

UNIT – I

Single Stage Amplifiers: Classification of Amplifiers – Distortion in amplifiers, Analysis of CE, CC and CB configurations with simplified hybrid model, Analysis of CE amplifier with emitter resistance and emitter follower, Miller's theorem and its dual, Design of single stage RC coupled Amplifier using BJT.

Multistage Amplifiers: Analysis of Cascaded RC coupled BJT amplifiers, Cascode Amplifier, Darlington Pair, Different Coupling Schemes used in Amplifiers – RC coupled amplifiers, Transformer Coupled Amplifier, Direct Coupled Amplifier.

Classification of Amplifiers

Type of Signal	Based on No.of Stages	Type of Configuration	Classification based on conduction angle	Frequency of Operation
Small Signal	Single Stage	Common Emitter	Class A Amplifier	Direct Current (DC)
Large Signal	Multistage	Common Base	Class B Amplifier	Audio Frequencies (AF)
		Common Collector	Class AB Amplifier	Radio Frequencies (RF)
			Class C Amplifier	VHF, UHF and SHF Frequencies

Different Regions Of Operation

Region of Operation	Emitter Base Junction	Collector Base Junction
Cut off	Reverse biased	Reverse biased
Active	Forward biased	Reverse biased
Saturation	Forward biased	Forward biased

Transistor Voltage specifications For Various Operating Regions

Transistor	V_{CE} (sat)	V_{BE} (sat)	V_{BE} (active)	V_{BE} (cut-in)	V_{BE} (cut-off)
Si	0.2 V	0.8 V	0.7 V	0.5 V	0 V
Ge	0.1 V	0.3 V	0.2 V	0.1 V	- 0.1 V

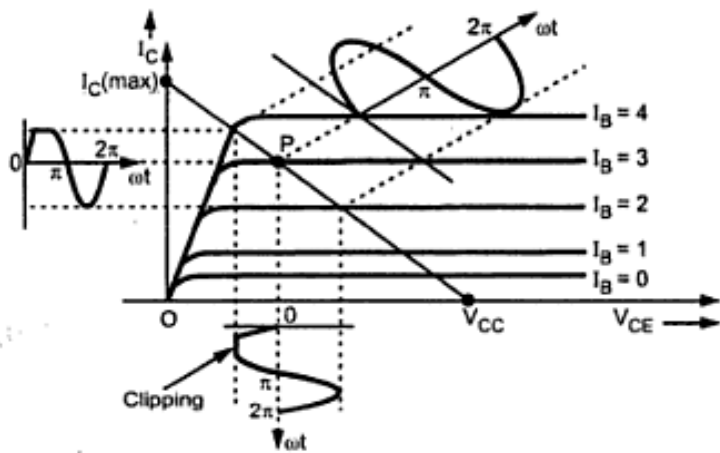
Condition for Active & Saturation Regions

For saturation :

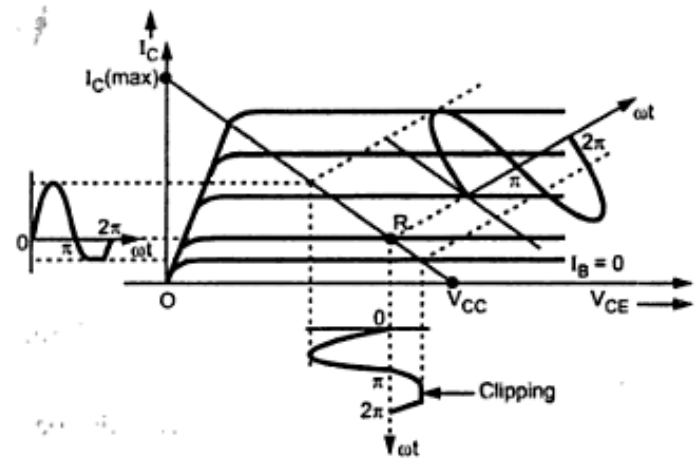
$$I_B > \frac{I_C}{\beta_{dc}}$$

For active region :

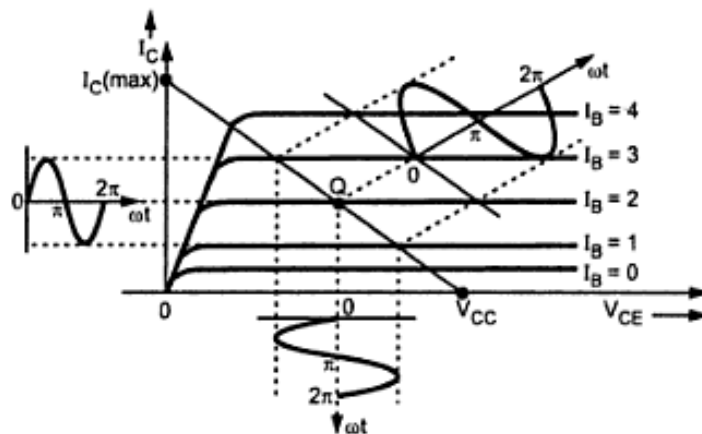
$$V_{CE} > V_{CE(sat)}$$



Operating point near saturation region gives clipping at the positive peaks

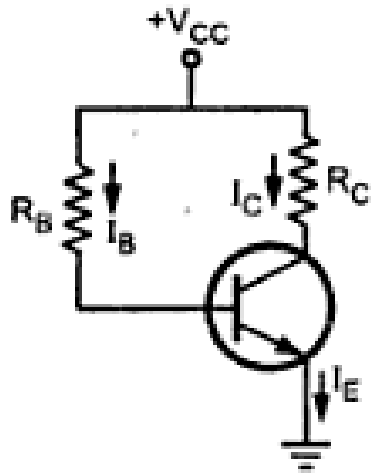


Operating point near cut-off region gives clipping at the negative peaks

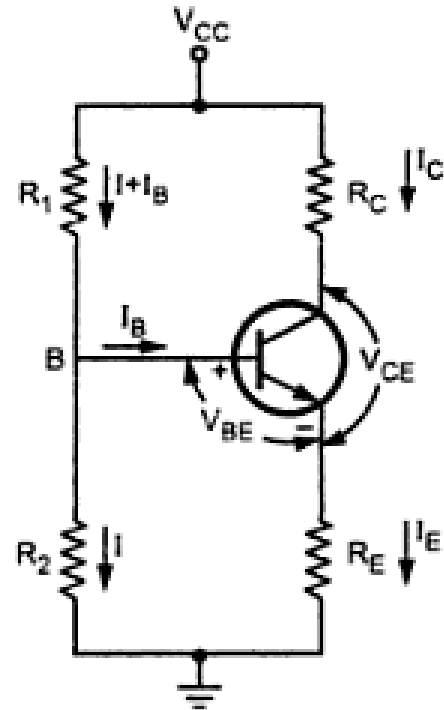


Operating point at the centre of active region is most suitable

Transistor Biasing

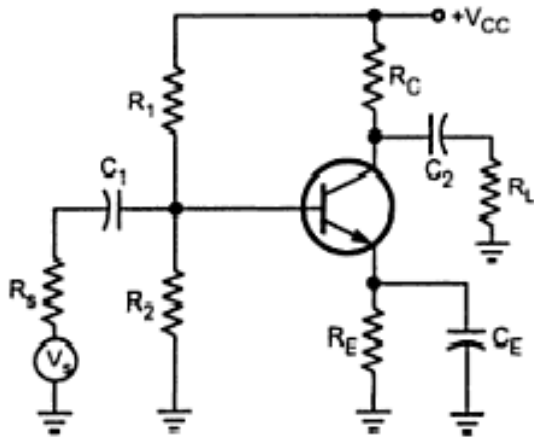


Fixed bias circuit

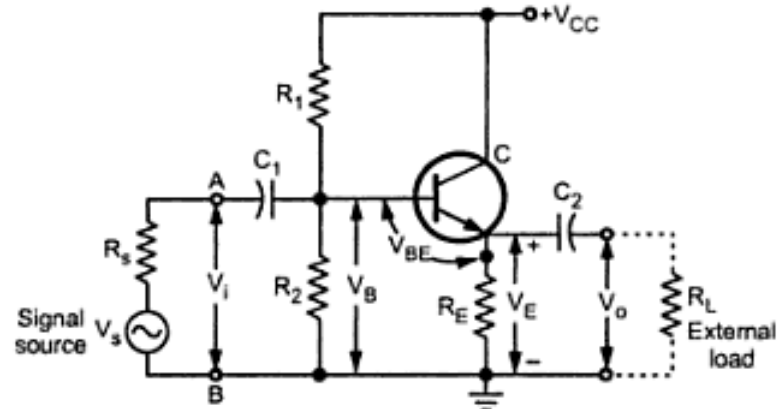


Voltage divider bias circuit

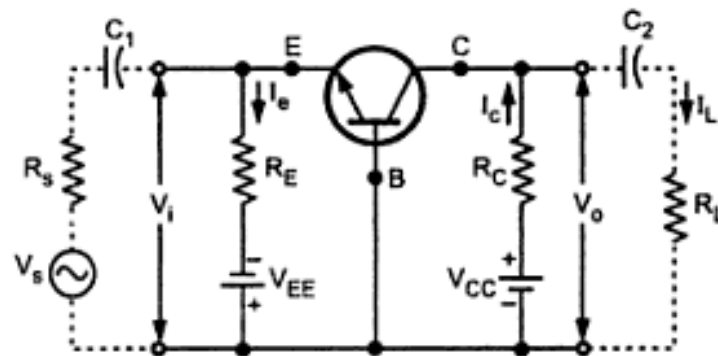
CE, CC, & CB Amplifiers



Practical common emitter amplifier circuit



Common collector circuit



Common base circuit

H-Parameters Representation Of An Amplifier



$$V_i = h_{11} I_i + h_{12} V_o$$

$$I_o = h_{21} I_i + h_{22} V_o$$

Definitions of h-parameter

The parameters in the above equation are defined as follows :

$$h_{11} = \left. \frac{V_i}{I_i} \right|_{V_o=0} = \text{Input resistance with output short-circuited, in ohms.}$$

$$h_{12} = \left. \frac{V_i}{V_o} \right|_{I_i=0} = \text{Fraction of output voltage at input with input open circuited.}$$

This parameter is ratio of similar quantities, hence unitless

$$h_{21} = \left. \frac{I_o}{I_i} \right|_{V_o=0} = \text{Forward current transfer ratio or current gain with output short circuited.}$$

This parameter is a ratio of similar quantities, hence unitless.

$$h_{22} = \left. \frac{I_o}{V_o} \right|_{I_i=0} = \text{Output admittance with input open-circuited, in mhos.}$$

a) With output short circuited :

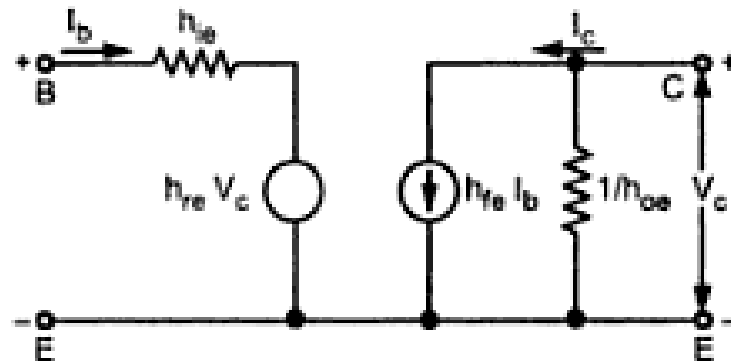
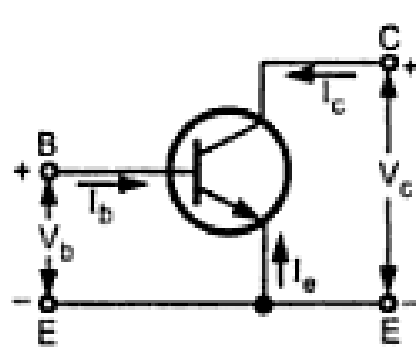
$h_{11} = h_i$: Input resistance

$h_{21} = h_f$: Short circuit current gain

b) With input open circuited :

$h_{12} = h_r$: Reverse voltage transfer ratio

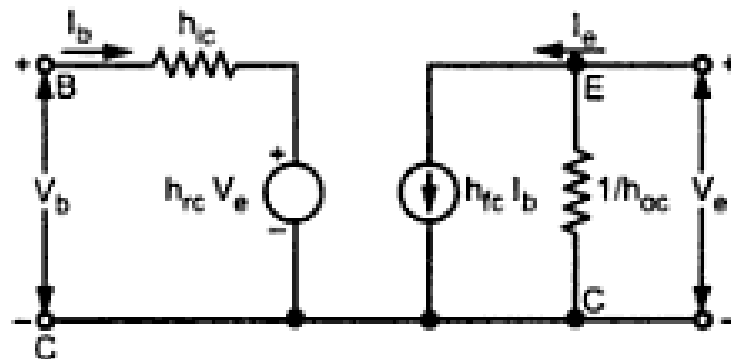
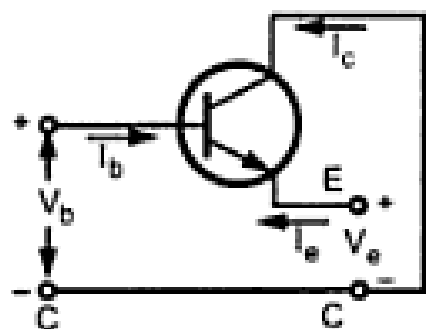
$h_{22} = h_o$: Output admittance



CE

$$V_b = h_{ie} I_b + h_{re} V_c$$

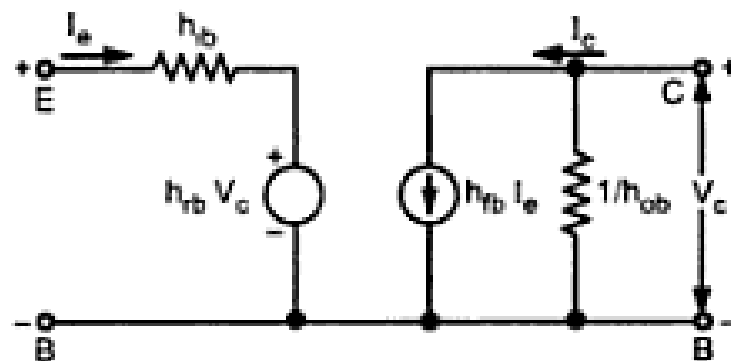
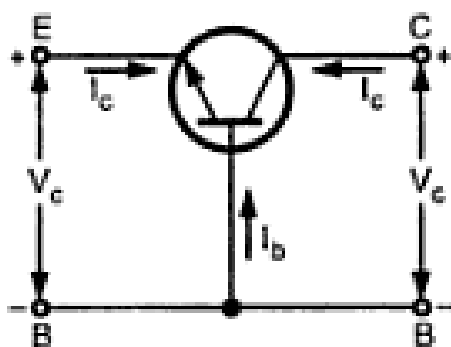
$$I_c = h_{fe} I_b + h_{oe} V_c$$



CC

$$V_b = h_{ic} I_b + h_{rc} V_e$$

$$I_e = h_{fc} I_b + h_{oc} V_e$$



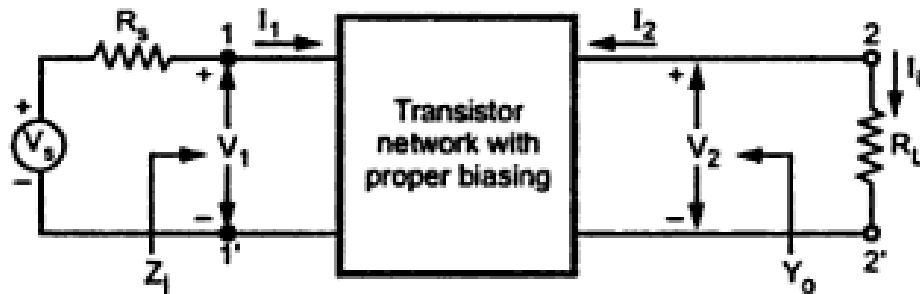
CB

$$V_e = h_{ib} I_e + h_{rb} V_c$$

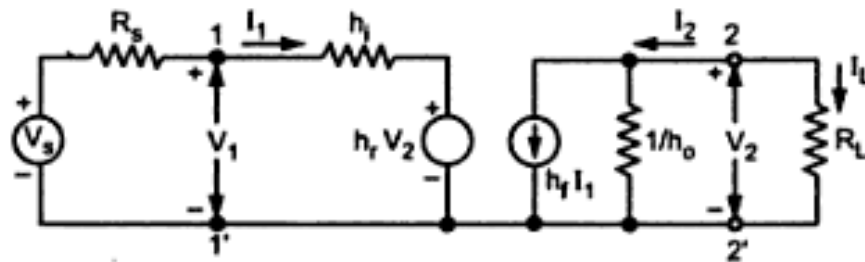
$$I_c = h_{fb} I_e + h_{ob} V_c$$

Transistor configurations and their hybrid models

Small Signal Analysis Of A Junction Transistor



Basic transistor amplifier



Transistor amplifier in its h-parameter model

small-signal analysis of a transistor amplifier

$$A_i = -\frac{h_f}{1 + h_o R_L}$$

$$A_{is} = \frac{A_i R_s}{Z_i + R_s}$$

$$Z_i = h_i + h_r A_i R_L = h_i - \frac{h_f h_r}{h_o + Y_L}$$

$$A_v = \frac{A_i R_L}{Z_i}$$

$$A_{vs} = \frac{A_v R_i}{Z_i + R_s} = \frac{A_i R_L}{Z_i + R_s} = \frac{A_{is} R_L}{R_s}$$

$$Y_o = h_o - \frac{h_f h_r}{h_i + R_s} = \frac{1}{Z_o}$$

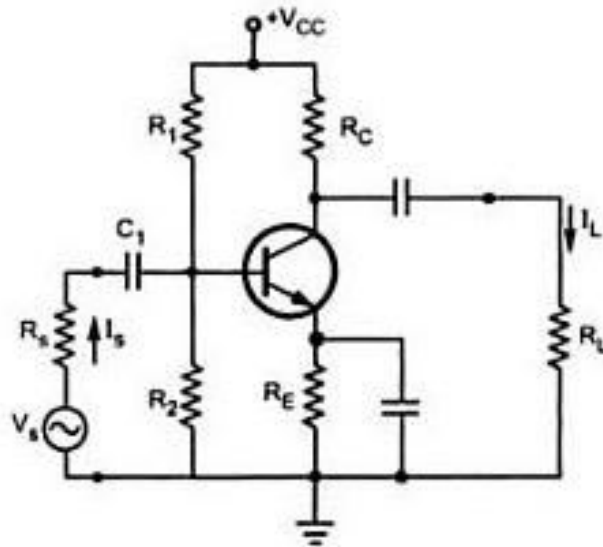
$$A_p = A_v A_i = A_i^2 \frac{R_L}{Z_i}$$

Guidelines for Analysis of a Transistor Circuit

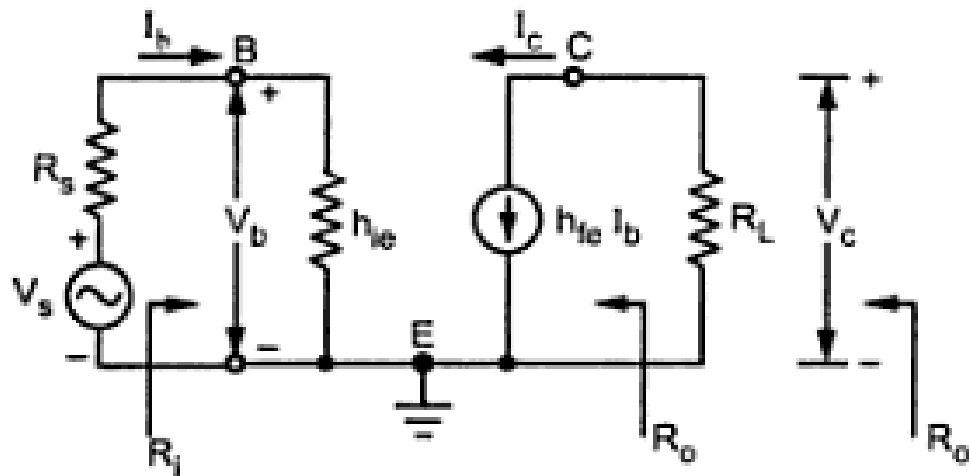
1. Draw the actual circuit diagram.
2. Replace coupling capacitors and emitter bypass capacitor by short circuit.
3. Replace dc source by a short circuit. In other words, short V_{CC} and ground lines.
4. Mark the points B(base), C(collector), E(emitter) on the circuit diagram and locate these points as the start of the equivalent circuit.
5. Replace the transistor by its h-parameter model.

Design Problem

- ➔ Consider a single stage CE amplifier with $R_s = 1 \text{ k}\Omega$, $R_1 = 50 \text{ K}$, $R_2 = 2 \text{ K}$, $R_C = 1 \text{ K}$, $R_L = 1.2 \text{ K}$, $h_{fe} = 50$, $h_{ic} = 1.1 \text{ K}$, $h_{ov} = 25 \text{ }\mu\text{A/V}$ and $h_{rc} = 2.5 \times 10^{-4}$, as shown in Fig.



Approximate H-Model For CE Amplifier



Approximate CE model

Current Gain $A_i \approx -h_{fe}$

Input Impedance $R_i \approx h_{ie}$

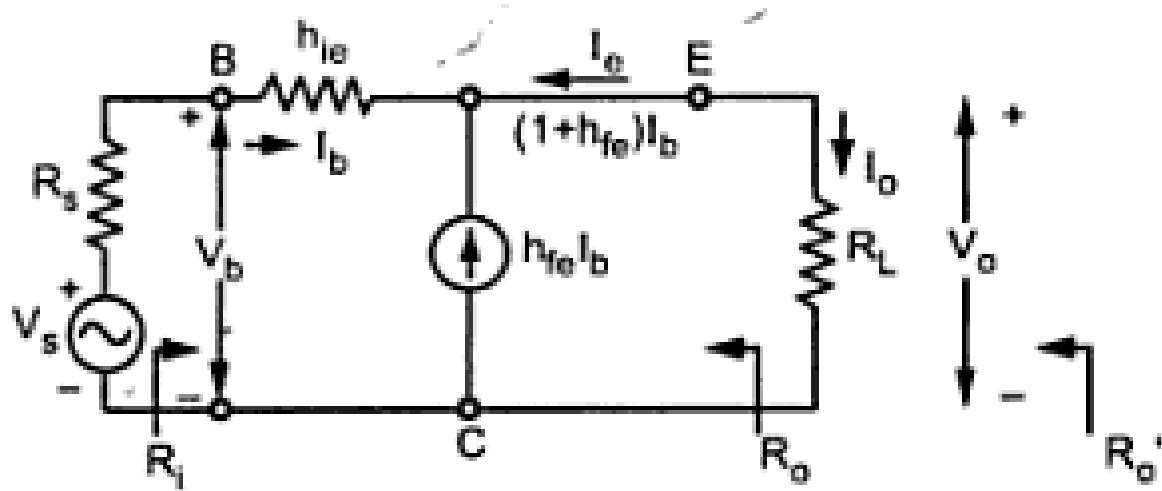
Voltage Gain : $A_v = \frac{A_i R_L}{R_i} = \frac{A_i R_L}{h_{ie}}$

Output Impedance $Y_o = 0$

$$R_o = \frac{1}{Y_o} = \infty$$

$R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L$

Approximate H-Model For CC Amplifier



Simplified CC model

Current gain $A_i = \frac{I_o}{I_b} = \frac{-I_c}{I_b} = 1 + h_{fe}$

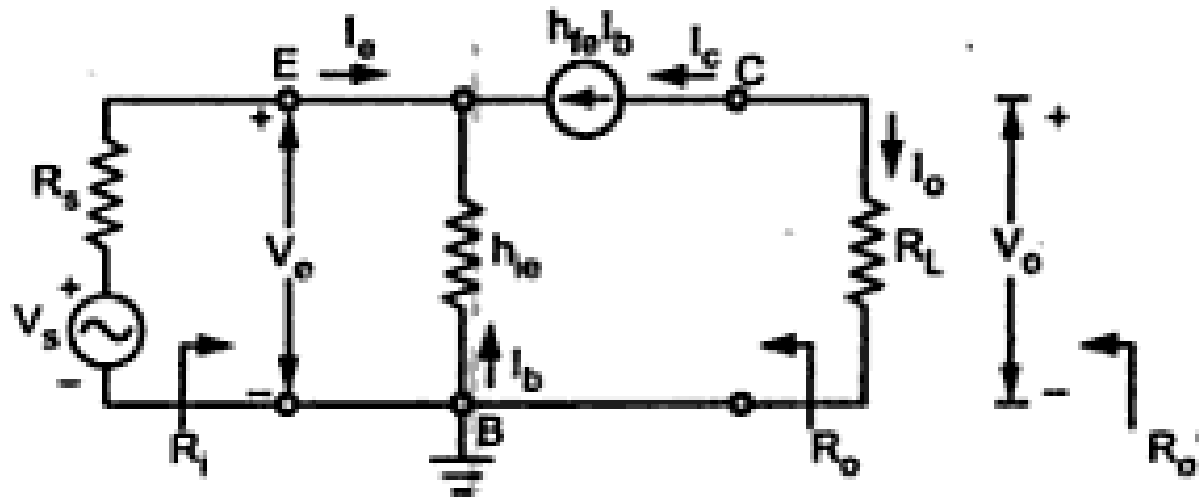
Input resistance : $R_i = \frac{V_b}{I_b} = h_{ie} + (1 + h_{fe}) R_L$

Voltage gain (A_v) $A_v = \frac{(1 + h_{fe}) R_L}{h_{ie} + (1 + h_{fe}) R_L} \cong 1$

