For Case of input Sine wave with large amplitude ⇒ Cross over distortion is small (Can be neglect)





مكتبة ... الكترونيات - تصوير - طباعة





* Supply power (P_S)

$$P_S = P_{+Vcc} + P_{-Vcc}$$

$$= V_{cc} \cdot i_{C1}(av) + V_{cc} \cdot i_{C2}(av)$$

$$i_{C1}(av) = i_{C2}(av) = \frac{I_P}{\pi} = \frac{\hat{I}}{\pi}$$

$$= \frac{V_P}{\pi R_L}$$

$$\therefore \boxed{P_S = 2\,(V_{cc})\left(\frac{V_P}{\pi R_L}\right)}$$

where V_P is max output voltage

* Load power (P_L):

$$P_L = V_{orms} * I_{orms}$$

$$= \frac{V_{orms}^2}{R_L}$$

$$\boxed{V_{rms} = \frac{V_{peak}}{\sqrt{2}}} \rightarrow \text{(for sine wave)}$$

$$\boxed{P_L = \frac{V_P^2}{2R_L}}$$

* power Conversion Efficiency:

$$\eta = \frac{P_L}{P_S} = \frac{V_p^2}{2R_L} \cdot \frac{\pi R_L}{2V_{cc}V_p}$$

$$= \frac{\pi V_p}{4V_{cc}}$$

At $V_p = V_{cc} \Rightarrow \eta_{max}$

$$\boxed{\eta_{max} = \frac{\pi}{4} = 78.5\,\%}$$ max efficienly of class B

* power dissipation (PD):

$$P_D = P_S - P_L$$

$$= \frac{2V_{cc}V_p}{\pi R_L} - \frac{V_p^2}{2R_L}$$

To find Pmax:

differentiate The equation of P_D and equal it with Zero (التفاضل بالنسبة لل V_p)

$$P_D = \frac{2 V_{cc} V_p}{\pi R_L} - \frac{V_p^2}{2 R_L}$$

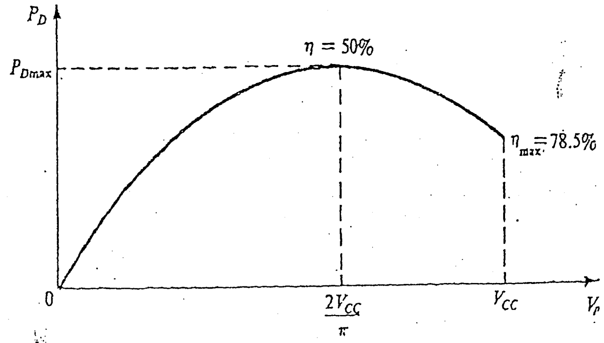
$$\frac{\partial P_D}{\partial V_p} = \frac{2 V_{cc}}{\pi \cancel{R_L}} - \frac{\cancel{2} V_p}{\cancel{2 R_L}}$$

$$\therefore \boxed{\frac{2 V_{cc}}{\pi} = V_p}$$

$\therefore$ max dissipation power at $V_p = \frac{2V_{cc}}{\pi}$

by substitution in P_D equation

$$\therefore \boxed{P_{D_{max}} = \frac{2 V_{cc}^2}{\pi^2 R_L}}$$



$$\eta \Big|_{V_p = \frac{2V_{cc}}{\pi}} = \frac{P_L}{P_S}\Big|_{V_p = \frac{2V_{cc}}{\pi}} = \frac{1}{2} = 50\%$$

$$P_{D_{N_{max}}} = P_{D_{P_{max}}} = \frac{1}{2} P_{D_{max}}$$

$$\boxed{P_{D_{N_{max}}} = \frac{V_{cc}^2}{\pi^2 R_L}}$$

where

$$P_D = P_{D_N} + P_{D_P}$$

$$= 2 P_{D_N}$$

* The Advantages of Class B over Class A:

1 - It's possible to obtain greater output power.