Output resistance R_o $R_o = \frac{V_o}{I_c} = \frac{R_s + h_{ie}}{1 + h_{fe}}$

$R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L$

Approximate H-Model For CB Amplifier



Simplified CB model

Current gain $A_i = \frac{h_{fe}}{1 + h_{fe}}$

Input resistance (R_i) $R_i = \frac{h_{ie}}{1 + h_{fe}}$

Voltage gain (A_v) $A_v = \frac{\frac{h_{fe}}{1 + h_{fe}} \times R_L}{\frac{h_{ie}}{1 + h_{fe}}} = \frac{h_{fe} R_L}{h_{ie}}$

Output resistance (R_o) $R_o = \left. \frac{V_o}{I_c} \right|_{V_s=0}$

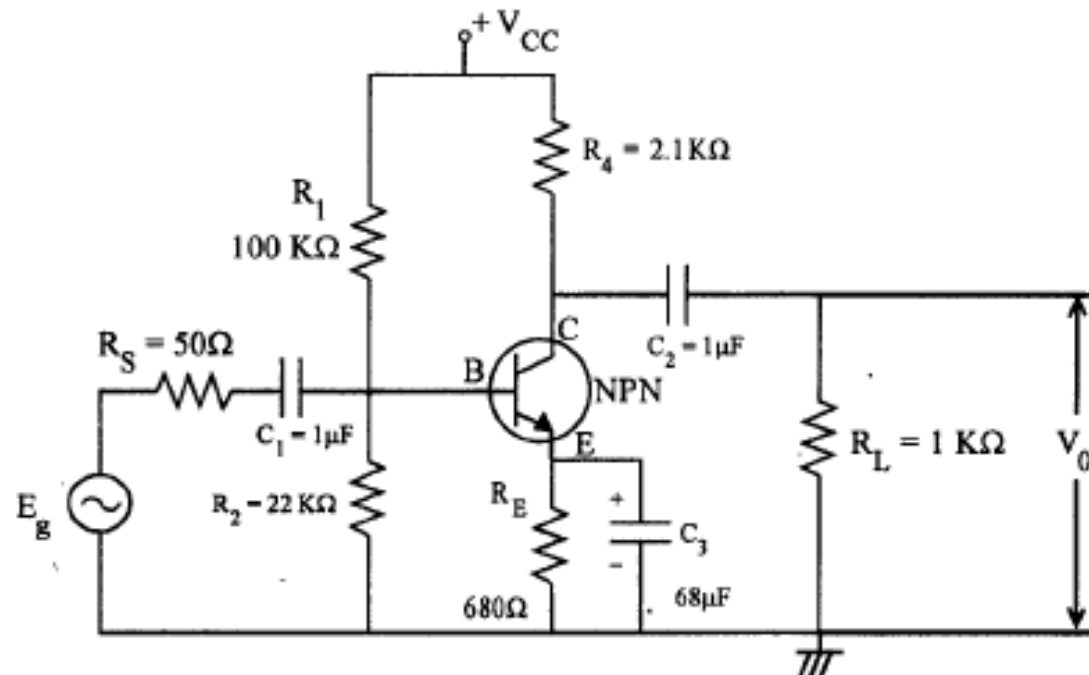
$R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L$

Design Problem

For the circuit shown in Fig. estimate A_p , A_v , R_i and R_o using reasonable approximations. The *h-parameters* for the transistor are given as

$$h_{fe} = 100 \quad h_{ie} = 2000 \Omega \quad h_{re} \text{ is negligible} \quad \text{and} \quad h_{oe} = 10^{-5} \text{ mhos}(\Omega).$$

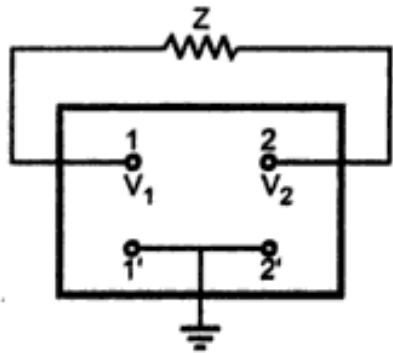
$$I_b = 100 \mu\text{A}.$$



CE Amplifier Circuit

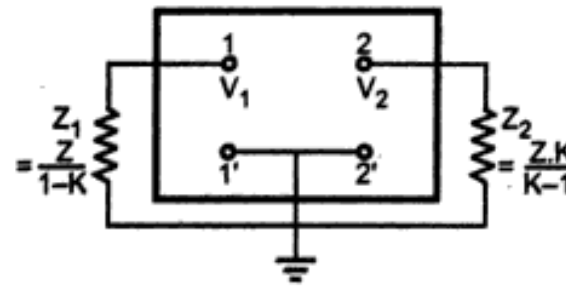
Miller's Theorem

Miller's theorem is used to simplify the analysis of a circuit whenever there is a feedback connection in the circuit



(a)

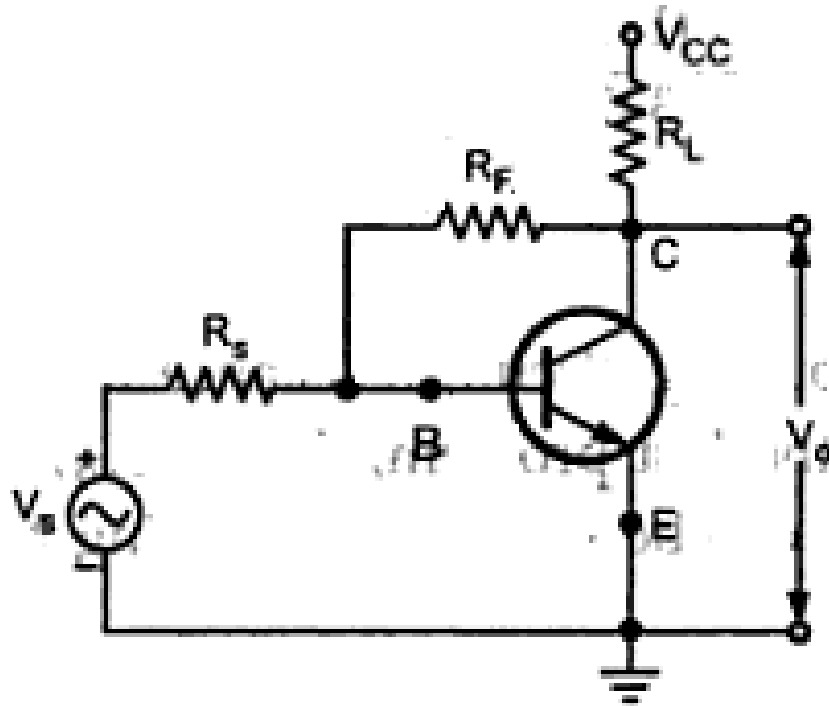
$$Z_1 = \frac{Z}{1-K}$$



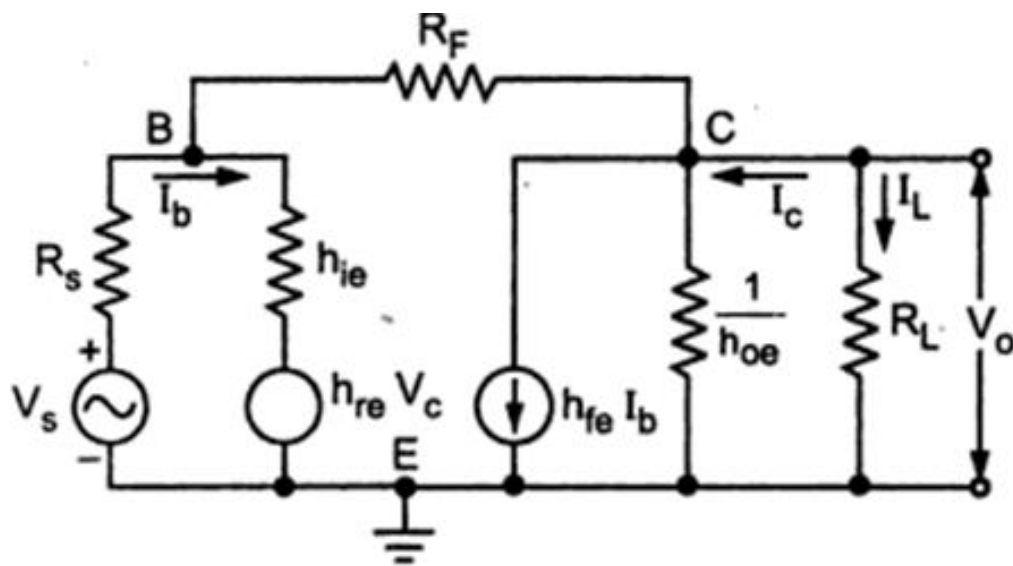
(b)

$$Z_2 = \frac{Z \cdot K}{K-1}$$

Analysis of Common Emitter Amplifier with Collector to Base Bias

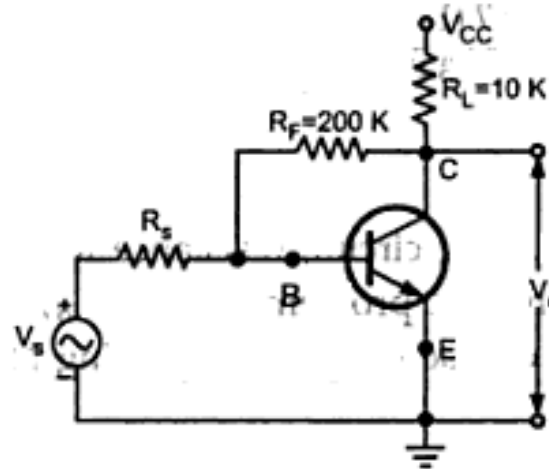


AC equivalent circuit



Design Problems

- ➡ The Fig. shows common emitter amplifier with collector to base bias. Calculate R_i , R_o , A_v , A_{vs} , A_i . The transistor parameters are $h_{ie} = 1.1 \text{ K}$, $h_{fe} = 50$, $h_{oe} = 25 \times 10^{-6} \text{ A/V}$, $h_{re} = 2.5 \times 10^{-4}$.

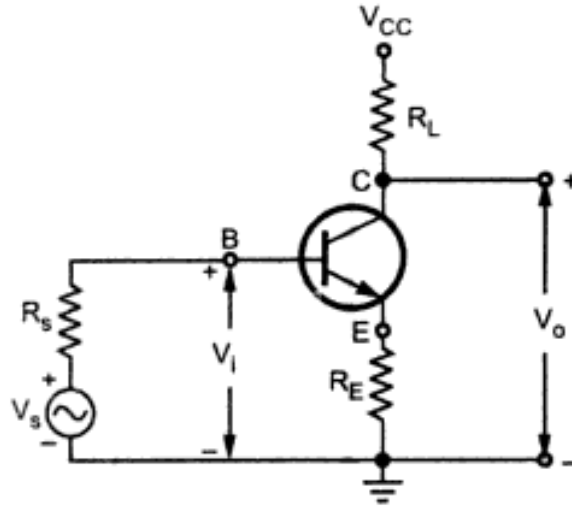


Design Problems

➔ For a Common Emitter Configuration, what is the maximum value of R_L for which R_1 differs by not more than 10% of its value at $R_2 = 0$?

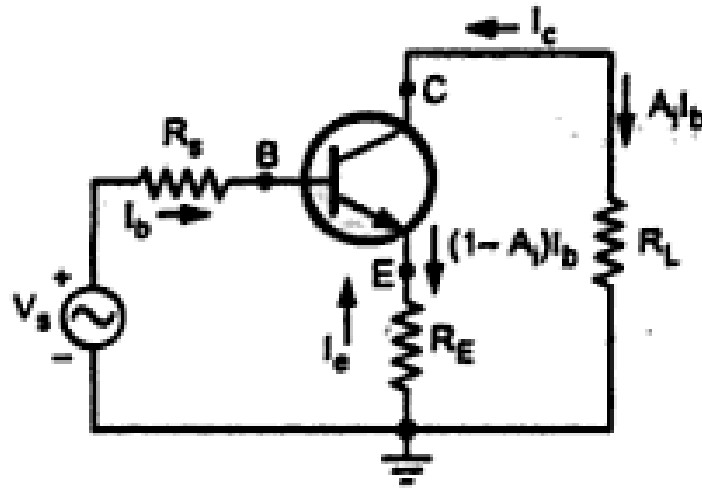
$$\begin{aligned} h_{ie} &= 1100\Omega; & h_{fe} &= 50 \\ h_{re} &= 2.50 \times 10^{-4}; & h_{oe} &= 25\mu A/v \end{aligned}$$

Analysis Of CE Amplifier With Unbypassed R_E

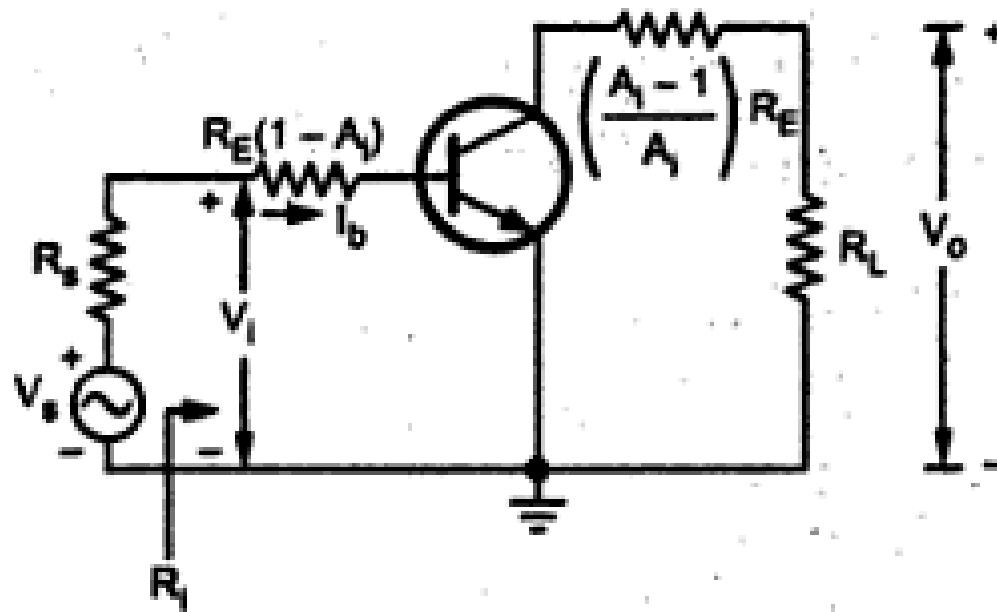


- ❖ R_E is added to stabilize the gain of the amplifier
- ❖ R_E acts as a feedback resistor
- ❖ The overall gain will reduce with unbypassed R_E

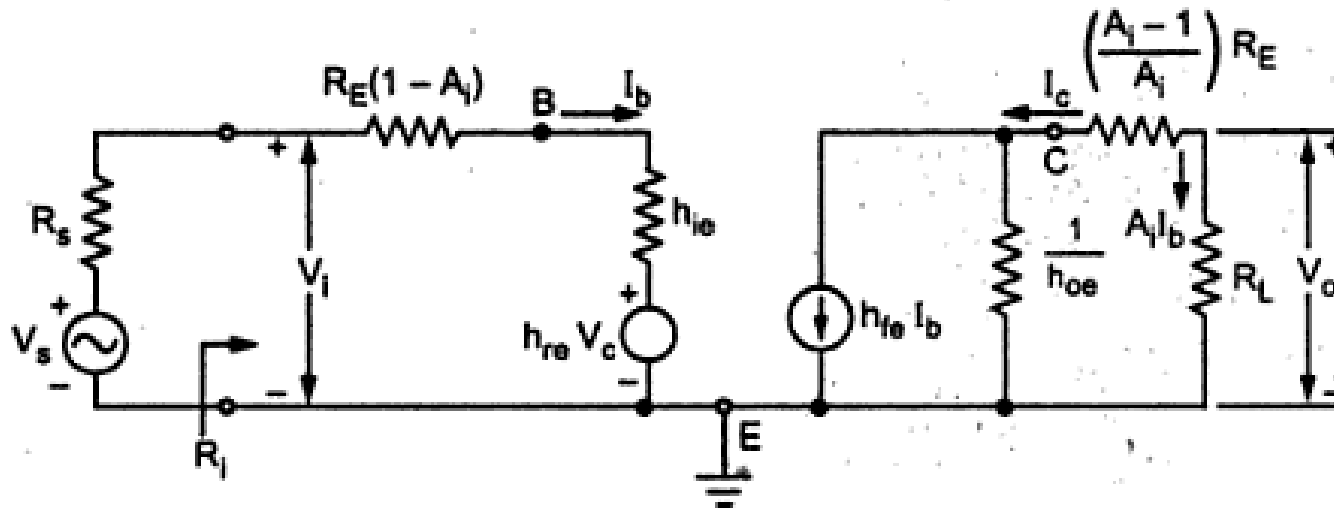
AC Equivalent Circuit For CE Amplifier with Unbypassed R_E



AC Equivalent Circuit For CE Amplifier with R_E Splitted using dual of Miller's Theorem

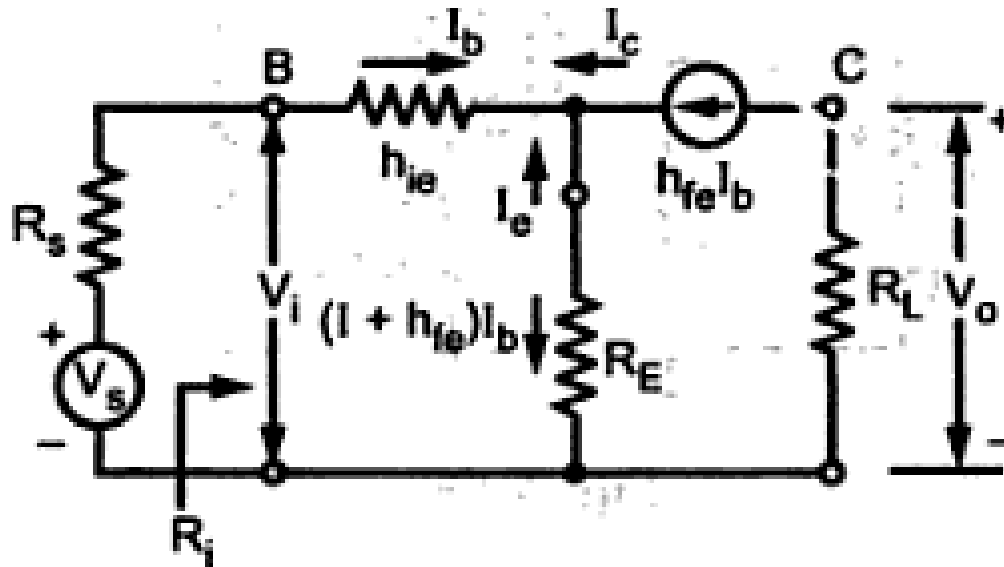


h-Parameter Equivalent Circuit (Exact Analysis)



$$A_i = \frac{-h_{fe}}{1 + h_{oe} R_L'} = \frac{-h_{fe}}{1 + h_{oe} \left(R_L + \frac{A_i - 1}{A_i} R_E \right)}$$

h-Parameter Equivalent Circuit (Approximate Analysis)



Approximate model for CE amplifier with R_E

$$\text{Current gain } A_i = \frac{-I_c}{I_b} = \frac{-h_{fe}I_b}{I_b} = -h_{fe}$$

$$\text{Input resistance } R_i = \frac{V_i}{I_b} = h_{ie} + (1 + h_{fe}) R_E$$

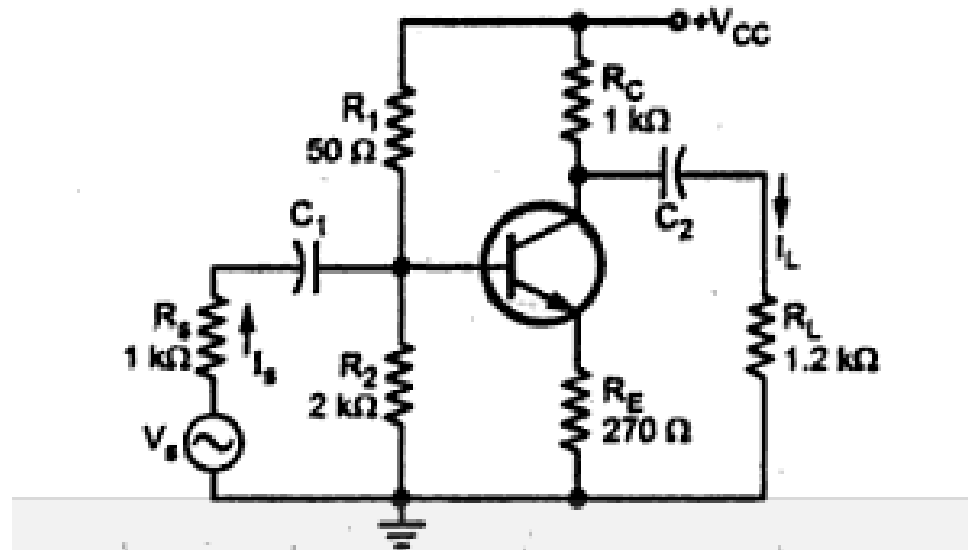
$$\text{Voltage gain } A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_L}{h_{ie} + (1 + h_{fe}) R_E}$$

$$\text{Output resistance } R_o = \left. \frac{V_o}{I_o} \right|_{V_s=0}$$

$$R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L$$

Design Problems

- ➡ **Example** Fig. shows a single stage CE amplifier with unbypassed emitter resistance find current gain, input resistance, voltage gain and output resistance. Use typical values of h-parameter

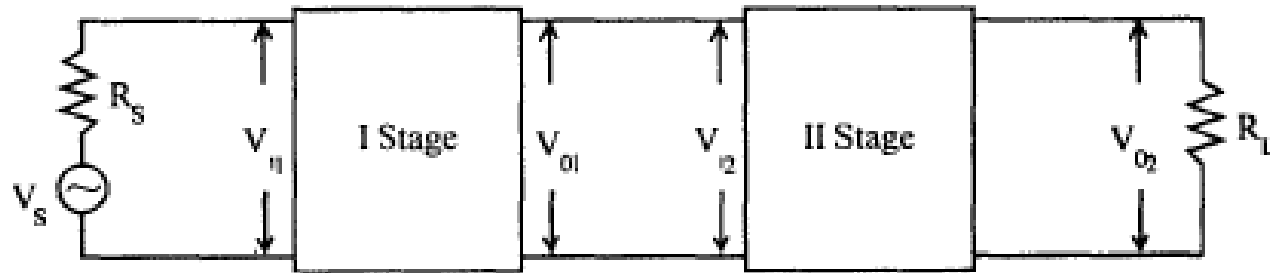


MULTISTAGE AMPLIFIERS

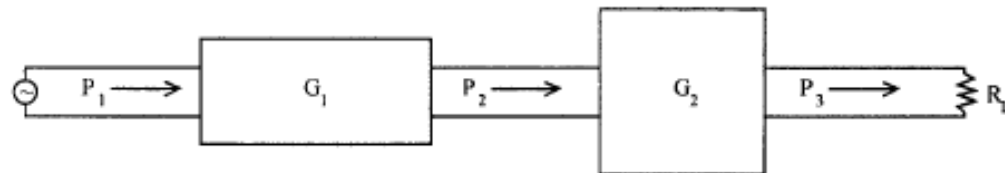
Need For Cascading

- When the amplification of a single stage amplifier is not sufficient, or,
- When the input or output impedance is not of the correct magnitude, for a particular application two or more amplifier stages are connected, in cascade. Such amplifier, with two or more stages is also known as multistage amplifier.

Block diagram of 2-Stage Cascade Amplifier



Gain of 2-Stage Cascade Amplifier



$$G_1 = \frac{P_2}{P_1}; \quad G_2 = \frac{P_3}{P_2}$$

Overall gain

$$G = \frac{P_3}{P_1}$$
$$= \frac{P_2}{P_1} \cdot \frac{P_3}{P_2}$$

$$G = G_1 G_2$$

Decibel Voltage Gain

Cascaded Stages

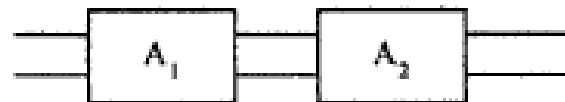


Fig. 2.23 Cascaded stages

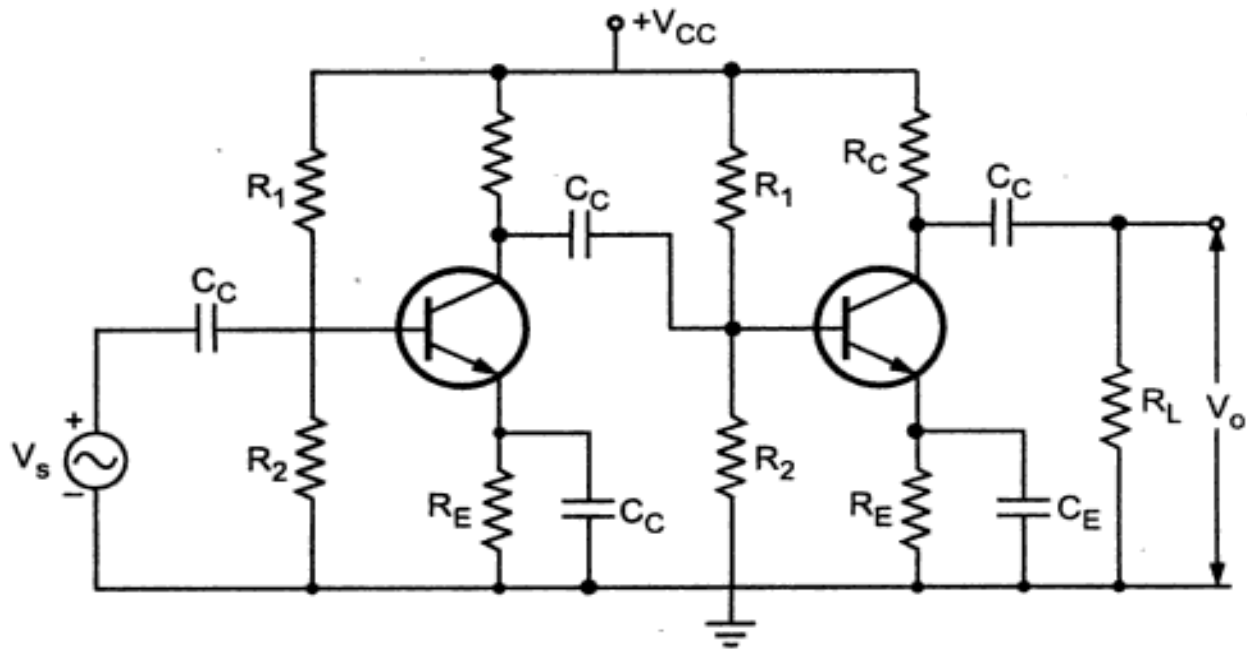
$$A = A_1 \times A_2$$

$$A_1 = A_1' + A_2' \text{ (in decibels)}$$

Methods of Inter Stage Coupling

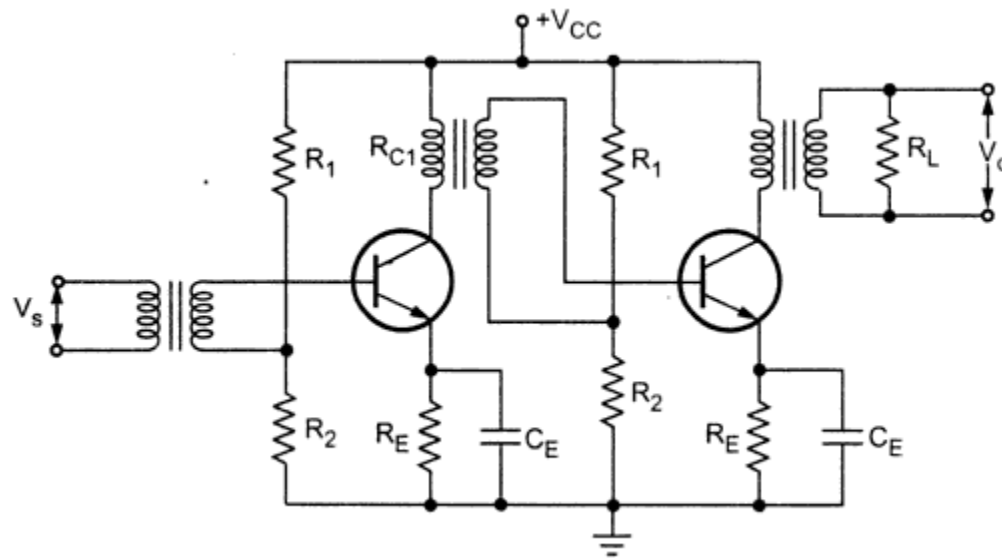
In multistage amplifier, the output signal of preceding stage is to be coupled to the input **circuit** of succeeding stage. For this interstage coupling, different types of coupling elements can be employed. These are :

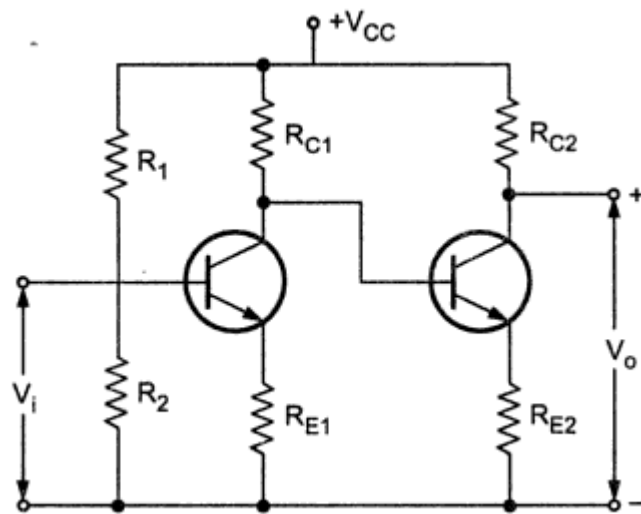
1. RC coupling
2. Transformer coupling
3. Direct coupling



Two stage RC coupled amplifier using transistors

Two stage transformer coupled amplifier using transistors





Two stage directly coupled amplifier using transistors

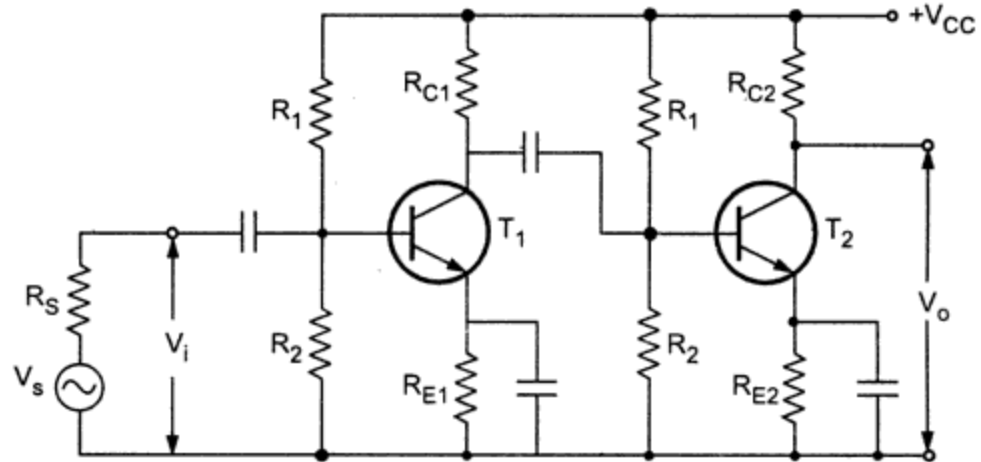
Frequency Response of 2-Stage RC Coupled Amplifier



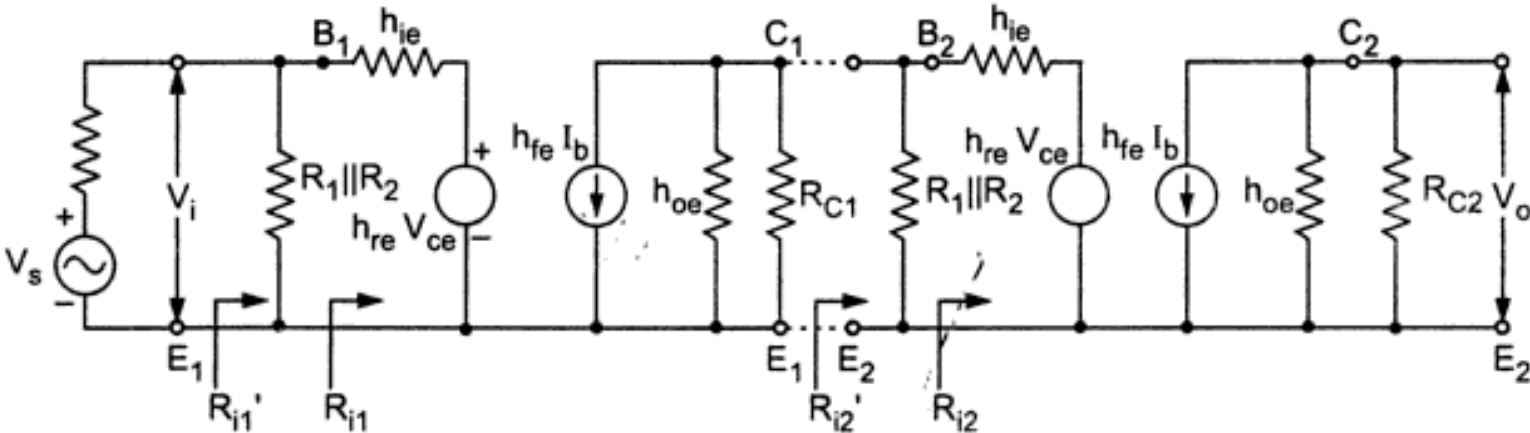
Comparison Between Coupling Method

Parameter	RC Coupled	Transformer Coupled	Direct Coupled
Coupling Components	Resistor and Capacitor	Impedance matching transformer	-
Block DC	Yes	Yes	No
Frequency response	Flat at middle frequencies	Not uniform, high at resonant frequency and low at other frequencies	Flat at middle frequencies and improvement in the low frequency response
Impedance matching	Not achieved	Achieved	Not achieved
DC amplification	No	No	Yes
Weight	Light	Bulky and heavy	
Drift	Not present	Not present	Present
Hum	Not present	Present	Not present
Application	Used in all audio small signal amplifiers. Used in record players, tape recorders, public address systems, radio receivers and television receivers.	Used in amplifier where impedance matching is an important criteria. Used in the output stage of the public address system to match the impedance of loudspeaker. Used in the RF amplifier stage of the receiver as a tuned voltage amplifier.	Used in amplification of slow varying parameters and where DC amplification is required.

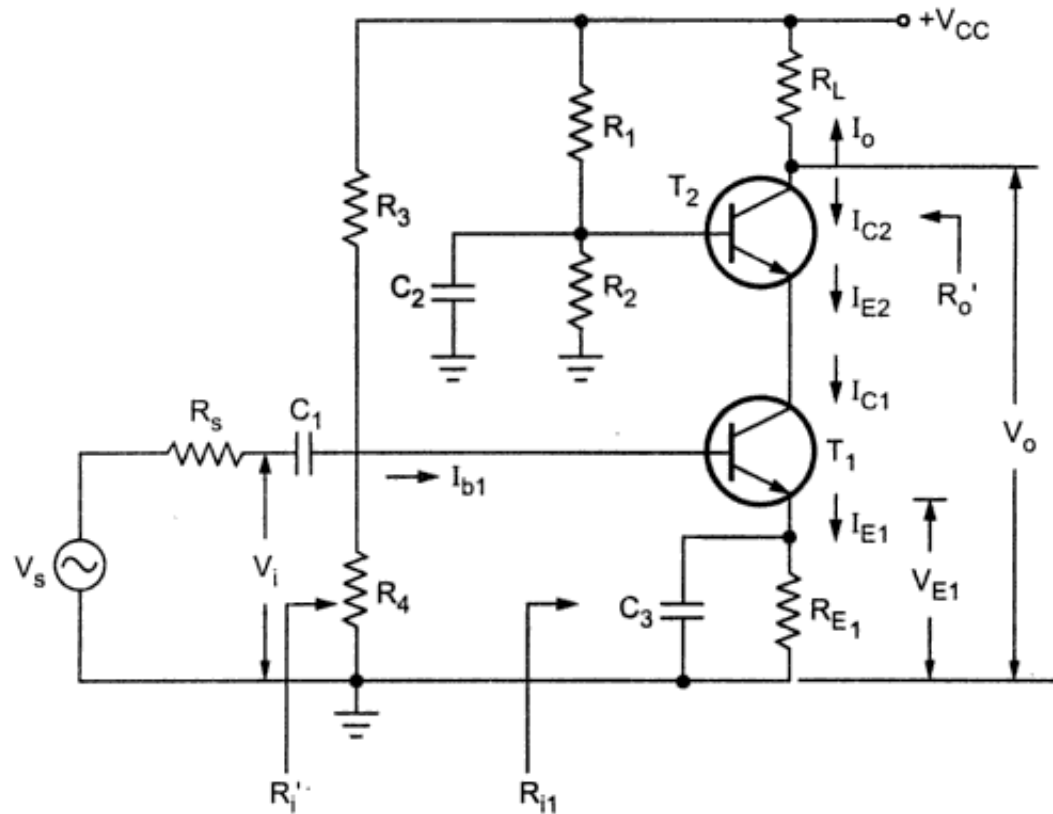
CE-CE Cascade Amplifier



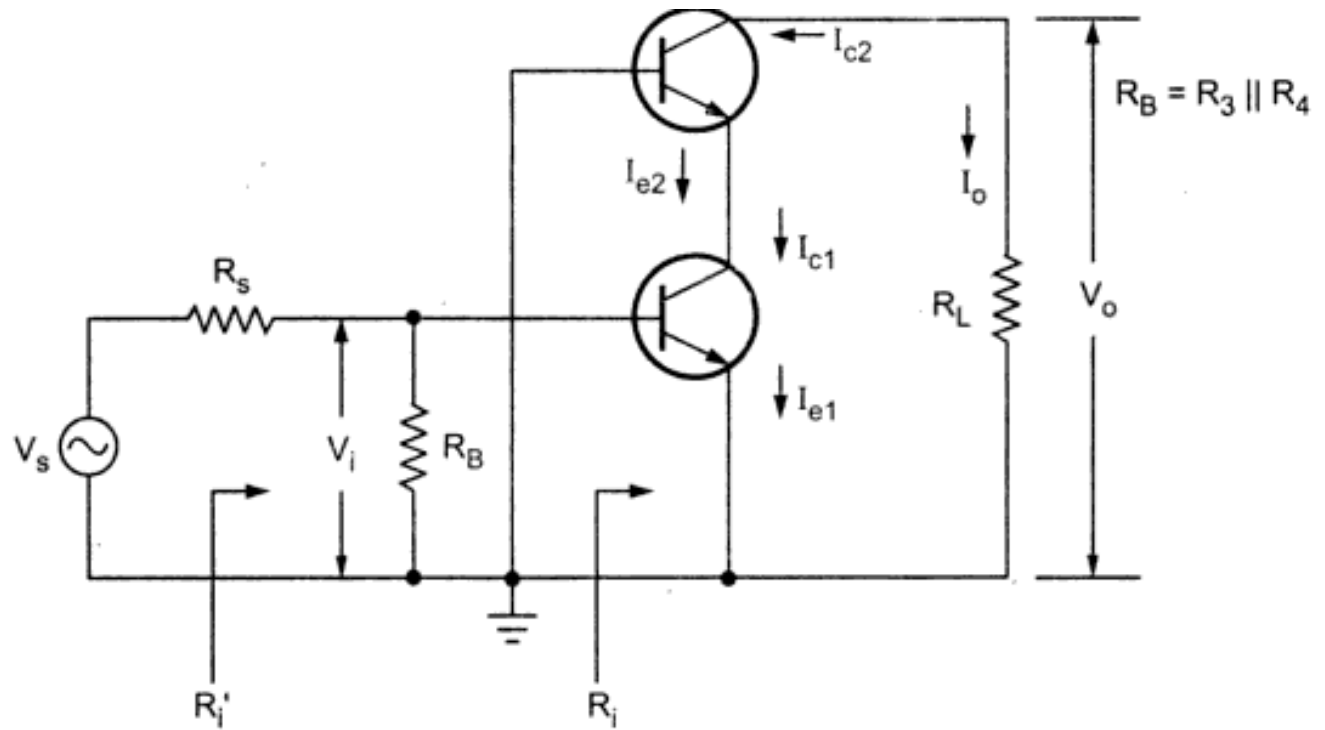
h-parameter equivalent circuit for CE-CE cascade amplifier



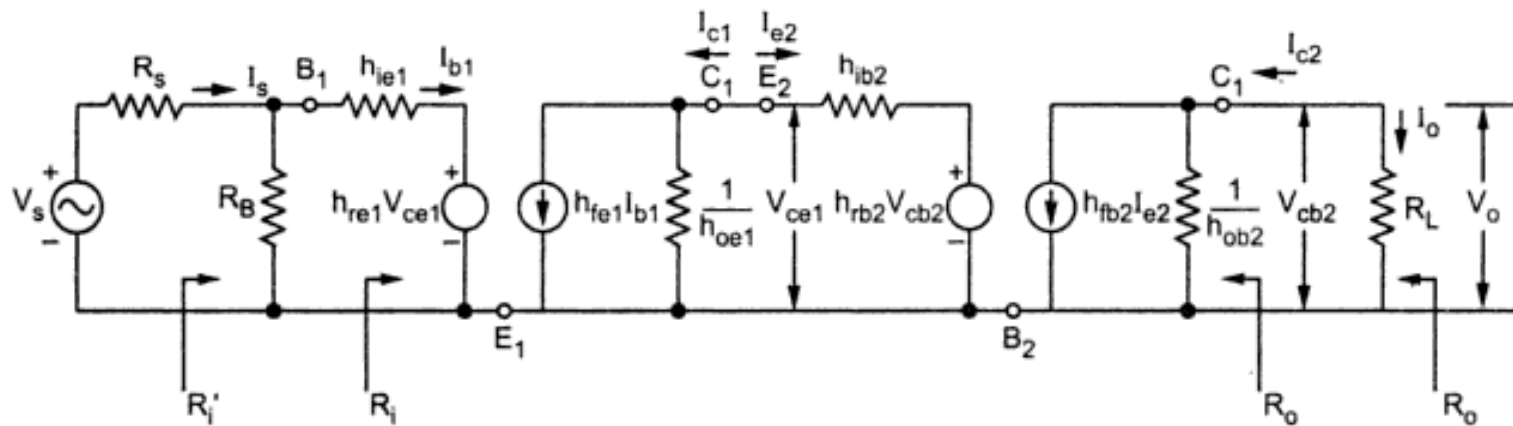
Cascode Amplifier



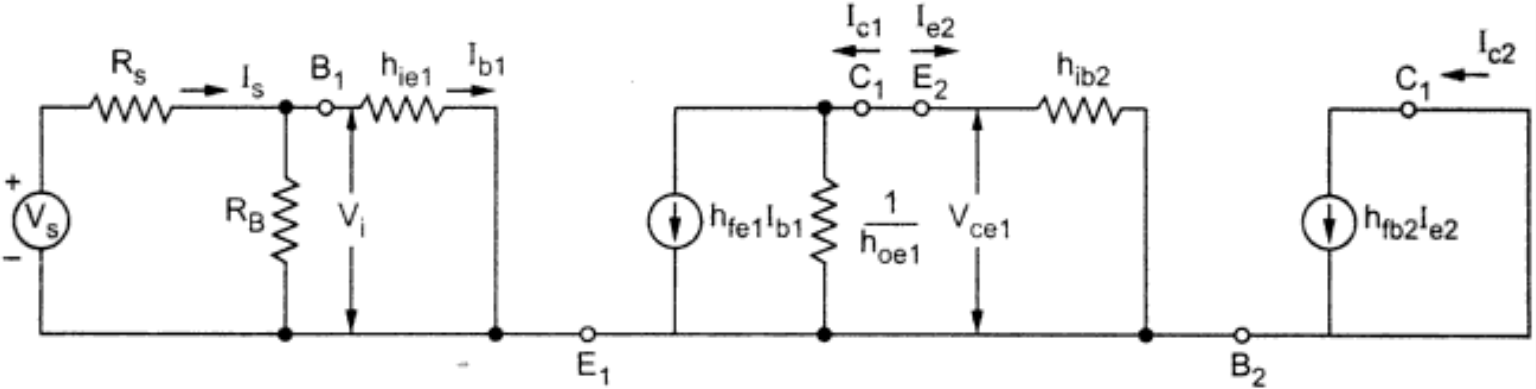
AC equivalent circuit



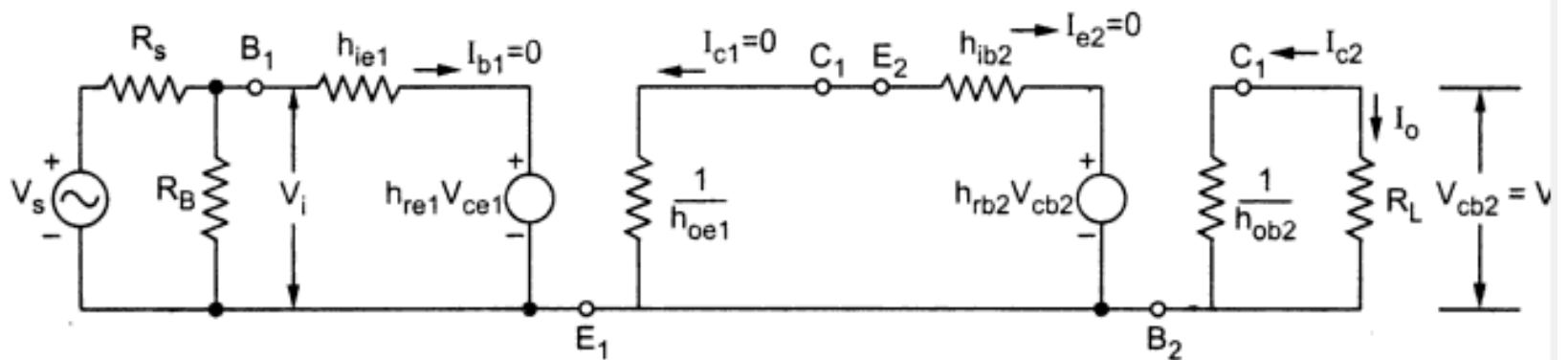
h-parameter equivalent circuit for cascode amplifier



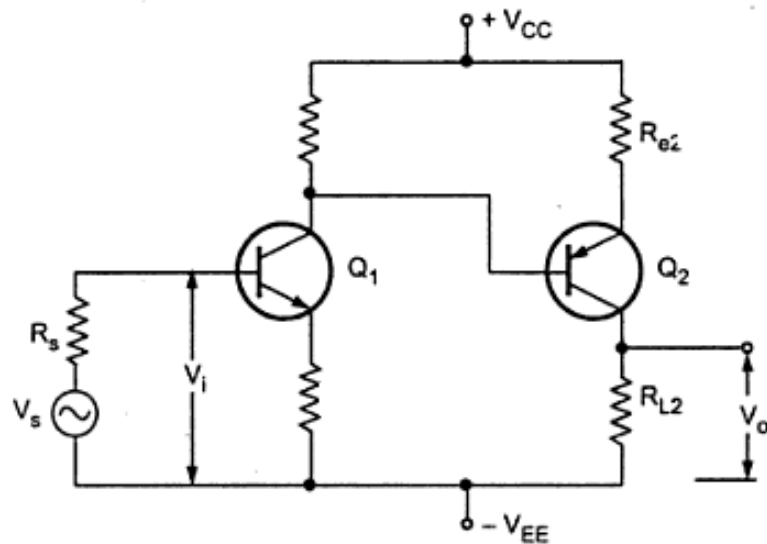
h-parameter equivalent circuit when output shorted



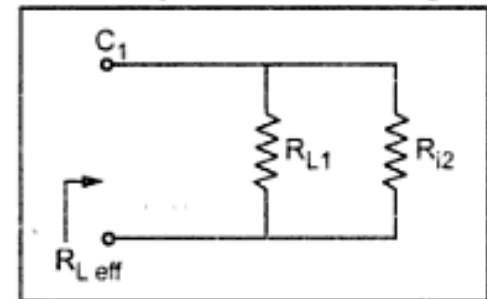
h-parameter equivalent circuit when $I_b = 0$



CE-CC Amplifier

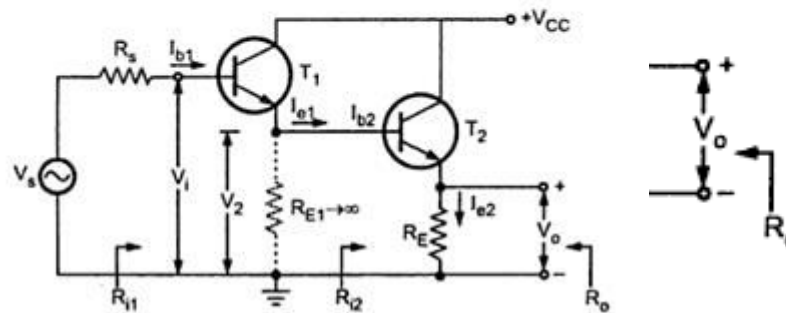


Analysis for first stage

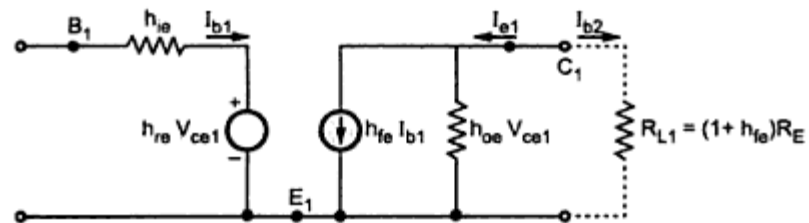
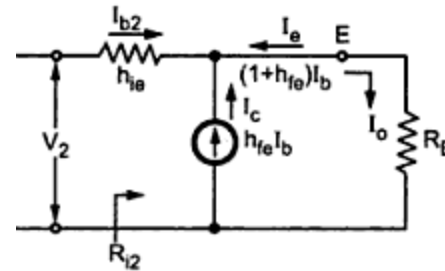
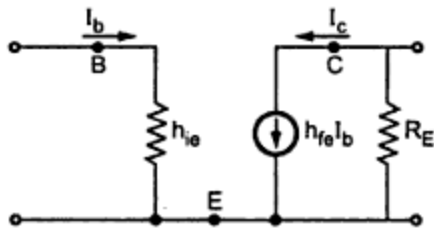