2 - The efficiency is higher

3 - At no signal ($V_p = 0$), The power dissipation is Zero

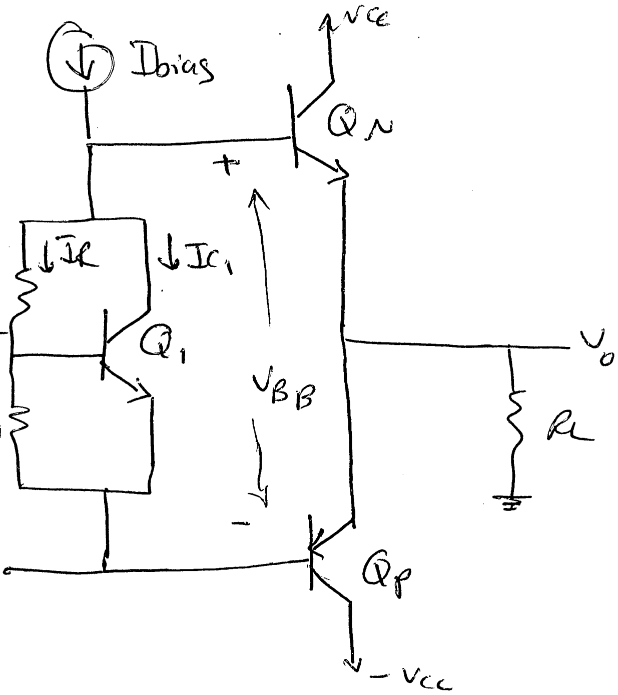
Disadvantages:

[1] The harmonic distortion is high due to the Crossover distortion.

* Biasing using The V_{BE} Multiplier:

- If we neglect the base current of Q_1

$\therefore$ R_1, R_2 carry the same current



$$\boxed{I_R = \frac{V_{BE_1}}{R_1}}$$

V_{BB} across the bias network

$$V_{BB} = I_R(R_1+R_2)$$

$$= \frac{V_{BE_1}}{R_1}(R_1+R_2)$$

$$= V_{BE_1}\left(1+\frac{R_2}{R_1}\right)$$

The circuit simply multiply V_{BE} by the factor $(1+R_2/R_1)$ and is know as "The V_{BE} multiplier"

$$\boxed{I_{C_1} = I_{bias} - I_R}$$

$$\boxed{V_{BE_1} = V_T \ln \frac{I_{C_1}}{I_{S_1}}}$$

Sheet (3).

Class B problems.

14.9 Consider the circuit of a complementary-BJT class B output stage. For what amplitude of input signal does the crossover distortion represent a 10% loss in peak amplitude?

Sol:

Amplitude of $\hat{V}_p$ = ?? (for 10% loss in peak due to crossover distortion)

$$\frac{V_o}{\hat{V}_p} = 0.9 \Rightarrow \boxed{V_o = 0.9\, V_i}$$

but $V_o = V_i - 0.5 = V_p \sin\omega t - 0.5$

$$\therefore \frac{V_p - 0.5}{V_p} = 0.9$$

$$\therefore \boxed{V_p = 5 \text{ volt}}$$

$$\therefore \boxed{V_{in} = 5 \sin\omega t}$$

✓

✓**14.12** Consider the complementary-BJT class B output stage and neglect the effects of finite V_{BE} and V_{CEsat}. For ±10-V power supplies and a 100-Ω load resistance, what is the maximum sine-wave output power available? What supply power corresponds? What is the power-conversion efficiency? For output signals of half this amplitude, find the output power, the supply power, and the power-conversion efficiency.

Given $V_{BE}, V_{CEsat} \simeq 0$

$V_{CC} = 10V$ $\quad R_L = 100\,\Omega$

find $P_{L_{max}}$, $P_{S_{max}}$, η_{max}

for $V_{p_{new}} = \frac{1}{2} V_{old}$ ⇒ find P_S, η ?