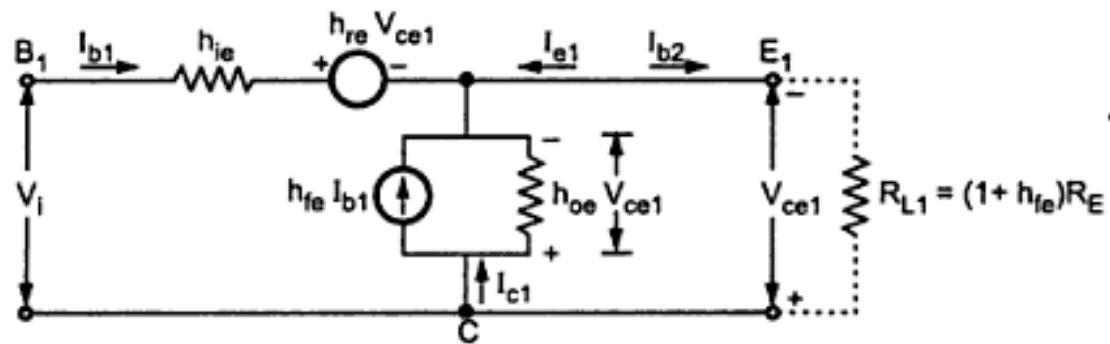
Darlington Transistors

Darlington Transistors $+V_{CC}$



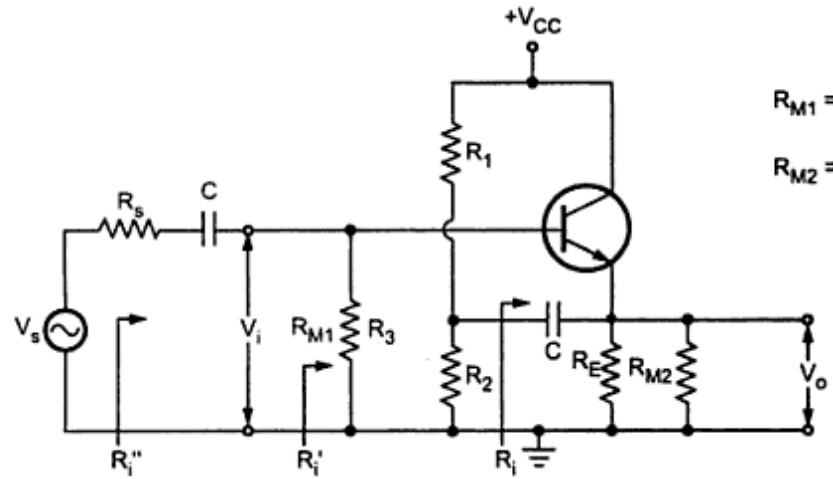
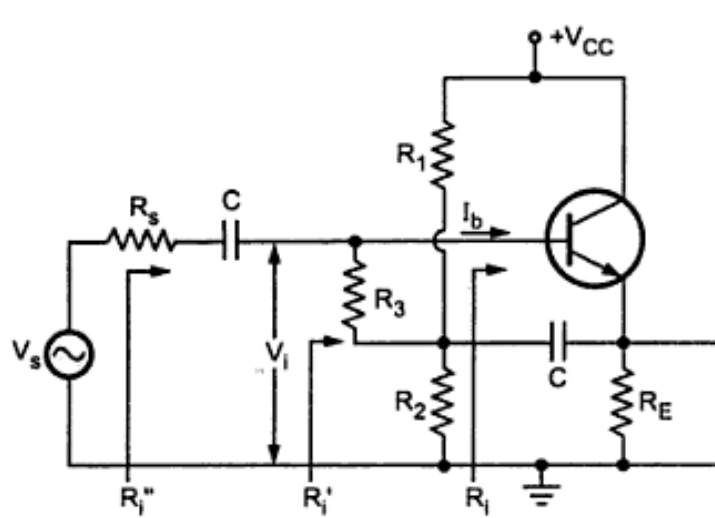
AC Equivalent Circuit :





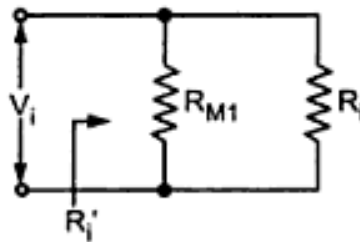
Parameter	Single stage	Darlington
Input Resistance	$R_i = (1 + h_{fe}) R_E = 168.3 \text{ k } \Omega$	$R_i = \frac{(1 + h_{fe})^2 R_E}{1 + h_{oe} (1 + h_{fe}) R_E} \approx 1.65 \text{ M } \Omega$
Current Gain	$A_i = 1 + h_{fe} = 51$	$A_i = \frac{(1 + h_{fe})^2}{1 + h_{oe} (1 + h_{fe}) R_E} \approx 500$

Bootstrap Emitter Follower

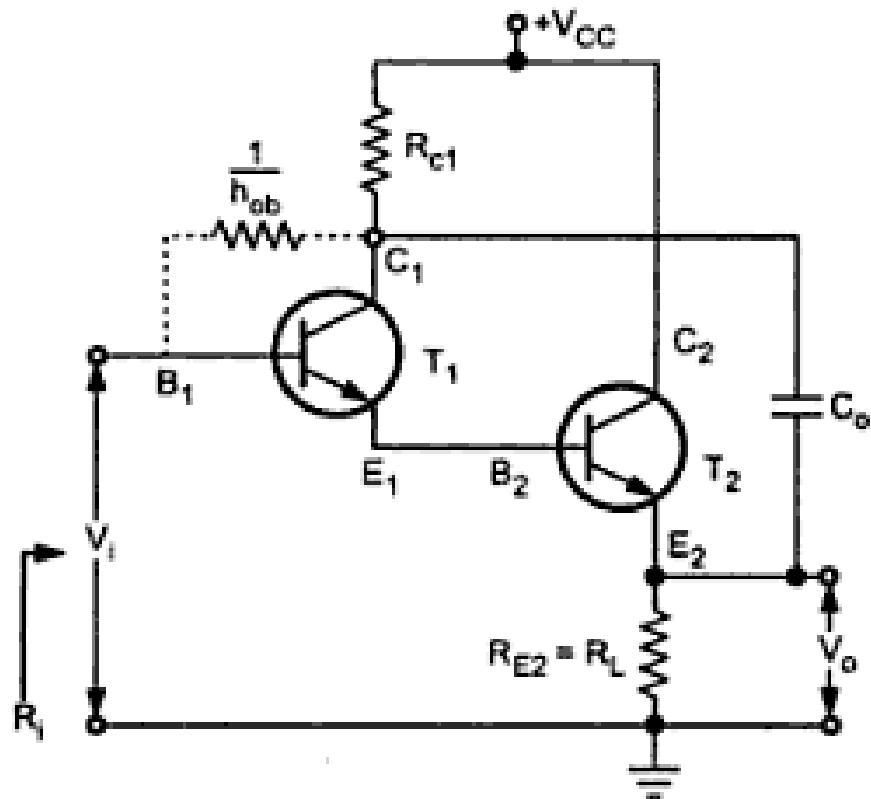


$$R_{M1} = \frac{R_3}{1 - A_v}$$

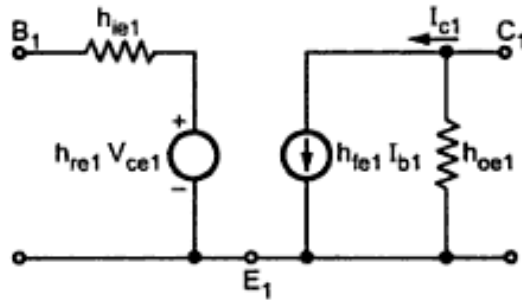
$$R_{M2} = \frac{R_3 A_v}{A_v - 1}$$



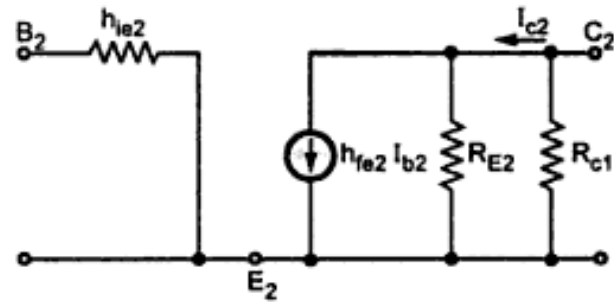
Bootstrapped Darlington circuit



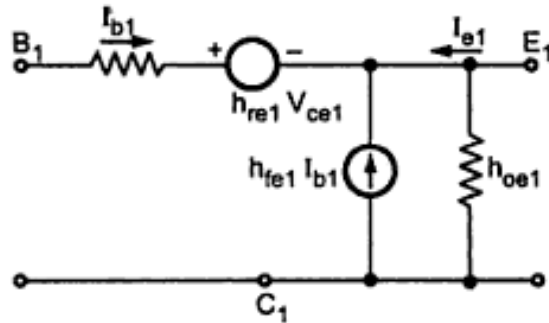
AC Equivalent circuit for bootstrapped Darlington circuit



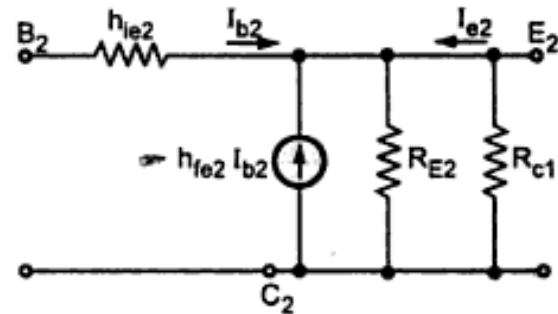
(a)



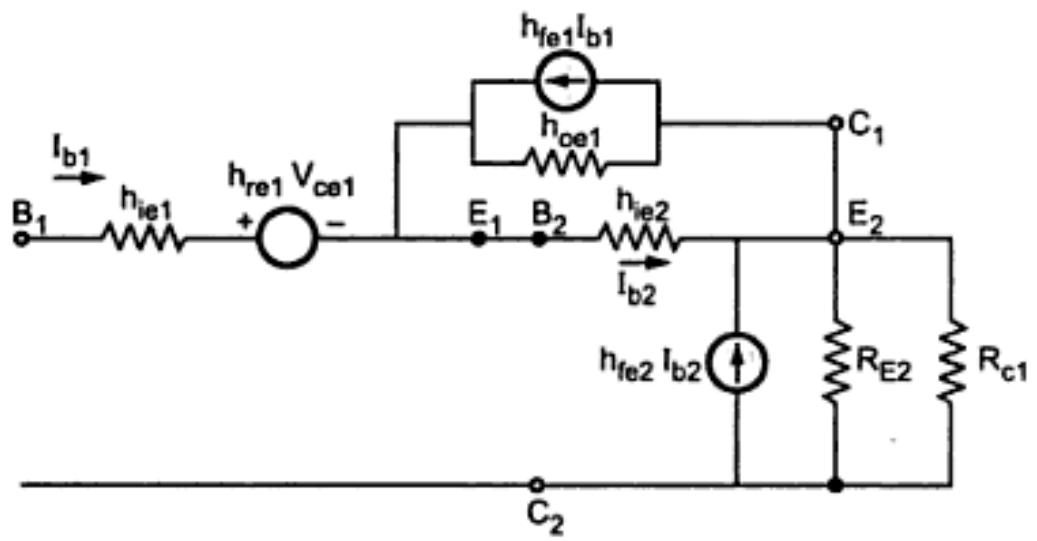
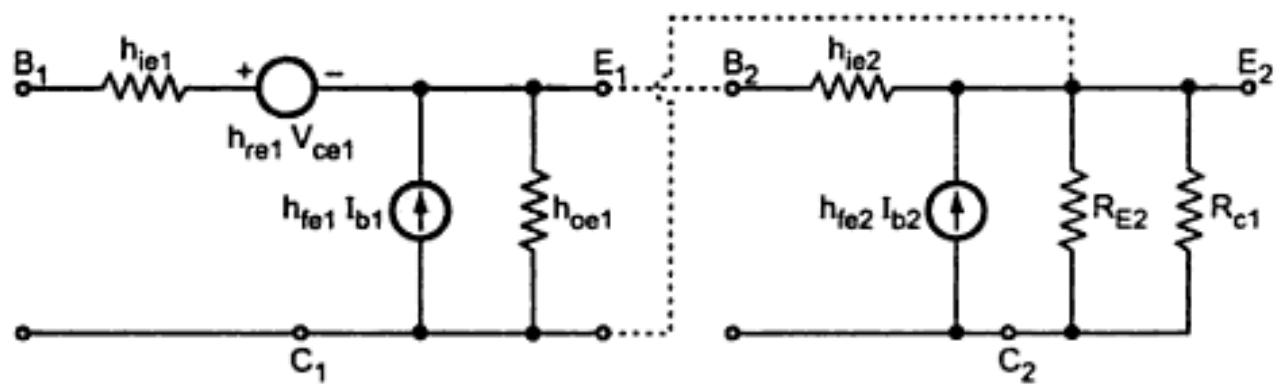
(b)



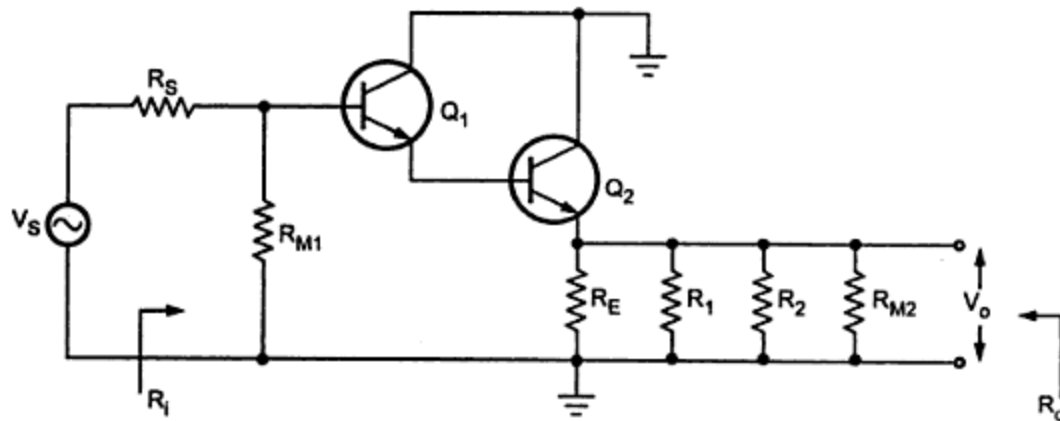
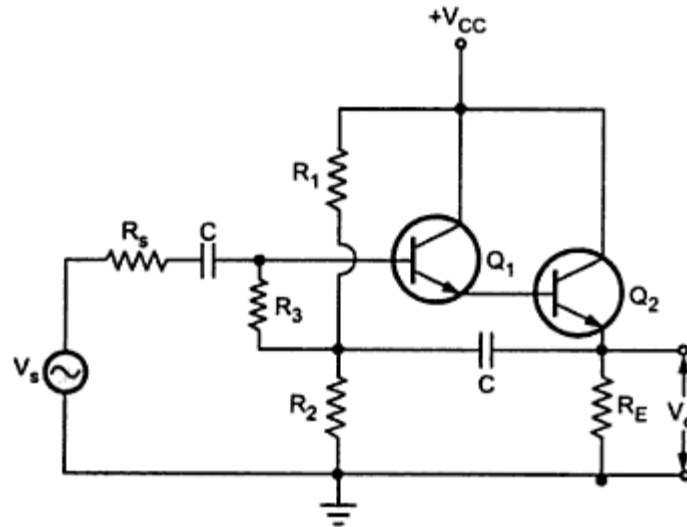
(c)



(d)

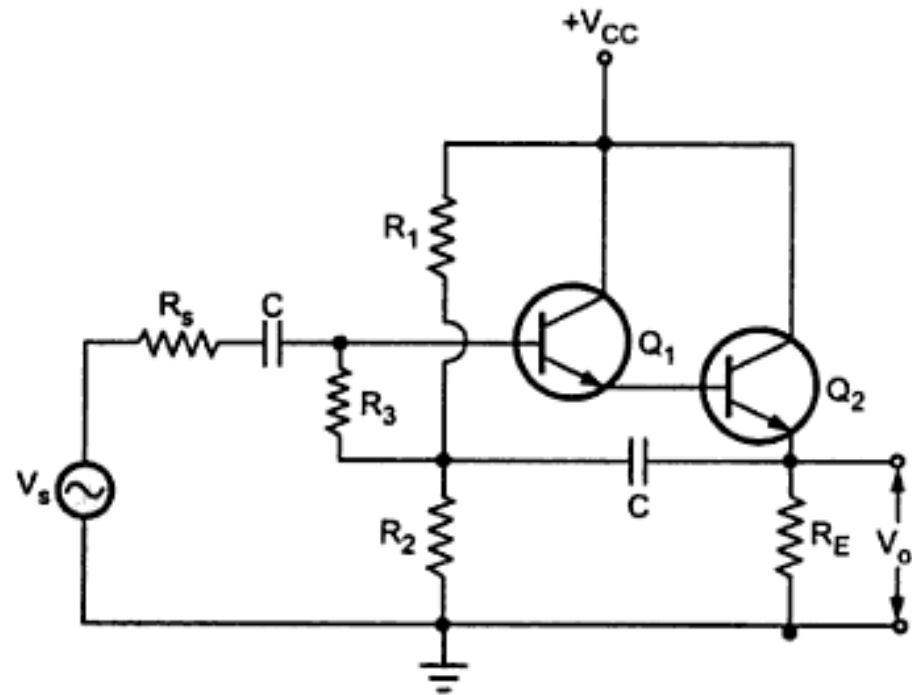


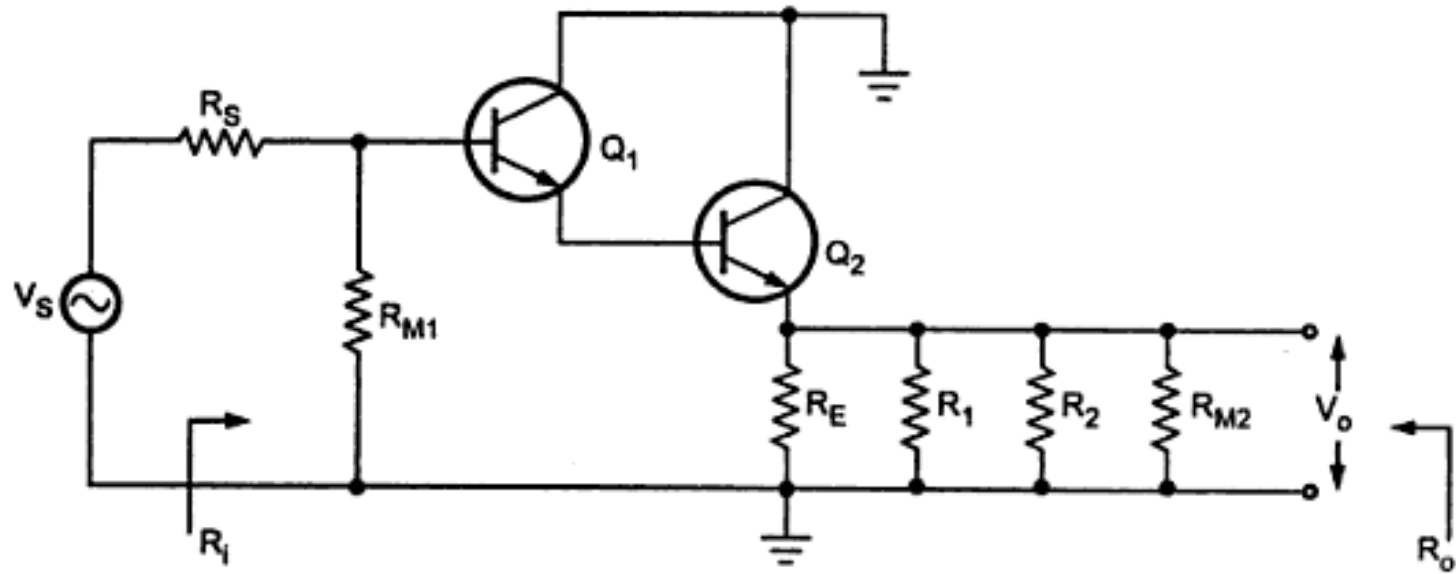
Bootstrapped Darlington Circuit Alternative Approach



AC equivalent circuit

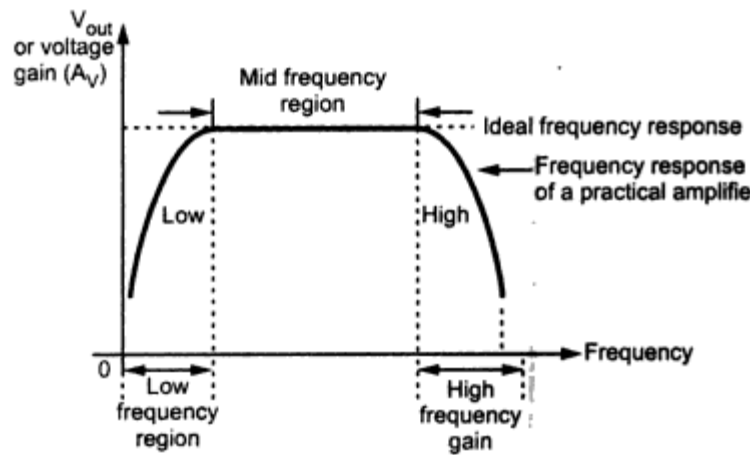
Bootstrapped Darlington Circuit Alternative Approach



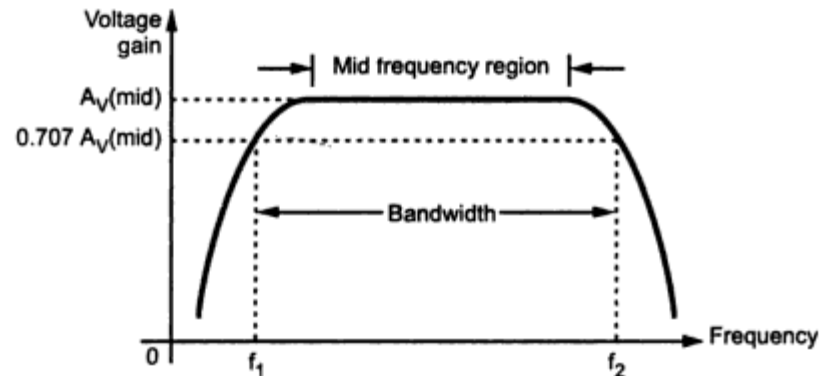


AC equivalent circuit

Frequency Response of an RC Coupled Amplifier



Bandwidth of an Amplifier



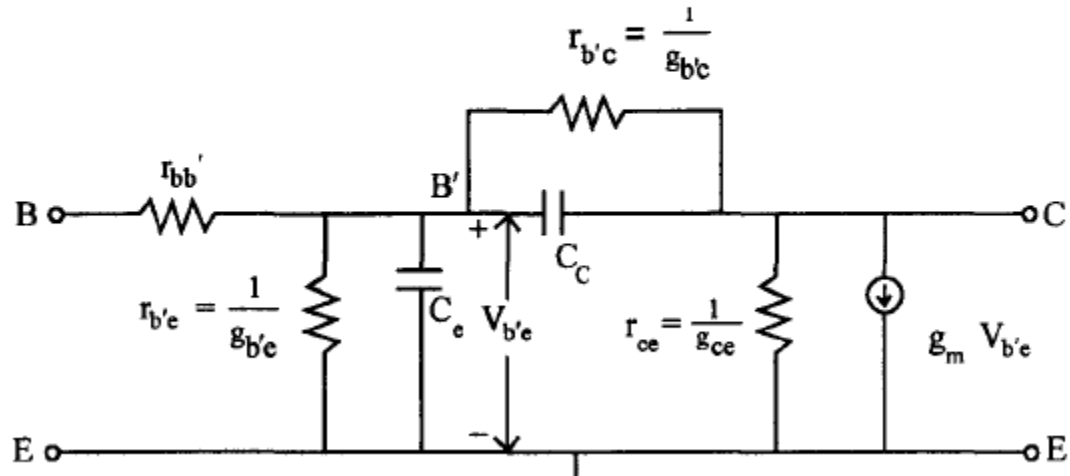
Frequency response, half power frequencies and bandwidth of an RC coupled amplifier

UNIT – II

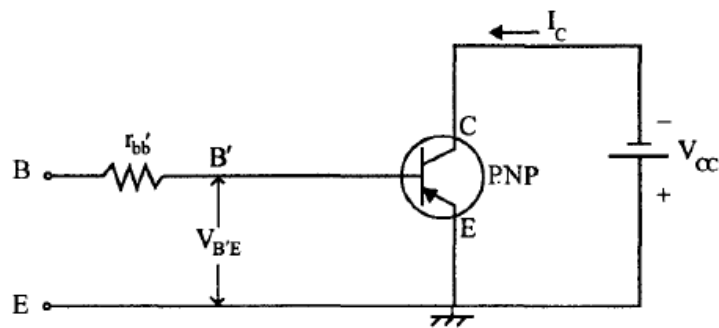
BJT Amplifiers-Frequency Response: Logarithms, Decibels, General frequency considerations, Frequency response of BJT Amplifier, Analysis at low and high frequencies, Effect of coupling and bypass capacitors. The Hybrid pi model –Common Emitter Transistor Model, CE Short Circuit current gain, current gain with resistive load, Single stage CE transistor Amplifier Response, Gain –Bandwidth Product, Emitter follower at high frequencies.

MOS Amplifiers: Basic Concepts, MOS Small signal model, Common source amplifier with resistive load

Hybrid - π C.E BJT Model



PNP transistor amplifier



Hybrid - π Parameter Values

Typical values of the hybrid- π parameter at $I_C = 1.3$ mA are as follows :

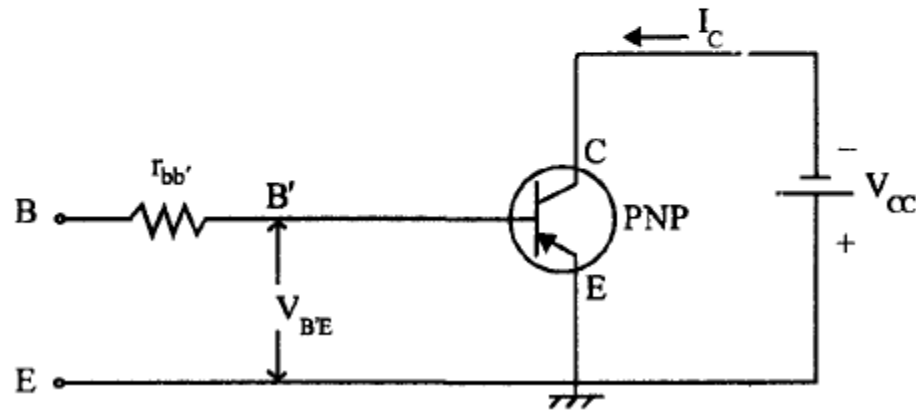
$$\begin{array}{lll} g_m = 50 \text{ mA/V} & r_{bb'} = 100 \ \Omega & r_{b'e} = 1 \text{ k}\Omega \\ r_{ce} = 80 \text{ k}\Omega & C_c = 3 \text{ pf} & C_e = 100 \text{ pf} \\ r_{b'c} = 4 \text{ M}\Omega & & \end{array}$$

These values depend upon :

1. Temperature
2. Value of I_C

Determination of Hybrid- π Conductances

Transconductance or Mutual Conductance (g_m)



$$g_m = \frac{-I_C}{V_T}$$

If

If

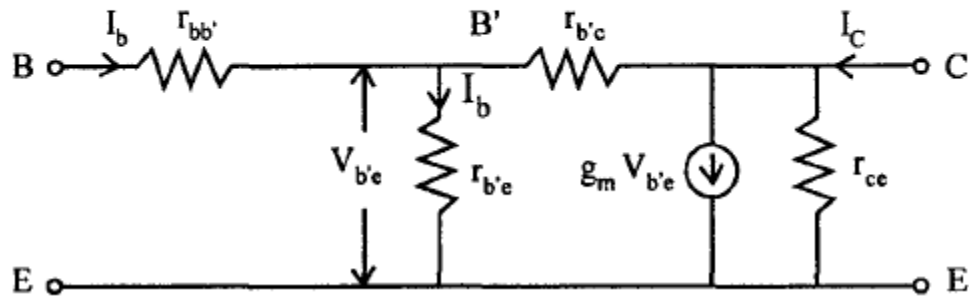
$$g_m = \frac{|I_C|}{26}, I_C \text{ is in mA.}$$

$$I_C = 1.3 \text{ mA}, g_m = 0.05 \text{ A/V}$$

$$I_C = 10 \text{ mA}, g_m = 400 \text{ mA/V}$$

Input Conductance ($g_{b'e}$)

Equivalent circuit at low frequencies



$$g_{b'e} = \frac{|I_C|}{h_{fe} V_T} \quad \text{or} \quad \frac{g_m}{h_{fe}} \quad \quad r_{b'e} = \frac{h_{fe}}{g_m}$$

Feedback Conductance ($g_{b'e}$)

h_{re} = reverse voltage gain, with input open or $I_b = 0$

$$= \frac{V_{b'e}}{V_{ce}} = \frac{\text{Input voltage}}{\text{Output voltage}}$$

$$\boxed{g_{b'e} = h_{re} g_{b'e}} \quad \frac{1}{r_{b'e}} = g_{b'e} = \frac{h_{re}}{r_{b'e}}$$

Base Spreading Resistance ($r_{bb'}$)

$$r_{bb'} = h_{ie} - r_{b'e}$$

Output Conductance (g_{ce})

$$g_{ce} = h_{oe} - h_{fe} \cdot g_{b'c}$$

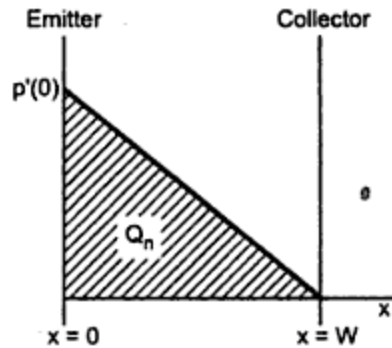
$$g_{ce} = h_{oe} - g_m \cdot h_{re}$$

Relation between hybrid- π and h-parameters

Sr. No	Parameter Relation
1	$g_m = \frac{I_C}{V_T}$
2	$r_{b'e} = \frac{h_{fe}}{g_m}$
3	$r_{bb'} = h_{ie} - r_{b'e}$
4	$r_{b'e} = \frac{r_{b'c}}{h_{re}}$
5	$g_{ce} = \frac{1}{r_{ce}} = h_{oe} - g_{b'e} h_{fe}$

The Hybrid- π Capacitances

$$C_e = C_{De} + C_{Te} \approx C_{De}$$



$$Q_B = \frac{1}{2} P'(0) A W q$$

$$\begin{aligned} I &= -Aq D_B \frac{dp'}{dx} \\ &= Aq D_B \frac{p'(0)}{W} \end{aligned}$$

Combining equations (1) and (2) we get

$$Q_B = \frac{IW^2}{2D_B}$$

$$\begin{aligned} C_{De} &= \frac{dQ_B}{dV} = \frac{W^2}{2D_B} \frac{dI}{dV} \\ &= \frac{W^2}{2D_B} \frac{1}{r_e} \end{aligned}$$

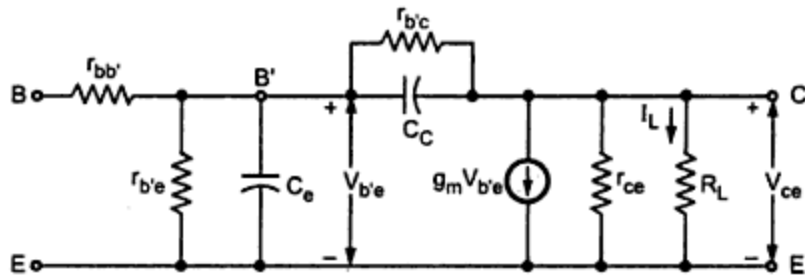
$r_e = dV/dI = V_T/I_E$ is the emitter junction incremental resistance.

$$C_{De} = \frac{W^2 I_E}{2 D_B V_T}$$

$$= g_m \frac{W^2}{2 D_B}$$

$$C_e \approx \frac{g_m}{2 \pi f_T}$$

CE Short-Circuit Current Gain using Hybrid π Model



The hybrid- π circuit for a single transistor with a resistive load R_L

A_i under short circuit condition is,

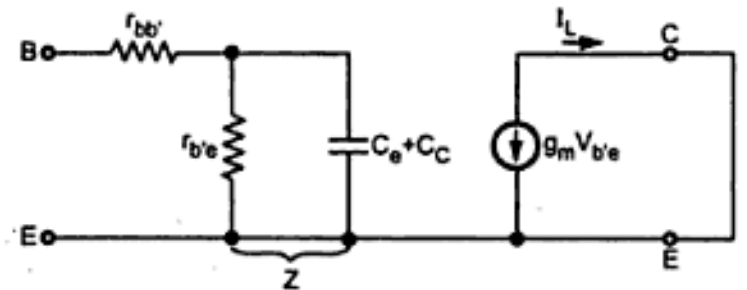
$$A_i = \frac{I_L}{I_i} = \frac{-g_m}{g_{b'e} + j\omega(C_e + C_c)}$$

--

$$A_i = \frac{-1}{\frac{1}{h_{fe}} + j \left(\frac{f}{f_T} \right)}$$

$$= \frac{-h_{fe}}{1 + j h_{fe} \left(\frac{f}{f_T} \right)}$$

$$A_i = \frac{-h_{fe}}{1 + j \left(\frac{f}{f_\beta} \right)}$$



Simplified hybrid- π model for short circuit CE transistor

But, $\frac{f_T}{h_{fe}} = f_\beta$

$\therefore |A_i| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_\beta}\right)^2}}$

Where $f_\beta = \frac{g_{b'e}}{2\pi(C_e + C_c)}$

$$g_{b'e} = \frac{g_m}{h_{fe}}$$

$\therefore f_\beta = \frac{g_m}{h_{fe} 2\pi(C_e + C_c)}$

At $f = f_\beta$, $A_i = \frac{1}{\sqrt{2}} = 0.707$ of h_{fe} .

The frequency range upto f_β is referred to as the Bandwidth of the circuit.

The Parameters f_T

f_T is the frequency at which the short circuit Common Emitter current gain becomes unity.

i.e.,

$$A_i = 1, \quad \text{or} \quad \frac{h_{fe}}{\sqrt{1 + \left(\frac{f_T}{f_\beta}\right)^2}} = 1$$

Let at

$$f = f_T, \quad A_i = 1$$

or

$$h_{fe} = \sqrt{1 + \left(\frac{f_T}{f_\beta}\right)^2}$$

$$(h_{fe})^2 = 1 + \left(\frac{f_T}{f_\beta}\right)^2 \cong \left(\frac{f_T}{f_\beta}\right)^2$$

\therefore

$$h_{fe} \cong \frac{f_T}{f_\beta} \quad \text{when } A_i = 1$$

\therefore

$$\boxed{f_T \cong h_{fe} \cdot f_\beta}$$

But

$$f_\beta = \frac{g_m}{h_{fe} \{C_e + C_c\}}$$

\therefore

$$f_T = f_\beta \cdot h_{fe} = \frac{g_m}{2\pi(C_e + C_c)}$$

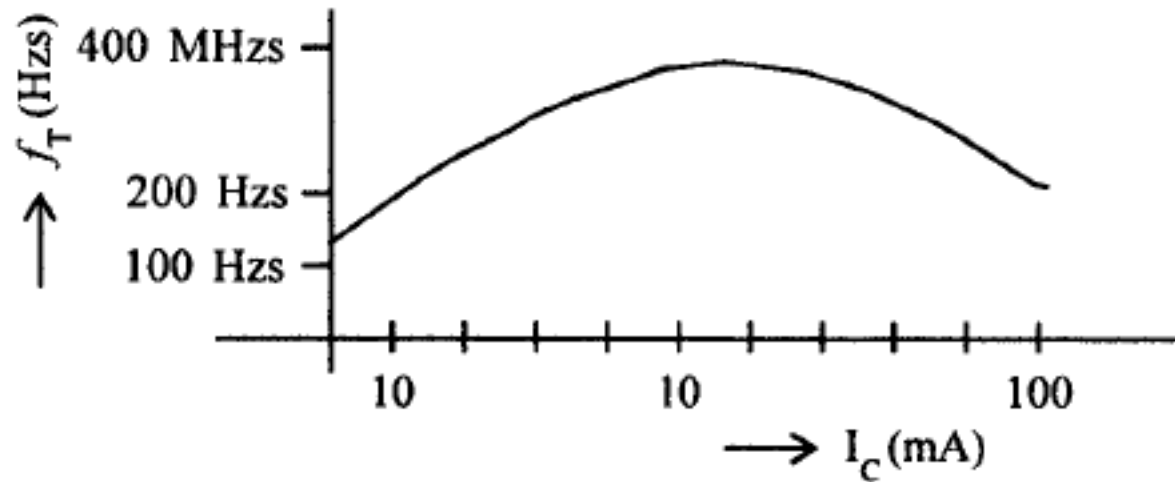
But

$$C_e \gg C_c$$

\therefore

$$\boxed{f_T \cong \frac{g_m}{2\pi C_e}}$$

Variation of f_T with frequency



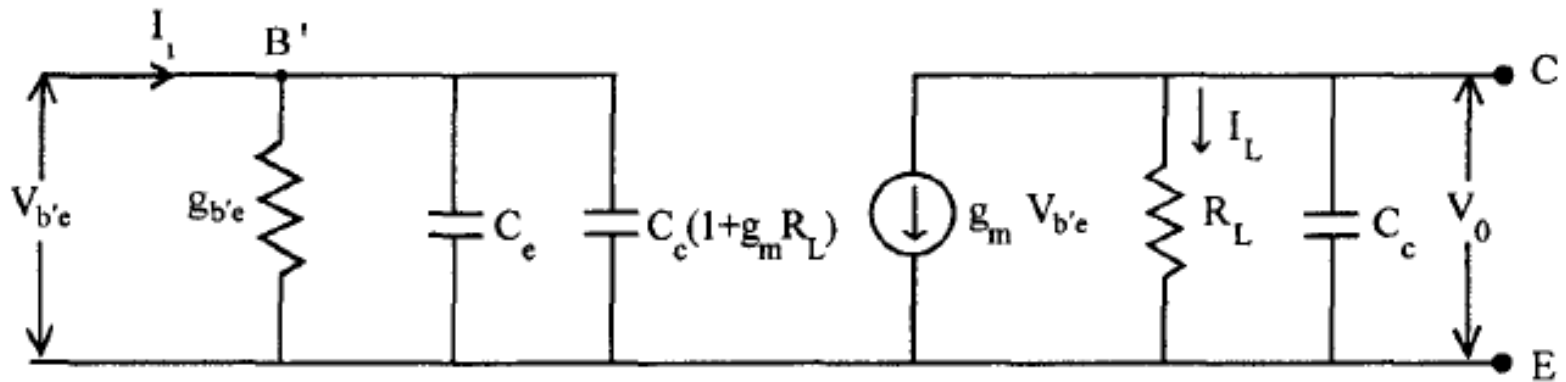
$$f_T = h_{fe} \cdot f_\beta$$

Current Gain with Resistance Load :

$$f_T = f_\beta \cdot h_{fe} = \frac{g_m}{2\pi(C_e + C_c)}$$

$$f_H = \frac{1}{2\pi C_S (R_C \parallel R_L)}$$

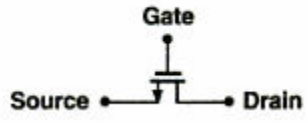
Simplified equivalent circuit



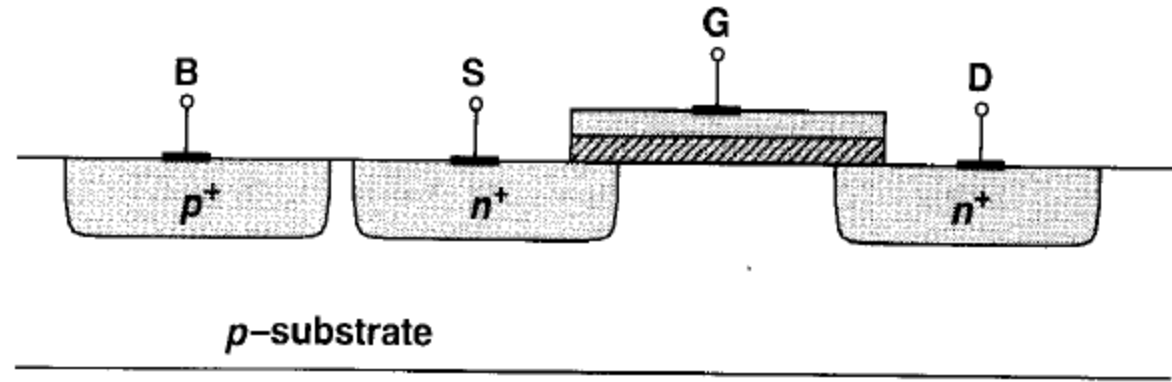
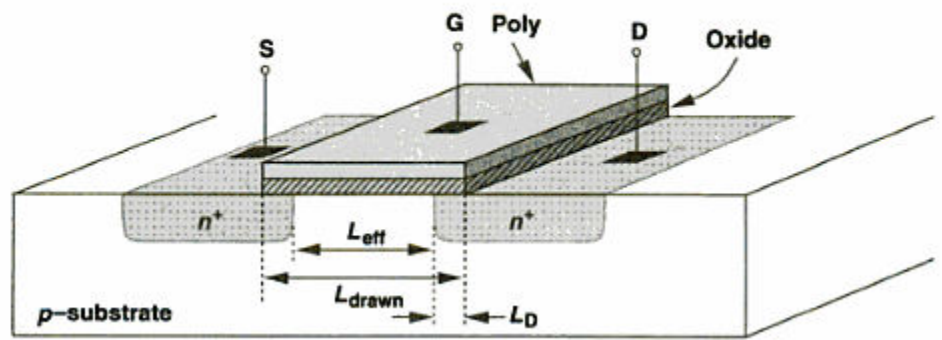
The 3db frequency $f_M = \frac{1}{2\pi r_{b'e} C} = \frac{g_{b'e}}{2\pi C}$

where $C = C_e + C_c (1 + g_m R_L)$

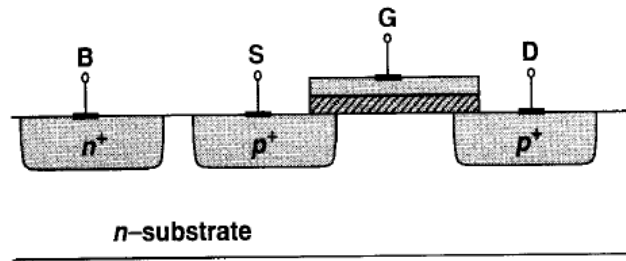
Simple view of a MOS



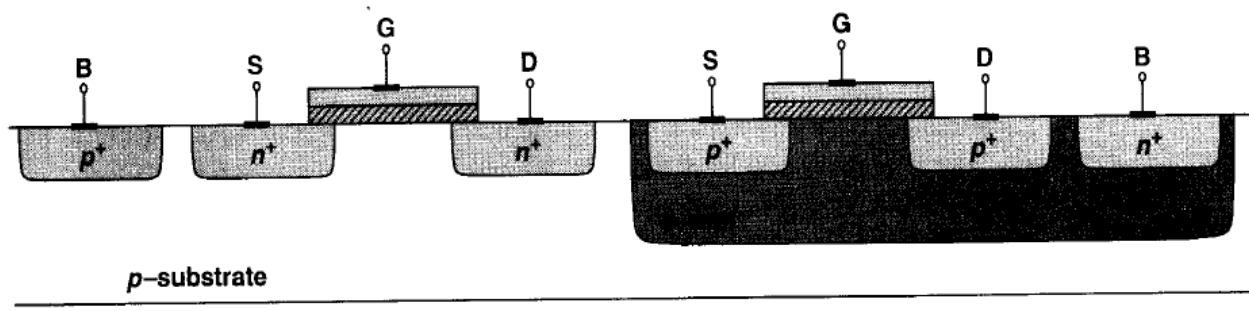
MOSFET Structure



Substrate connection.



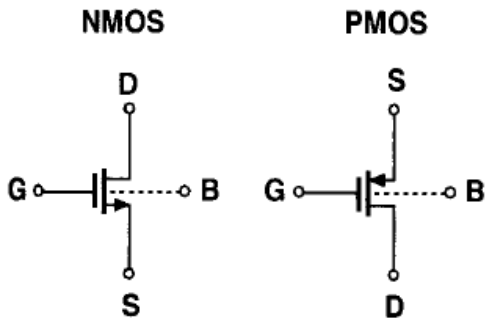
(a)



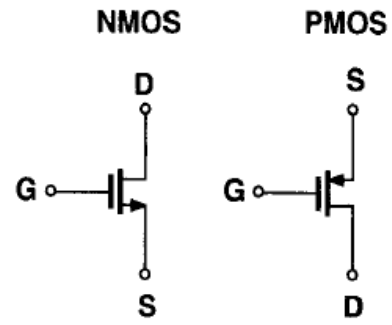
(b)

(a) Simple PMOS device, (b) PMOS inside an *n*-well.

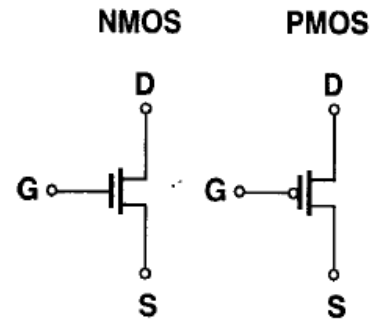
MOS symbols.



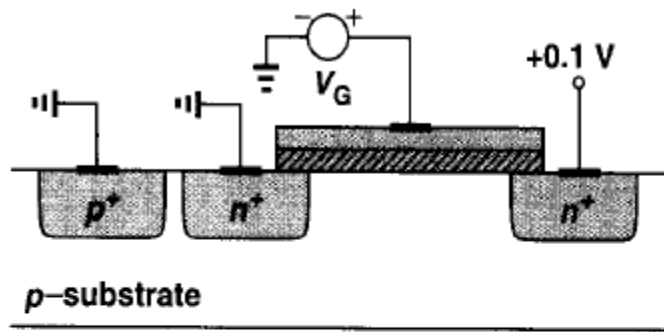
(a)



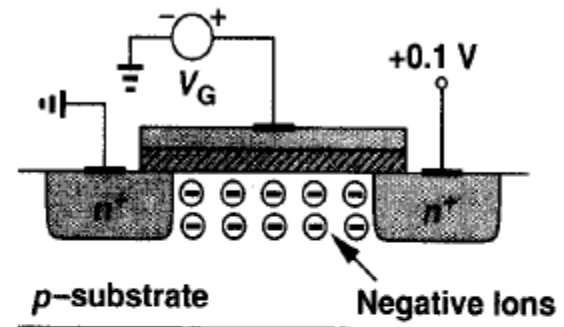
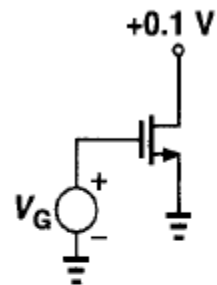
(b)



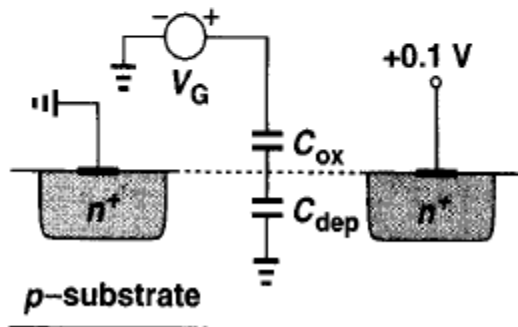
(c)



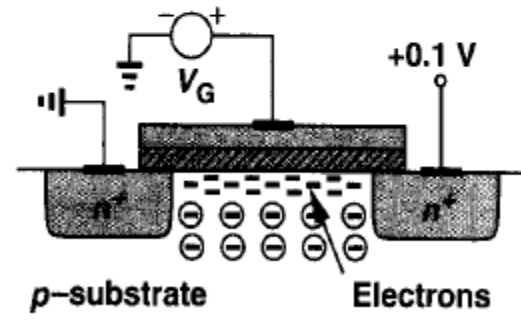
(a)



(b)



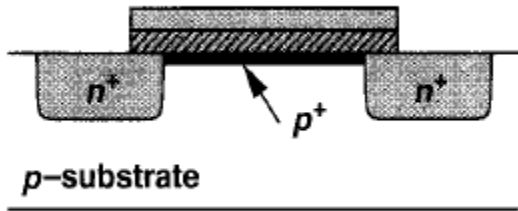
(c)



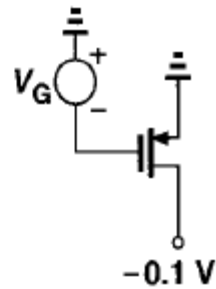
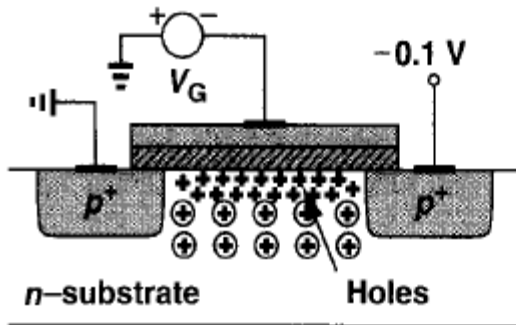
(d)

(a) A MOSFET driven by a gate voltage, (b) formation of depletion region, (c) onset of inversion, (d) formation of inversion layer.

$$V_{TH} = \Phi_{MS} + 2\Phi_F + \frac{Q_{dep}}{C_{ox}},$$



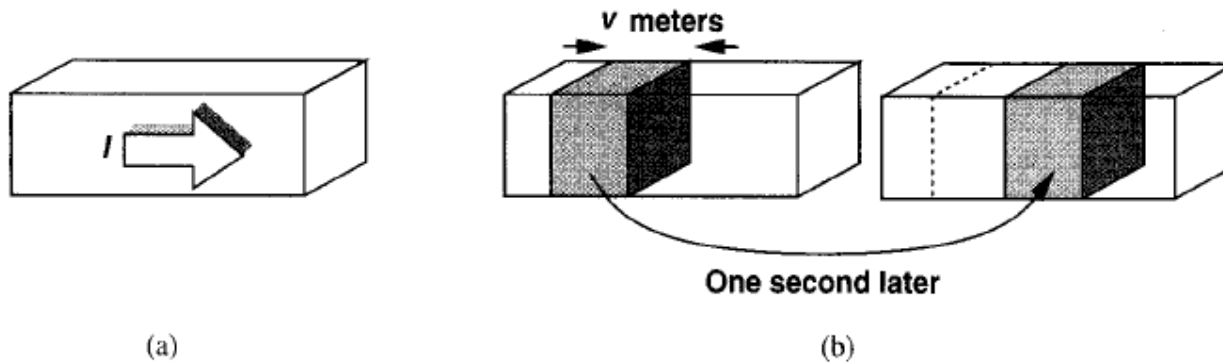
Implantation of p^+ dopants to alter the threshold.



Formation of inversion layer in a PFET.

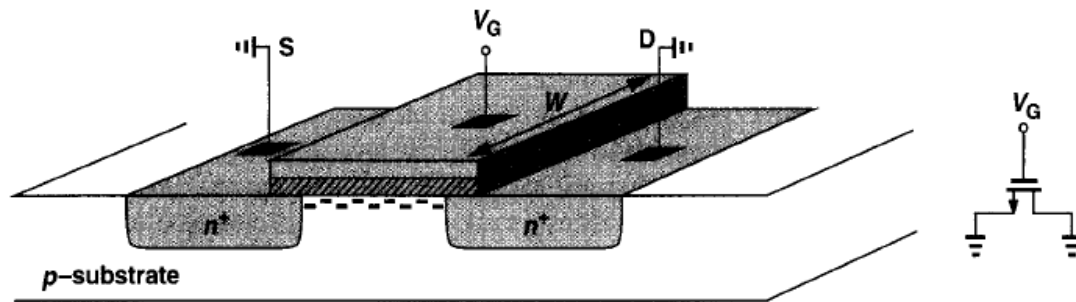
Derivation of I/V Characteristics

$$I = Q_d \cdot v.$$

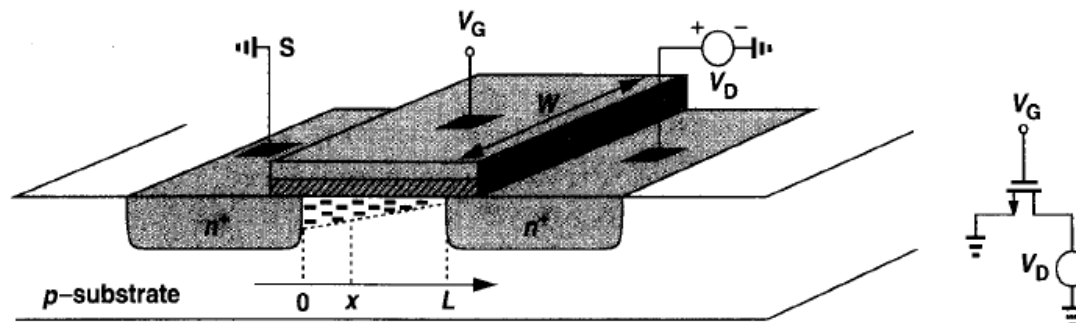


(a) A semiconductor bar carrying a current I , (b) snapshots of the carriers one second apart.