ⓐ for $V_p = V_{CC} = 10V$ (max)

$$P_{L_{max}} = \frac{V_{CC}^2}{2R_L} = 0.5\,W$$

$$P_{S_{max}} = \frac{2V_{CC}^2}{\pi R_L} = 0.637\,W$$

$$\eta_{max} = 78.5\,\%$$

ⓑ for $V_p = \frac{1}{2} V_{CC} = 5V$

$\therefore$ $P_L = \frac{1}{8}$ Watt

$P_S = \frac{1}{\pi}$ watt $\qquad \therefore \eta = 39.25\,\%$

D14.13 A class B output stage operates from ±5-V supplies. Assuming relatively ideal transistors, what is the output voltage for maximum power-conversion efficiency? What is the output voltage for maximum device dissipation? If each of the output devices is individually rated for 1-W dissipation, and a factor-of-2 safety margin is to be used, what is the smallest value of load resistance that can be tolerated, if operation is always at full output voltage? If operation is allowed at half the full output voltage, what is the smallest load permitted? What is the greatest possible output power available, in each case?

$V_{CC} = 5V$

what is output Voltage for max power dissipation

$$V_o \simeq V_p = \frac{2 V_{CC}}{\pi}$$

if $P_{DQ} = \frac{1\,W}{2} = 0.5\,W \Rightarrow$ find $\underline{R_L}$

find R_L for (full output voltage)
(half output voltage)

and find P_L

at full output voltage: $(V_p = V_{CC})$

$$\therefore \eta = 78.5\%$$

$$= \frac{P_L}{P_S} = \frac{P_L}{P_D + P_L}$$

$$P_D = 2 P_{DQ} = 1\text{ watt}$$

$$0.785 = \frac{P_L}{P_L + 1}$$

$$\therefore P_L = 3.65 \text{ watt}$$

$$= \left.\frac{V_p^2}{2R_L}\right|_{V_p = V_{cc}}$$

$$\therefore \boxed{R_L = \frac{V_p^2}{2P_L} = 3.42\,\Omega}$$

At half output voltage $\left(V_p = \frac{V_{cc}}{2}\right)$

$$\therefore \eta = \frac{P_L}{P_S} = \frac{\pi}{4}\frac{V_p}{V_{cc}}$$

at $V_p = \frac{V_{cc}}{2}$

$$\therefore \eta = 39.25\,\%$$

$$0.3925 = \frac{P_L}{P_L + 1}$$

$$\therefore P_L = 0.646 \text{ watt}$$

$$\therefore R_L = \left.\frac{V_p^2}{2P_L}\right|_{V_p = \frac{V_{cc}}{2}} = 4.83\,\Omega$$

D14.14 A class B output stage is required to deliver an average power of 100 W into a 16-Ω load. The power supply should be 4 V greater than the corresponding peak sine-wave output voltage. Determine the power-supply voltage required (to the nearest volt in the appropriate direction), the peak current from each supply, the total supply power, and the power-conversion efficiency. Also, determine the maximum possible power dissipation in each transistor for a sine-wave input.

$P_L = 100\,W$ at $R_L = 16\,\Omega$

$\boxed{V_{cc} = 4\,\text{Volt} + V_p}$

Find P_s, I_p, P_s, η, $P_{Dmax}(Q_n, Q_p) = ??$

$\because \; P_L = 100\,W = \dfrac{V_p^2}{2R_L}$

$\therefore \; \boxed{V_p = 56.6 \text{ volt}}$

$\therefore \; V_{cc} = 4 + 56.6 = 60.6 \text{ volt}$

$P_s = \dfrac{2 V_{cc} V_p}{\pi R_L} = 136.47\,W$

$I_p = \dfrac{V_p}{R_L} = 3.53\,A$

$$\eta = \frac{P_L}{P_S} = \frac{100\,W}{136.47}$$

$$\boxed{\eta = 73.2\,\%}$$

$$P_{D_{max}}(Q_n, Q_p) = \frac{1}{2}(P_S - P_L)$$

$$P_{D_{N}max} = \frac{V_{CC}^2}{\pi^2 R_L}$$

$$= 23.25 \text{ watt}$$