Channel charge with (a) equal source and drain voltages, (b) unequal source and drain voltages.

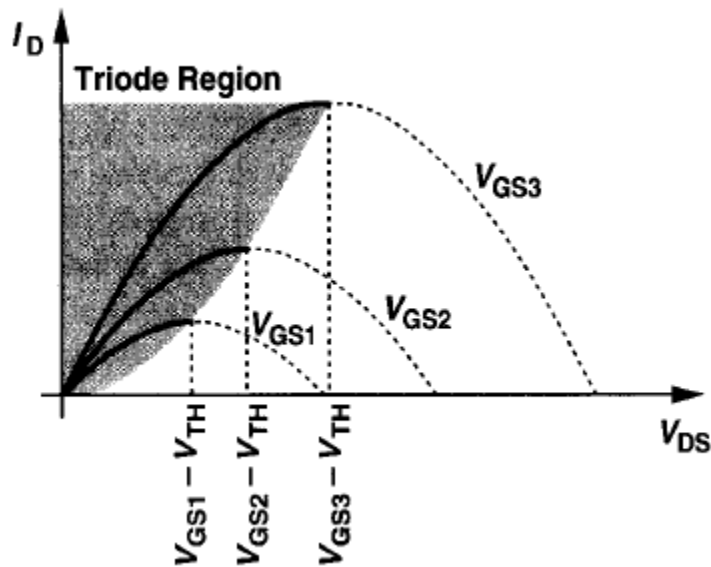


(a)



(b)

$$I_D = WC_{ox}[V_{GS} - V(x) - V_{TH}]\mu_n \frac{dV(x)}{dx},$$

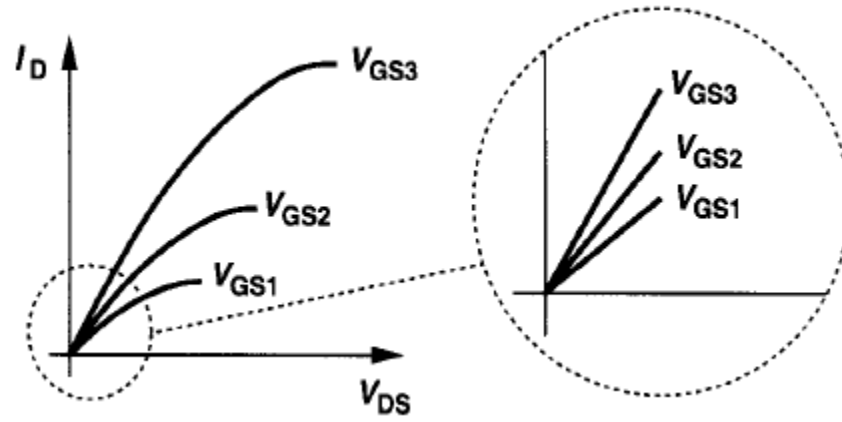


Drain current versus drain-source voltage in the triode region.

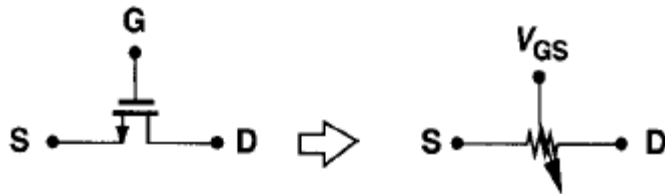
$$I_{D,max} = \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2.$$

$$I_D \approx \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH}) V_{DS},$$

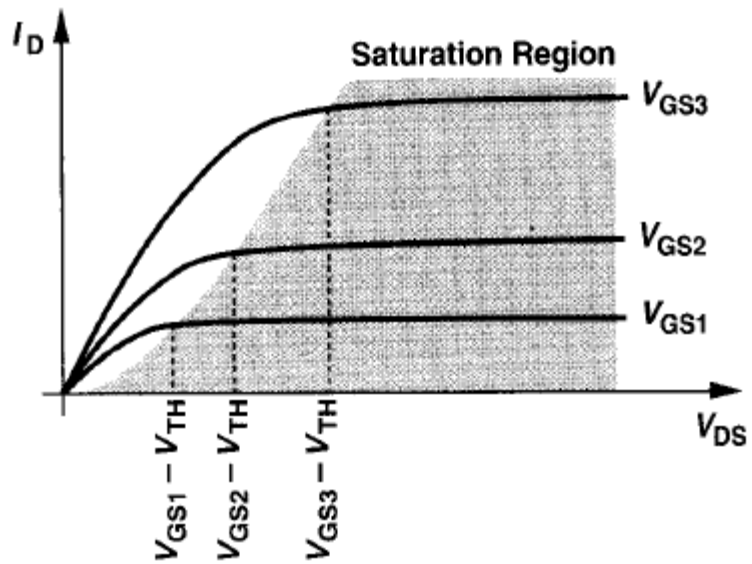
$$R_{on} = \frac{1}{\mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})}.$$



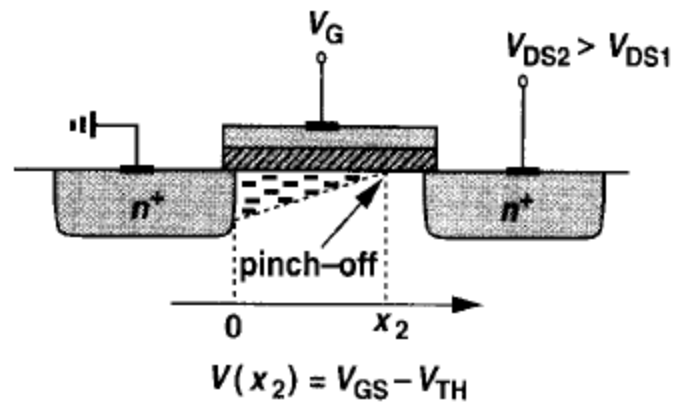
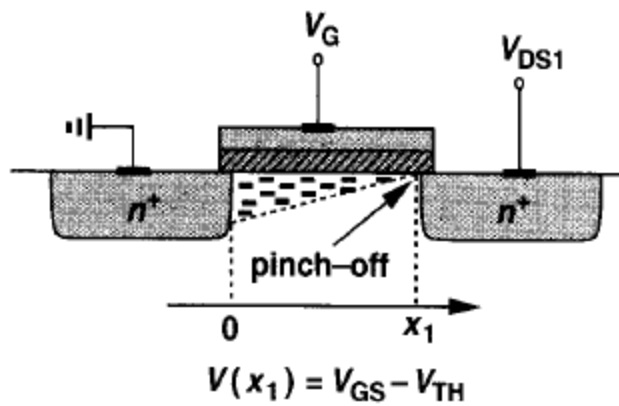
Linear operation in deep triode region.



With the condition $V_{DS} \ll 2(V_{GS} - V_{TH})$, we say the device operates in deep triode region.



Saturation of drain current.

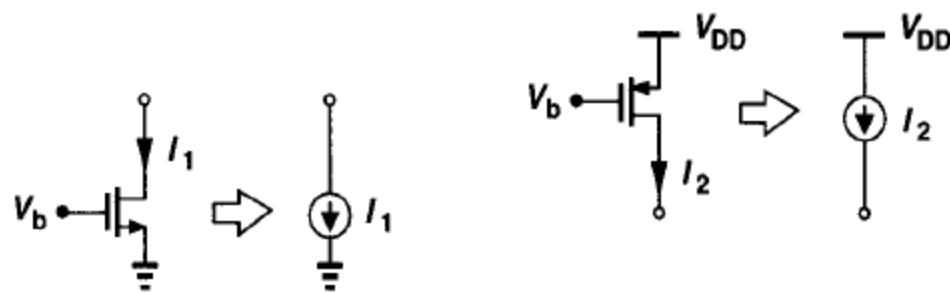


Pinch-off behavior.

$$I_D = \frac{1}{2} \mu_n C_{ox} \frac{W}{L'} (V_{GS} - V_{TH})^2,$$

$$I_D = -\mu_p C_{ox} \frac{W}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$I_D = -\frac{1}{2} \mu_p C_{ox} \frac{W}{L'} (V_{GS} - V_{TH})^2.$$

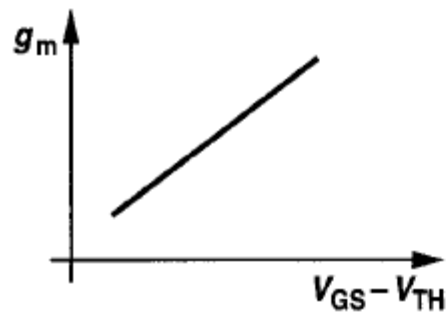


Saturated MOSFETs operating as current sources.

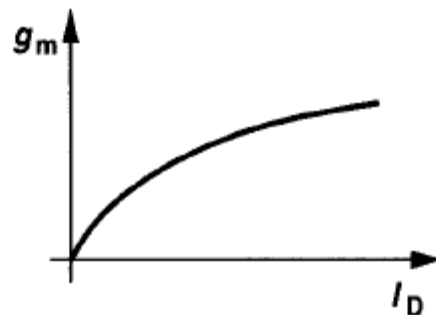
$$g_m = \left. \frac{\partial I_D}{\partial V_{GS}} \right|_{V_{DS, \text{const.}}} \\ = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH}).$$

$$g_m = \sqrt{2\mu_n C_{ox} \frac{W}{L} I_D} \\ = \frac{2I_D}{V_{GS} - V_{TH}}.$$

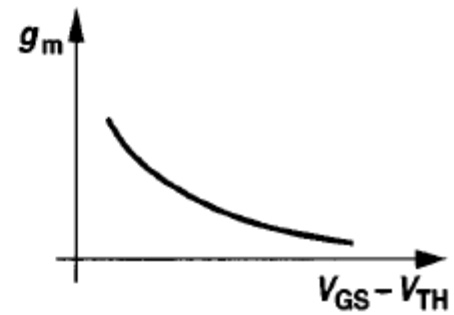
MOS transconductance as a function of overdrive and drain current.



W/L Constant

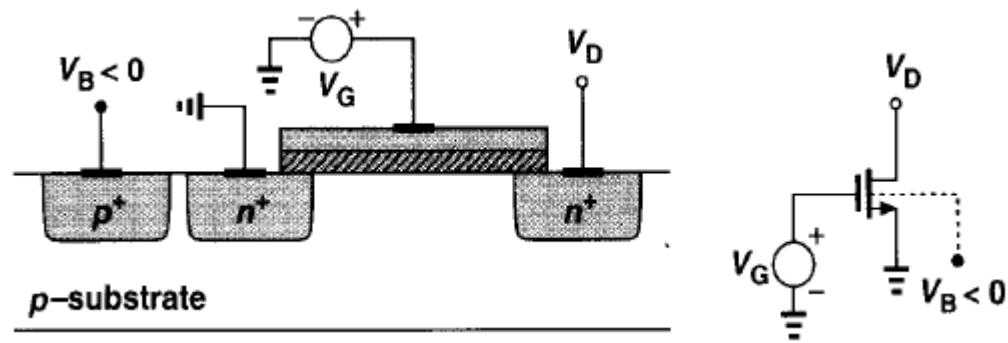


W/L Constant

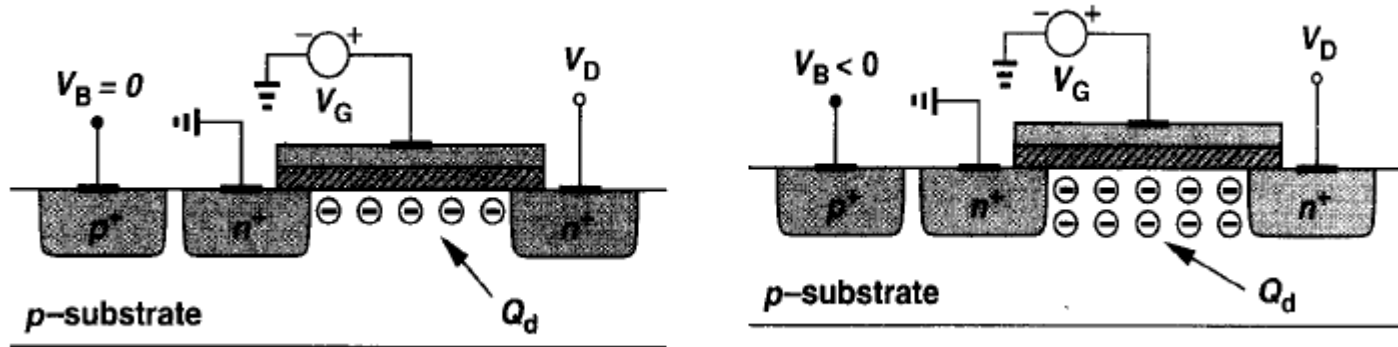


I_D Constant

NMOS device with negative bulk voltage.

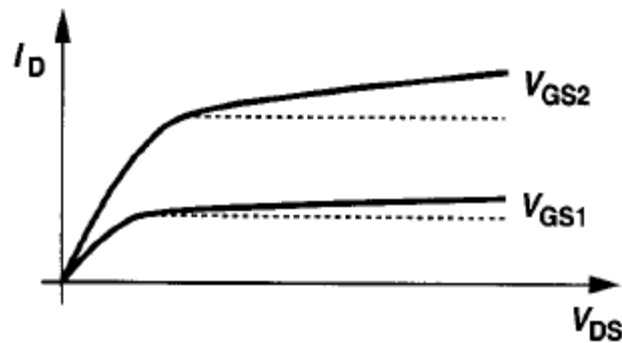


Variation of depletion region charge with bulk voltage.



Channel-Length Modulation

$$I_D \approx \frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS}),$$



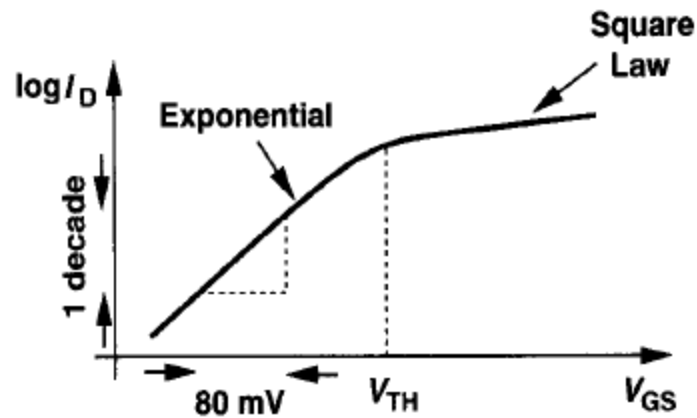
Finite saturation region slope resulting from channel-length modulation.

$$g_m = \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})(1 + \lambda V_{DS}).$$

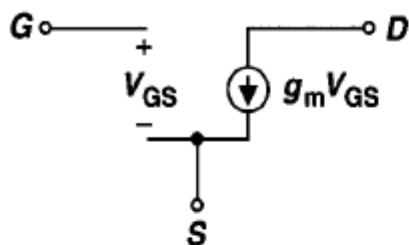
$$= \sqrt{\frac{2\mu_n C_{ox} (W/L) I_D}{1 + \lambda V_{DS}}},$$

Subthreshold Conduction

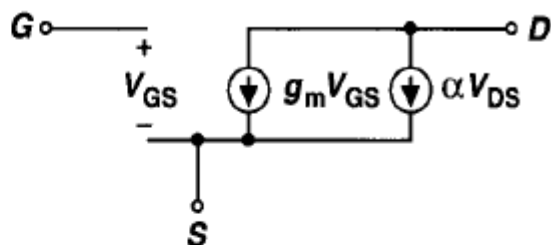
$$I_D = I_0 \exp \frac{V_{GS}}{\zeta V_T},$$



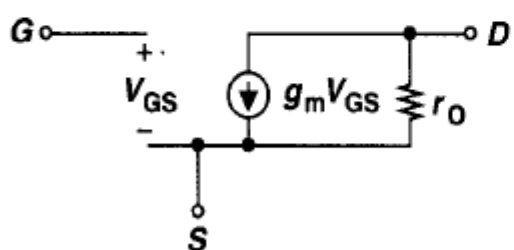
MOS subthreshold char-



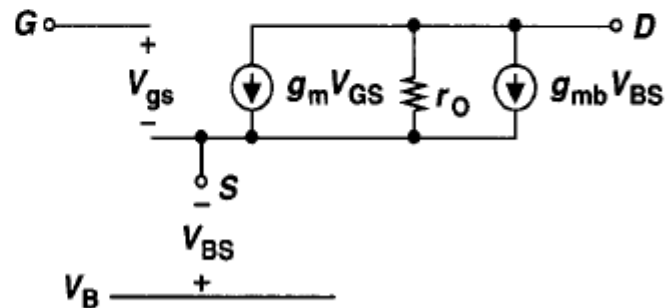
(a)



(b)



(c)



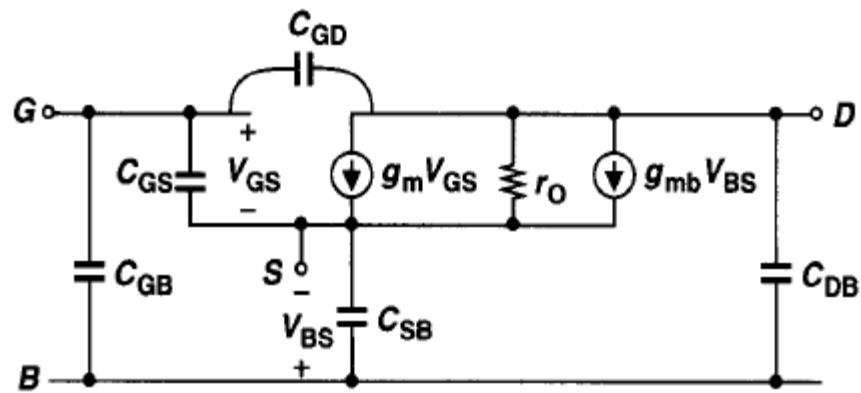
(d)

(a) Basic MOS small-signal model, (b) channel-length modulation represented by a dependent current source, (c) channel-length modulation represented by a resistor, (d) body effect represented by a dependent current source.

$$\begin{aligned}r_o &= \frac{\partial V_{DS}}{\partial I_D} \\&= \frac{1}{\partial I_D / \partial V_{DS}} \\&= \frac{1}{\frac{1}{2} \mu_n C_{ox} \frac{W}{L} (V_{GS} - V_{TH})^2 \cdot \lambda} \\&\approx \frac{1}{\lambda I_D}.\end{aligned}$$

$$\begin{aligned}g_{mb} &= g_m \frac{\gamma}{2\sqrt{2\Phi_F + V_{SB}}} \\&= \eta g_m,\end{aligned}$$

Complete MOS small-signal model.



UNIT – III

Feedback Amplifiers: Concepts of feedback, Classification of feedback amplifiers, General characteristics of negative feedback amplifiers, Effect of feedback on amplifier characteristics, Voltage Series, Voltage Shunt, Current Series and Current Shunt Feedback Configurations, Illustrative examples.

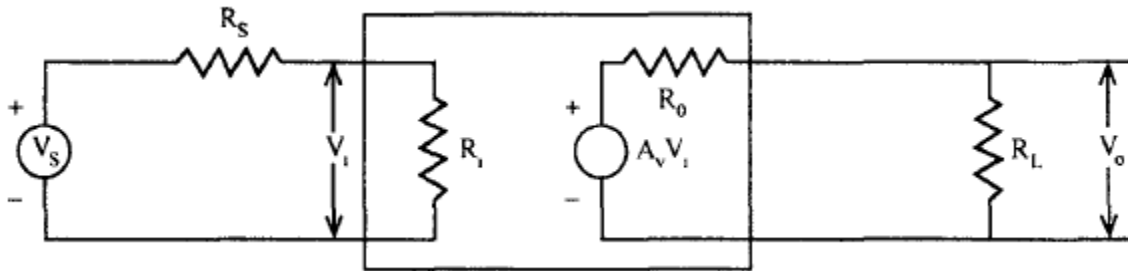
Oscillators: Classification of oscillators, Condition for oscillations, RC Phase shift Oscillators, Generalized analysis of LC Oscillators-Hartley and Colpitts Oscillators, Wien Bridge and crystal Oscillators, Stability of Oscillators

CLASSIFICATION OF AMPLIFIERS

- Amplifiers can be classified broadly as,
 - 1. Voltage amplifiers.
 - 2. Current amplifiers.
 - 3. Transconductance amplifiers.
 - 4. Transresistance amplifiers.

VOLTAGE AMPLIFIER

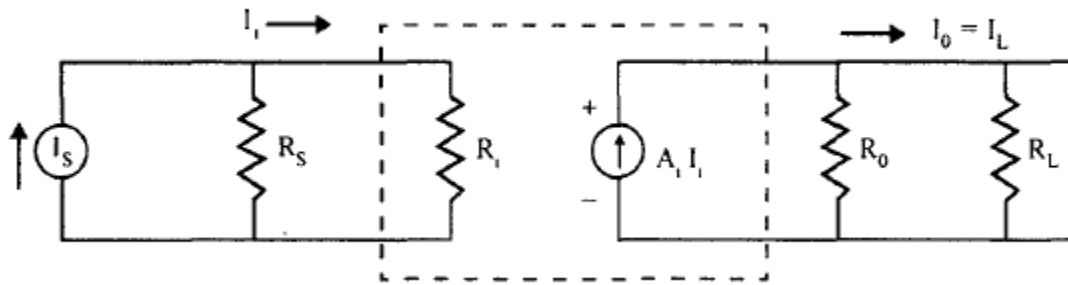
This circuit is a 2-port network and it represents an amplifier (see in Fig 7.1). Suppose $R_i \gg R_s$, drop across R_s is very small.



Equivalent circuit of voltage amplifiers.

CURRENT AMPLIFIER

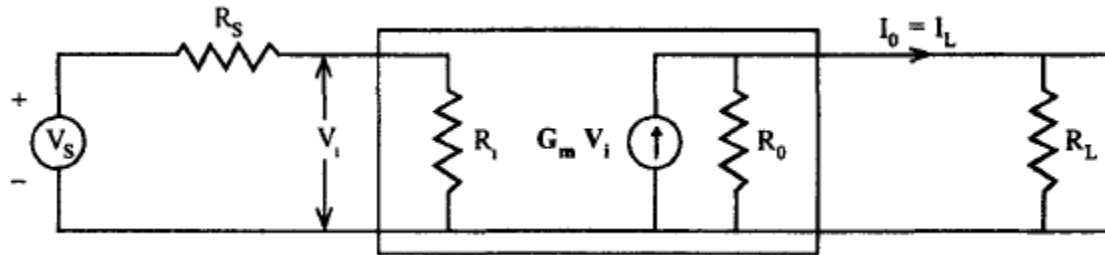
- An ideal current amplifier is one which gives output current proportional to input current and
- the proportionality factor is independent of R_s and R_L .



TRANSCONDUCTANCE AMPLIFIER

Ideal Transconductance amplifier supplies output current which is proportional to input voltage

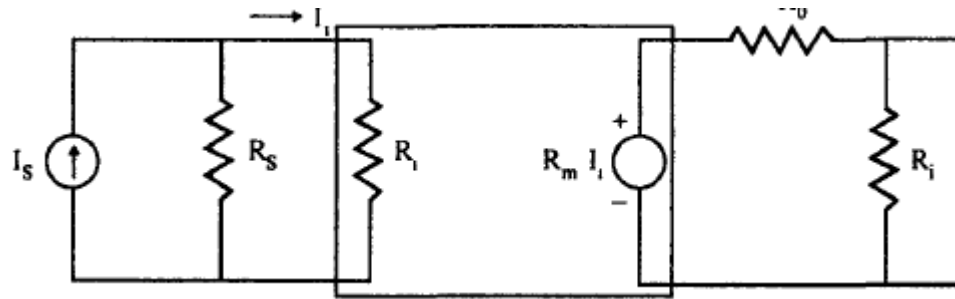
independently of the magnitude of R_s and R_L .



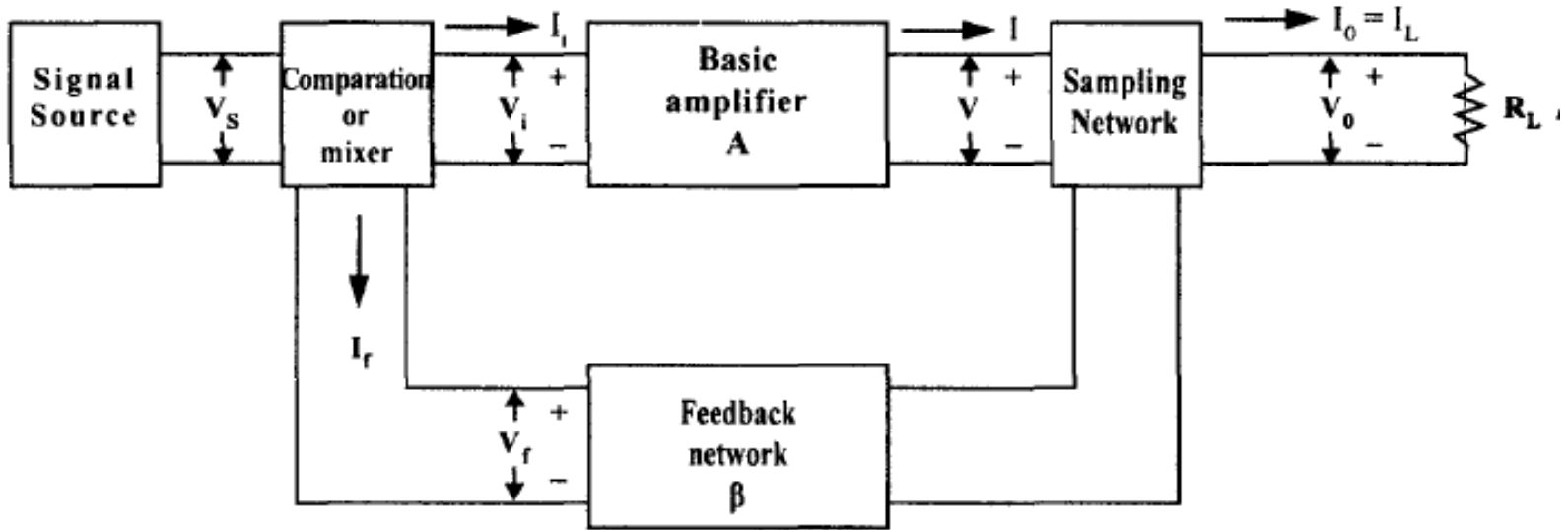
TRANS RESISTANCE AMPLIFIER

It gives output voltage V_o proportional to I_s , independent of R_s a. R_L . For *ideal amplifiers*

$$R_j = 0, R_o = 0$$



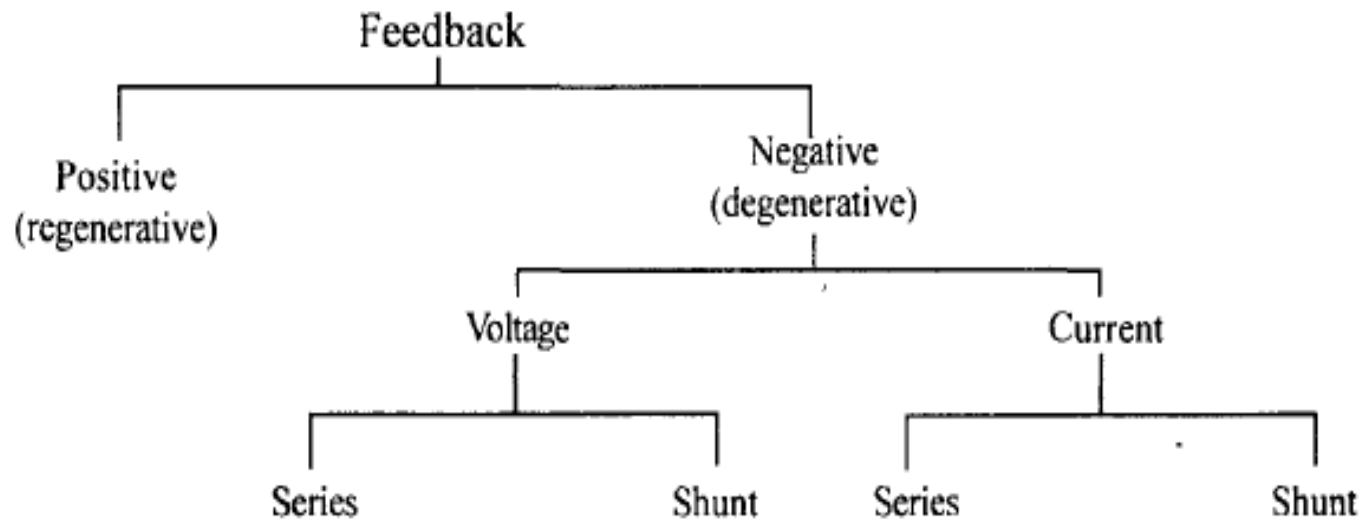
GENERALIZED BLOCK SCHEMATIC



Introduction To Feedback

- The process of injecting a fraction of output energy of some device back to the input is known as **feedback**.
- some of the short comings(drawbacks) of the amplifier circuit are:
 1. Change in the value of the gain due to variation in supplying voltage, temperature or due to components.
 2. Distortion in wave-form due to non linearities in the operating characters of the amplifying device.
 3. The amplifier may introduce noise (undesired signals)
- The above drawbacks can be minimizing if we introduce feedback

basic types of feedback in amplifiers



Positive feedback

- When the feedback energy (voltage or current) is in phase with the input signal and thus aids it, it is called *positive feedback*.
- *Both amplifier* and feedback network introduce a phase shift of 180° . The result is a 360° phase shift around the loop, causing the *feedback voltage V_f* to be in phase with the input signal V_{in} .

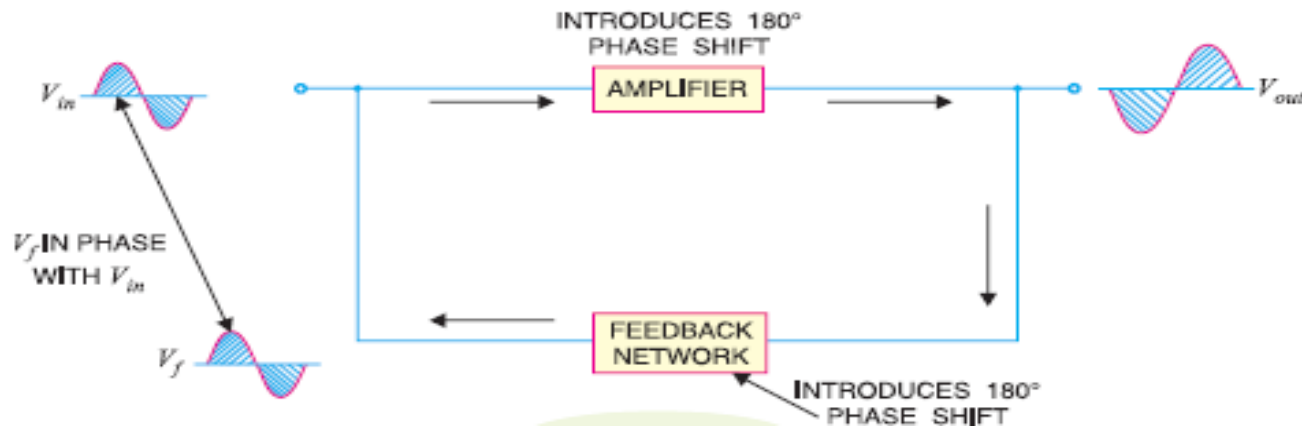


Fig. Block diagram for positive feedback

Negative feedback.

- When the feedback energy (voltage or current) is out of phase with the input signal and thus opposes it, it is called *negative feedback*.
- The amplifier introduces a phase shift of 180° into the circuit while the feedback network is so designed that it introduces no phase shift (*i.e.*, 0° phase shift).
- Negative feedback is also called as *degenerative feedback*.

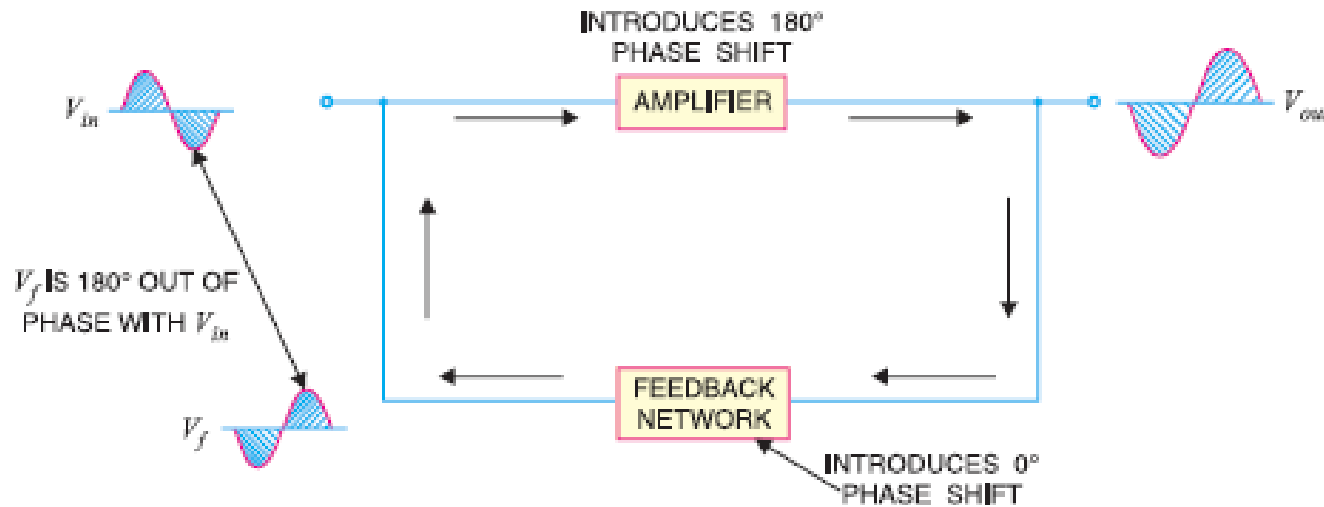
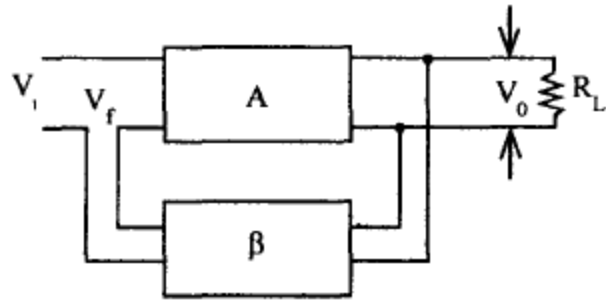
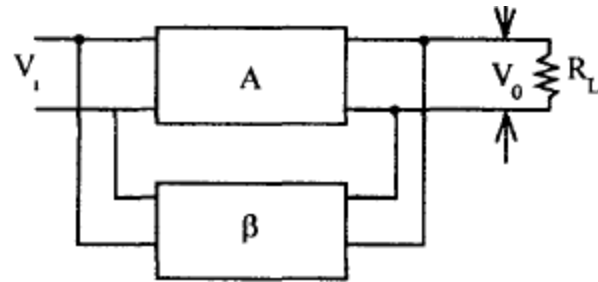


Fig.negative feedback amplifier

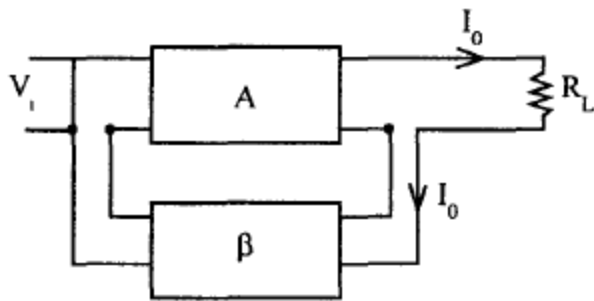
CLASSIFICATION OF FEEDBACK AMPLIFIERS



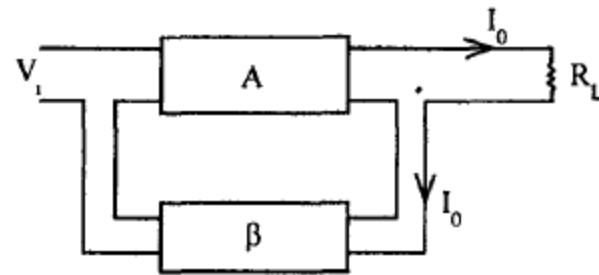
voltage series feedback.



Voltage shunt Feedback



Current Shunt Feedback



Current Series Feedback

$$A_{Vf} = \frac{V_o}{V_s}$$

$$A_{If} = \frac{I_o}{I_s}$$

$$G_{Mf} = \frac{I_o}{V_s}$$

$$R_{Mf} = \frac{V_o}{I_s}$$

EFFECT OF NEGATIVE FEEDBACK ON TRANSFER GAIN

❖ REDUCTION IN GAIN

$$A'_V = \frac{A_V}{1 + \beta A_V} \quad \text{Denominator is } > 1. \quad \therefore \quad A'_V < A_V$$

❖ INCREASE IN BANDWIDTH

$$f_H' = f_H (1 + \beta_v A_{v(\text{mid})})$$

$$f_L' = \frac{f_L}{1 + \beta_v A_{v(\text{mid})}}$$

❖ REDUCTION IN DISTORTION

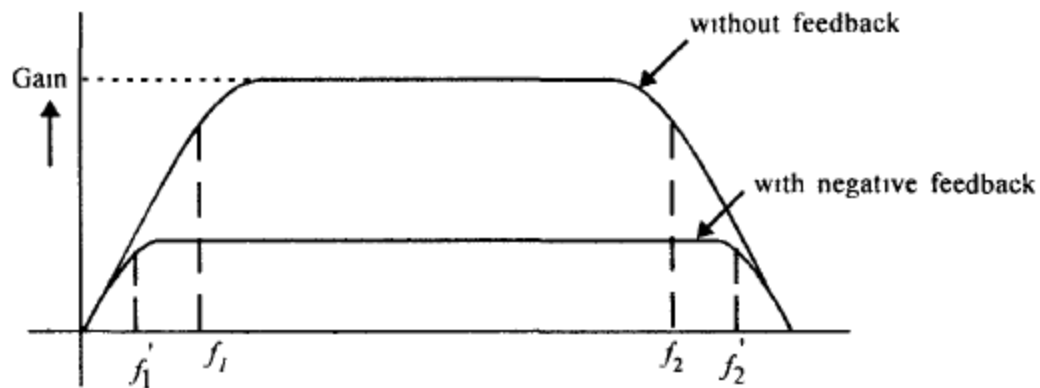
$$\frac{D}{1 + \beta_v A_v} \text{ is } < D$$

❖ FEEDBACK TO IMPROVE SENSITIVITY

❖ FREQUENCY DISTORTION

❖ BAND WIDTH

$$(BW)_f = (1 + \beta A_m) BW$$



❖ SENSITIVITY OF TRANSISTOR GAIN

$$\text{Sensitivity} = \frac{\left| \frac{dA_f}{A_f} \right|}{\left| \frac{dA}{A} \right|}$$

$$\text{Density} \quad \boxed{D = (1 + \beta A)}$$

❖ REDUCTION OF NONLINEAR DISTORTION

$$B_{2f} = \frac{B_2}{1 + \beta A} \quad B_{2f} < B_2$$

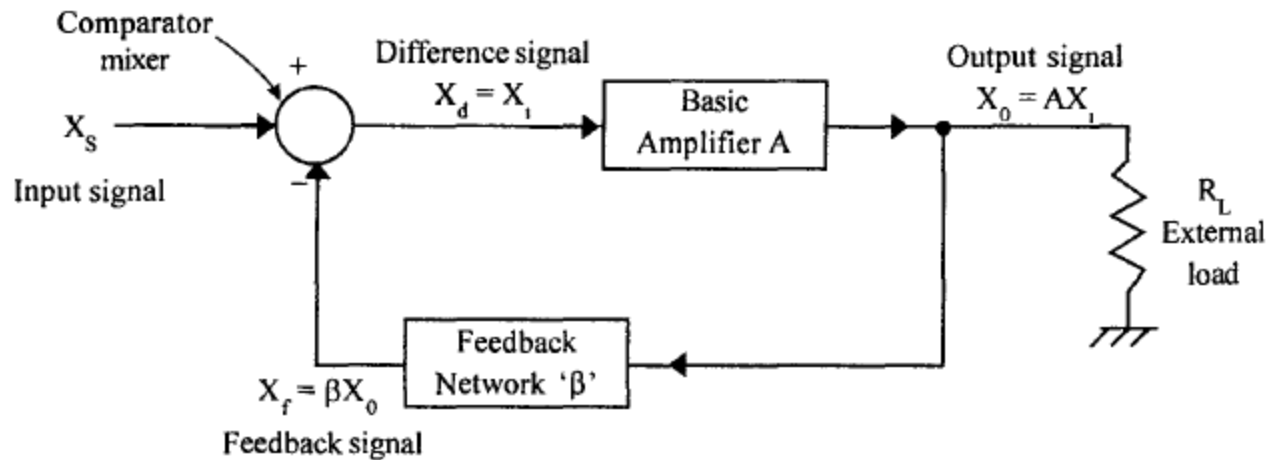
❖ REDUCTION OF NOISE

$$N_F = \frac{N}{1 + \beta A}$$

$N_F < N$. Noise is reduced with negative feedback.

TRANSFER GAIN WITH FEEDBACK

Consider the generalized feedback amplifier



$$A_f = \frac{A}{1 + \beta A}$$

A_f = gain with feedback.

A = transfer gain without feedback.

If $|A_f| < |A|$ the feedback is called as negative or degenerative, feedback

If $|A_f| > |A|$ the feedback is called as positive or regenerative, feedback

LOOP GAIN

Return Ratio

βA = Product of feedback factor β and amplification factor A is called as *Return Ratio*.

Return Difference (D)

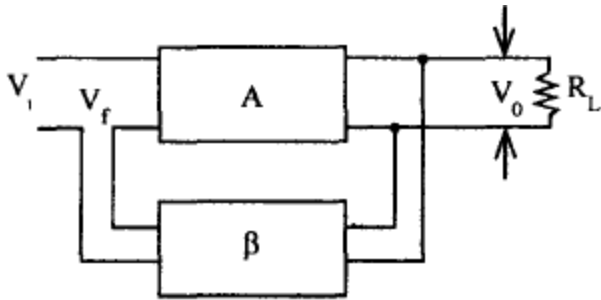
The difference between unity (1) and return ratio is called as *Return difference*.

$$D = 1 - (-\beta A) = 1 + \beta A.$$

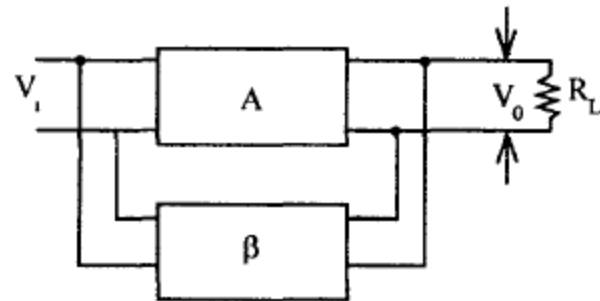
CLASSIFICATION OF FEEDBACK AMPLIFIERS

There are four types of feedback,

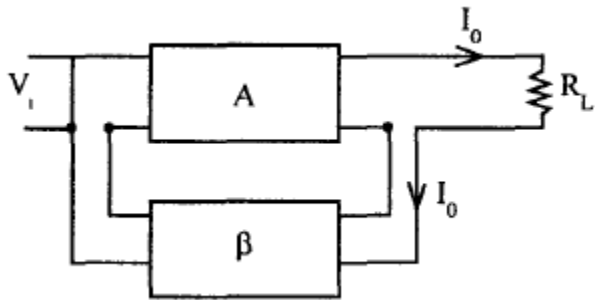
1. Voltage series feedback.
2. Voltage shunt feedback.
3. Current shunt feedback.
4. Current series feedback



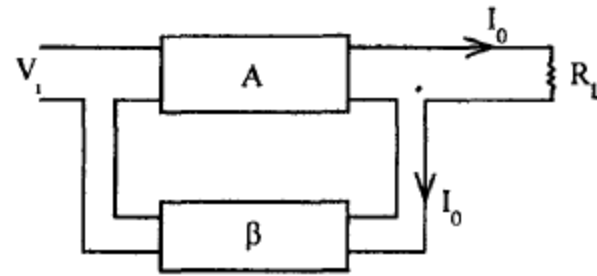
voltage series feedback.



Voltage shunt Feedback



Current Shunt Feedback



Current Series Feedback

EFFECT OF FEEDBACK ON INPUT RESISTANCE

Voltage shunt Feedback

$$R'_i = \frac{R_i}{(1 + \beta_i A_i)}$$

Current Shunt Feedback

$$R_{if} = \frac{V_i}{(1 + \beta A_i) I_i} = \frac{R_i}{1 + \beta A_i}$$

voltage series feedback.

$$R_{if} = R_i (1 + \beta A)$$

Current Series Feedback

$$R_{if} = R_i \left(1 + \beta \cdot \frac{V_o}{V_i} \right) = R_i (1 + \beta A_v)$$

EFFECT OF NEGATIVE FEEDBACK ON R_o

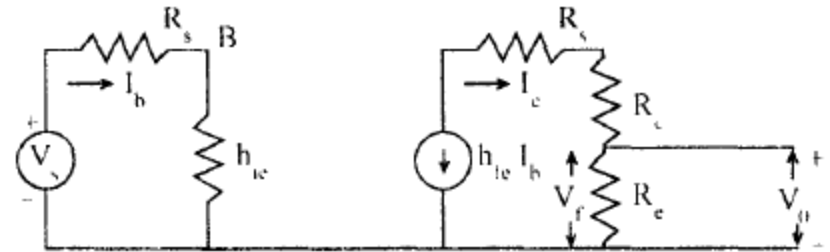
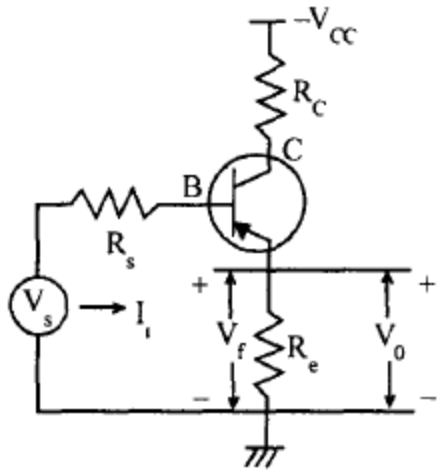
voltage series feedback.

$$R_{of}' = \frac{\frac{R_o}{1 + \beta A_v} \times R_L}{\frac{R_o}{1 + \beta A_v} + R_L} = \frac{R_o R_L}{R_o + R_L + \beta A_v R_L}$$

Current Shunt Feedback

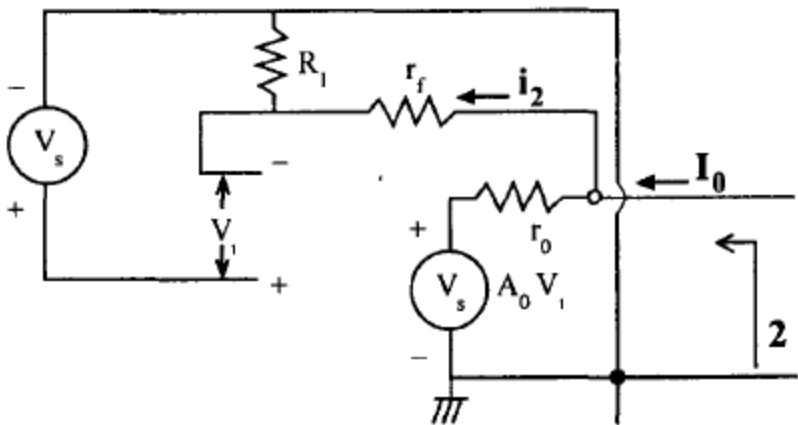
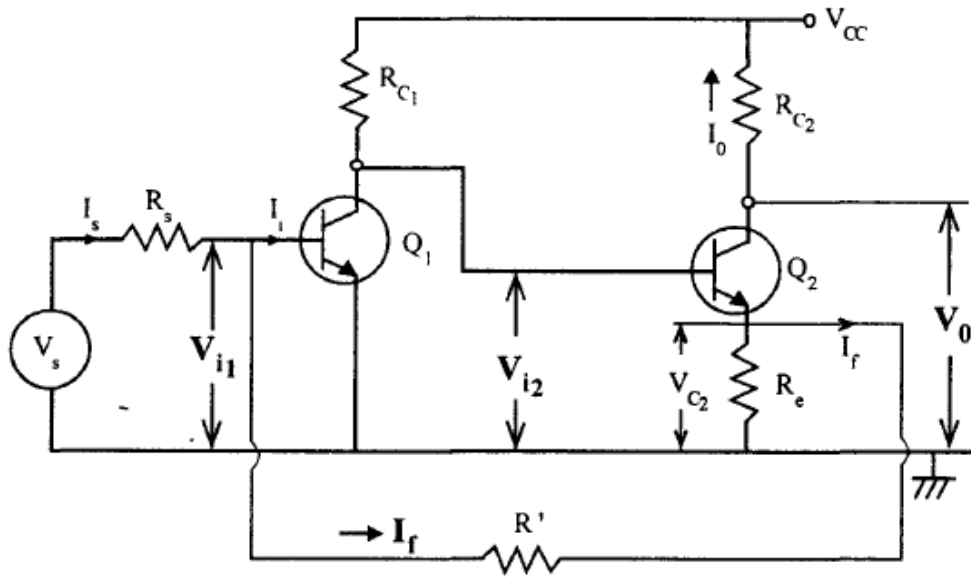
$$R_{of}' = R_o (1 + \beta A_i)$$

ANALYSIS OF FEEDBACK AMPLIFIERS



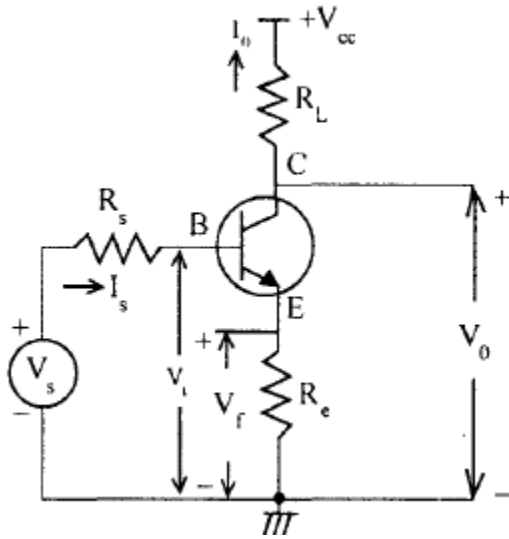
Block Schematic

Current shunt feedback.

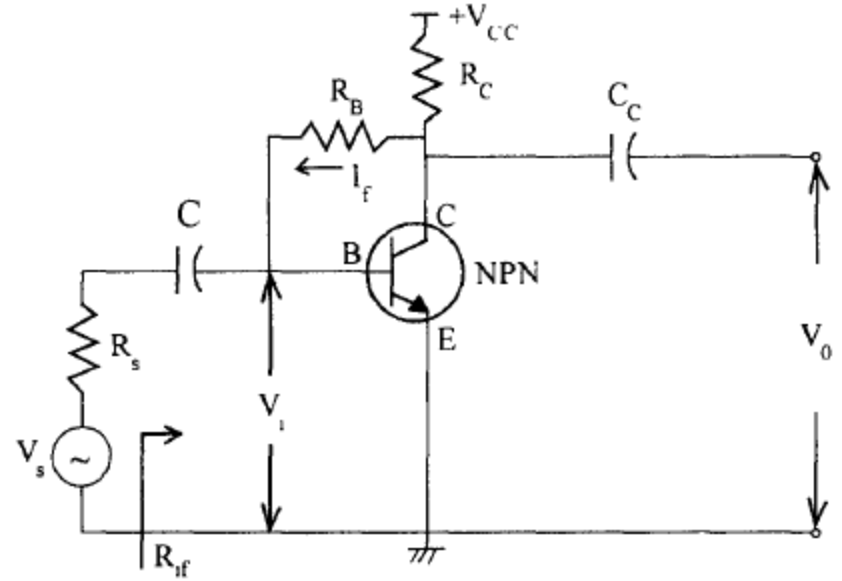


Equivalent circuit.

CURRENT SERIES FEEDBACK

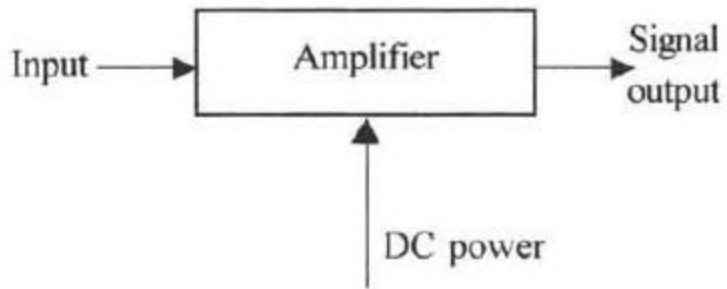


VOLTAGE SHUNT FEEDBACK

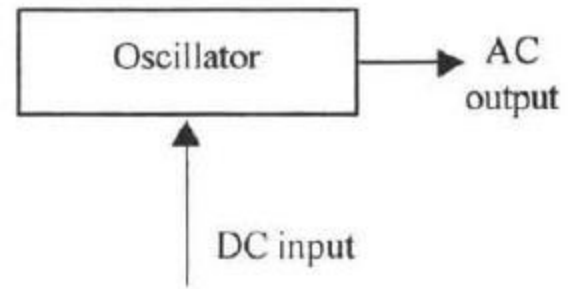


OSCILLATORS

Oscillator is a source of AC voltage or current.



(a) Amplifier circuit



(b) Oscillator circuit

Oscillator Circuit

- Oscillator is an electronic circuit which converts dc signal into ac signal.
- Oscillator is basically a positive feedback amplifier with unity loop gain.
- For an inverting amplifier- feedback network provides a phase shift of 180° while for non-inverting amplifier- feedback network provides a phase shift of 0° to get positive feedback .

$$\frac{V_o}{V_s} = \frac{A}{1 - A\beta} \quad \text{If } \beta A = 1 \text{ then } V_o = \infty ; \quad \text{Very high output with zero input.}$$

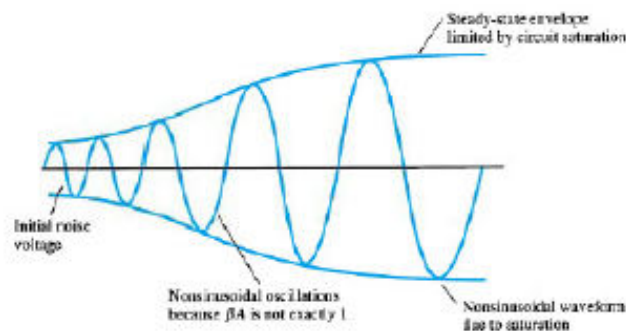
Use positive feedback through frequency-selective feedback network to ensure sustained oscillation at ω_0

Use of Oscillator Circuits

- ❖ Clock input for CPU, DSP chips ...
- ❖ Local oscillator for radio receivers, mobile receivers, etc
- ❖ As a signal generators in the lab
- ❖ Clock input for analog-digital and digital-analog converters

Oscillators

- If the feedback signal is not positive and gain is less than unity, oscillations dampen out.
- If the gain is higher than unity then oscillation saturates.



Type of Oscillators

Oscillators can be categorized according to the types of feedback network used:

- RC Oscillators: Phase shift and Wien Bridge Oscillators
- LC Oscillators: Colpitt and Hartley Oscillators
- Crystal Oscillators

There are two types of oscillators circuits:

I. Harmonic Oscillators

2. Relaxation Oscillators

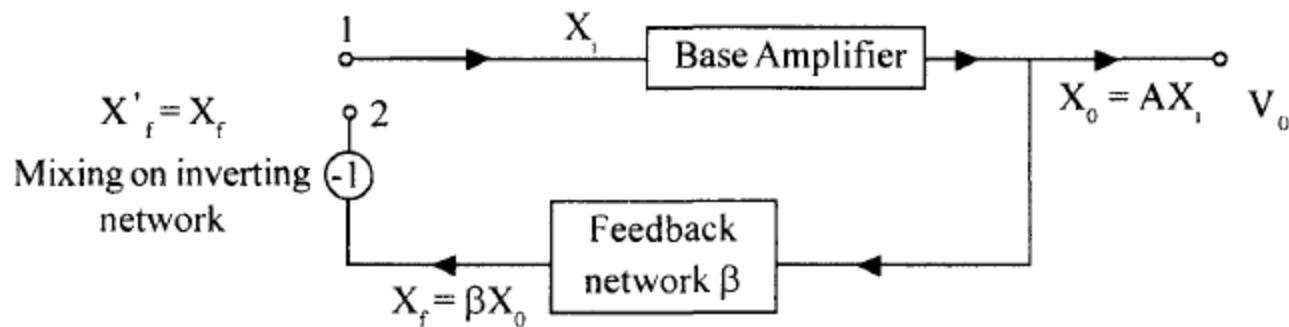
PERFORMANCE MEASURES OF OSCILLATOR CIRCUITS:

- ❖ ***Stability:***
- ❖ ***Amplitude stability:***
- ❖ ***Output Power:***
- ❖ ***Harmonics:***

Total phase shift = 360° ($180 + 180$). Therefore, to get sustained oscillations,

1. The loop gain must be unit 1.
2. Total Loop phase shift must be 0° or 360° . (Amplifier circuit produces 180° phase shift and feedback network another 180°).

SINUSOIDAL OSCILLATORS

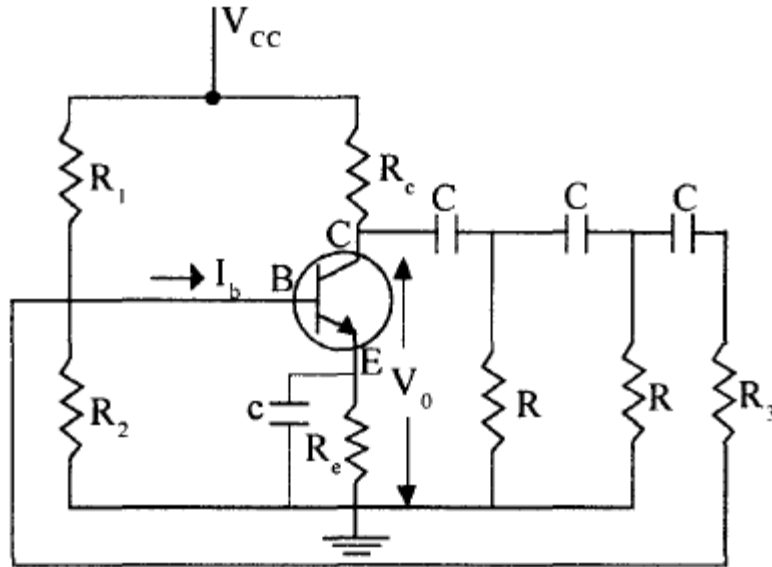


Block schematic

BARKHAUSEN CRITERION

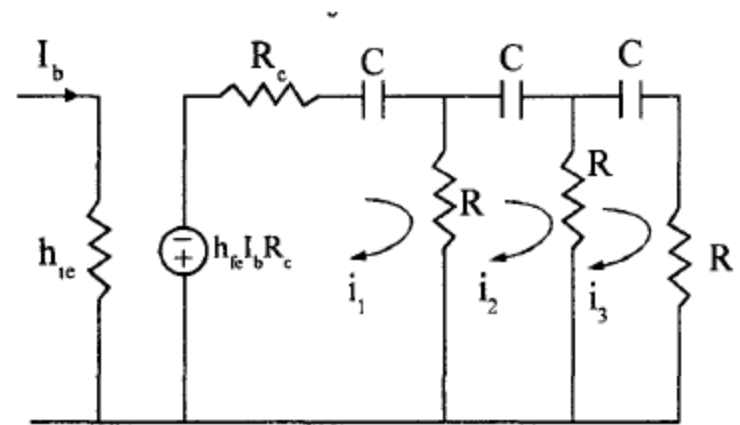
$$|\beta A| = 1 \text{ and phase of } -A\beta = 0.$$

R - C PHASE-SHIFT OSCILLATOR



(a)

Transistor phase shift oscillator.



R - C Equivalent circuit.

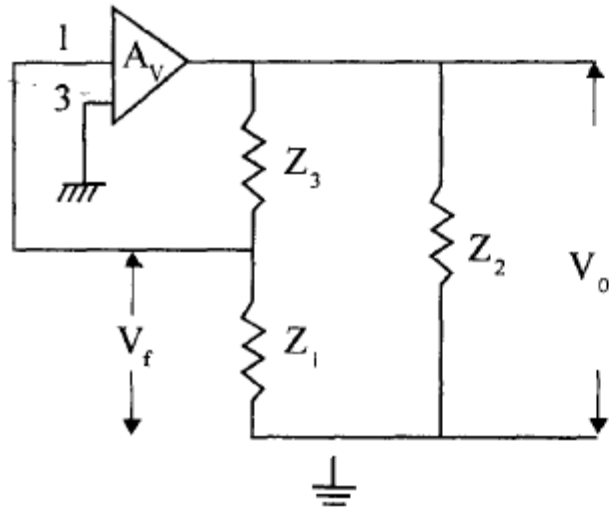
$$h_{fe} K > 4K^2 + 23K + 29$$

$$K < 2.7$$

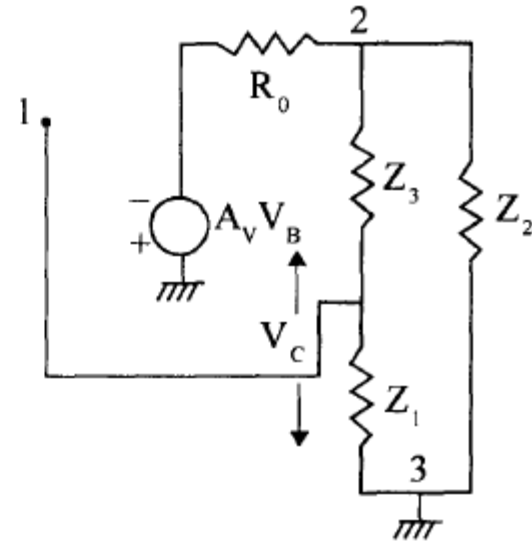
$$h_{fe} > 4K + 23 + \frac{29}{K}$$

$$h_{fe} > 44.5$$

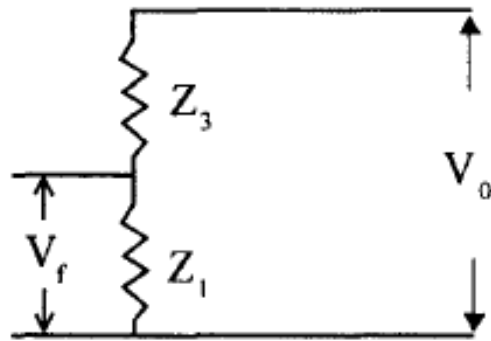
A GENERAL FORM OF LC OSCILLATOR CIRCUIT



(a)



(b)



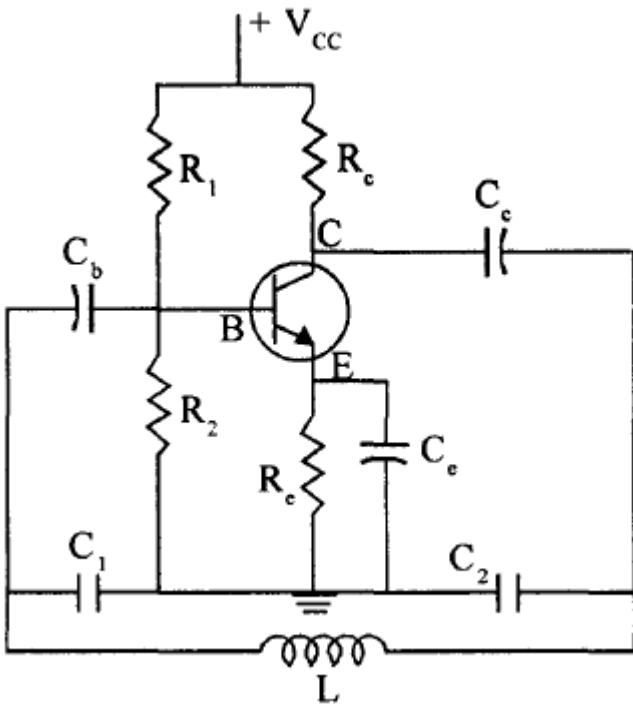
$$-A\beta = \frac{A_v X_1}{X_2}$$

- $A\beta$ must be positive, and at least unity in magnitude. Then X_1 and X_2 must have the same sign.

So if X_1 and X_2 are capacitive, X_3 should be inductive and vice versa.

If X_1 and X_2 are capacitors, the circuit is called ***Colpitts Oscillator***

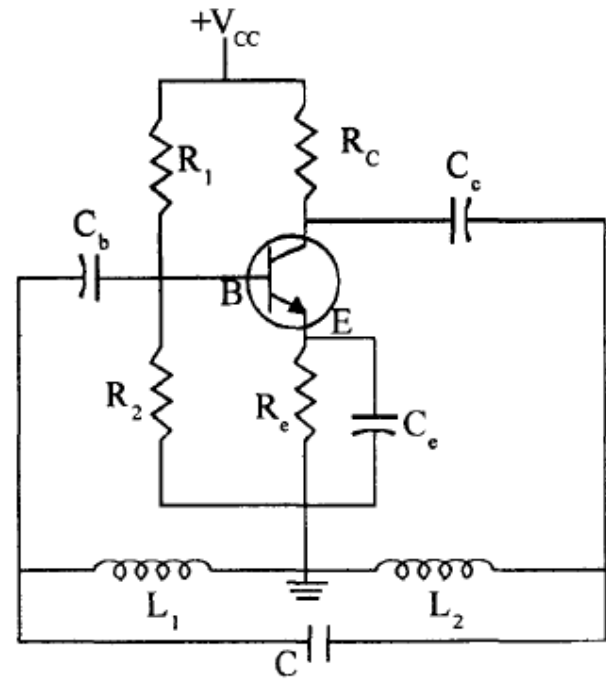
If X_1 and X_2 are inductors, the circuit is called ***Hartely Oscillators***



(a) Colpitts oscillator

$$f = \frac{1}{2\pi\sqrt{LC_T}}$$

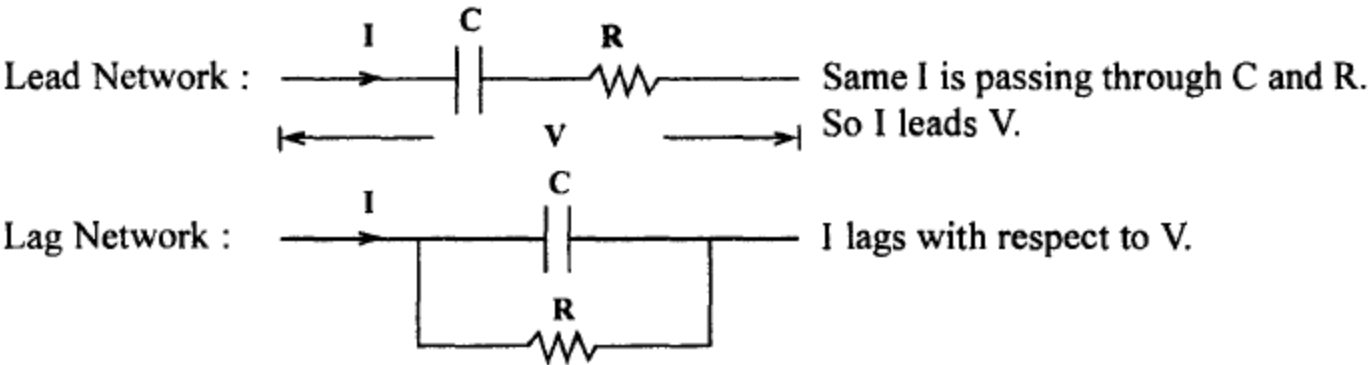
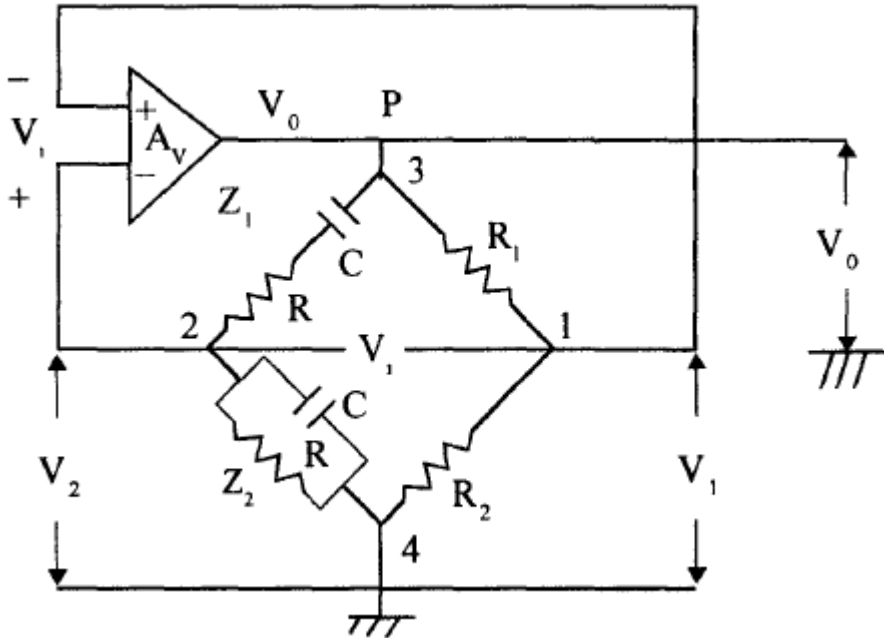
where $C_T = \frac{C_1 C_2}{C_1 + C_2}$

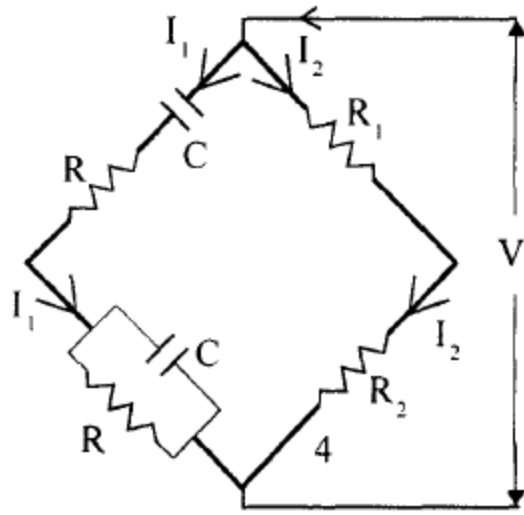


(b) Hartely oscillator circuit

$$f = \frac{1}{2\pi\sqrt{(L_1 + L_2) C_3}}$$

Wien bridge oscillator circuit.



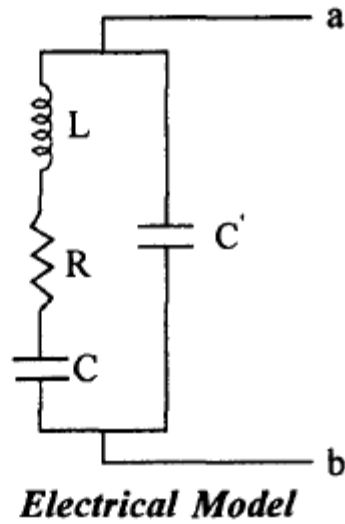
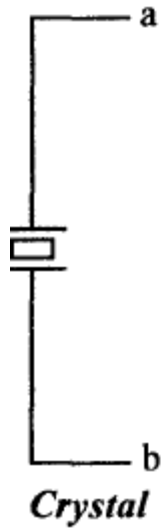


Wien Bridge oscillator circuit.

$$f = \frac{1}{2\pi RC}$$

$$h_{fe} = 4k + 23 + \frac{29}{K}$$

CRYSTAL OSCILLATORS



$$f = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

UNIT – IV

LARGE SIGNAL AMPLIFIERS: Classification, Class A Large signal amplifiers, Transformer Coupled Class A Audio Power amplifier, Efficiency of class A amplifier, Class B amplifier, Efficiency of class B Amplifier, class B Push pull Amplifier, Complementary Symmetry Class B Push Pull Amplifier, Distortion of Power Amplifiers, Thermal Stability and Heat sinks.

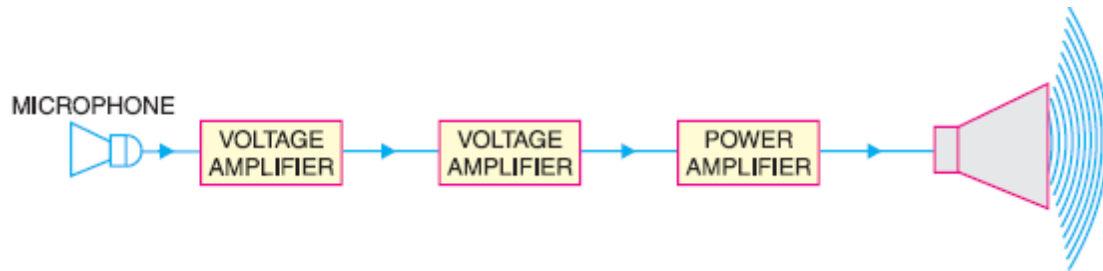
Transistor Audio Power Amplifier

- A transistor amplifier which raises the power level of the signals that have audio frequency range is known as **transistor audio power amplifier**.
- A transistor that is suitable for power amplification is generally called a *power transistor*.
- The typical power output rating of a power amplifier is 1W or more.

Factors to be considered in large signal amplifiers:

- Output power
- Distortion
- Operating region
- Thermal considerations
- Efficiency (η)

block diagram of an audio amplifier



Difference Between Voltage and Power Amplifiers

S. No.	Particular	Voltage amplifier	Power amplifier
1.	β	High (> 100)	low (5 to 20)
2.	R_c	High (4 – 10 k Ω)	low (5 to 20 Ω)
3.	<i>Coupling</i>	usually R – C coupling	Invariably transformer coupling
4.	<i>Input voltage</i>	low (a few mV)	High (2 – 4 V)
5.	<i>Collector current</i>	low (≈ 1 mA)	High (> 100 mA)
6.	<i>Power output</i>	low	high
7.	<i>Output impedance</i>	High (≈ 12 k Ω)	low (200 Ω)

Performance Quantities of Power Amplifiers

(i) Collector efficiency

*The ratio of a.c. output power to the zero signal power (i.e. d.c. power) supplied by the battery of a power amplifier is known as **collector efficiency**.*

(ii) Distortion

*The change of output wave shape from the input wave shape of an amplifier is known as **distortion**.*

(iii) Power dissipation capability

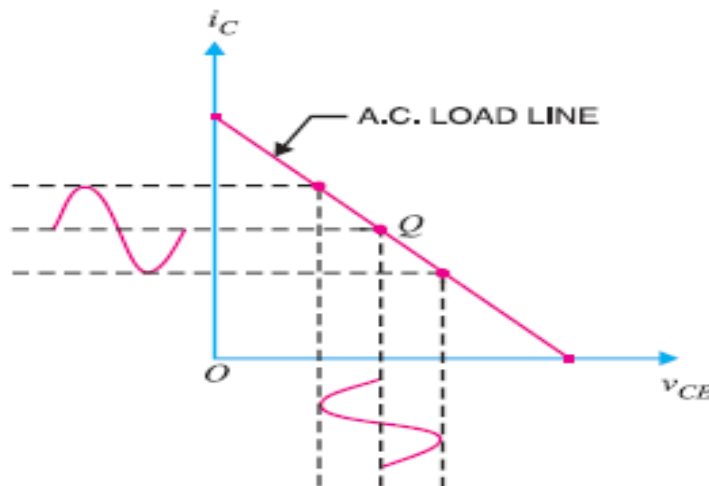
*The ability of a power transistor to dissipate heat is known as **power dissipation capability**.*

Classification of Power Amplifiers

- Class A: It is one, in which the active device conducts for the full 360° .
- Class B: Conduction for 180° .
- Class C: Conduction for $< 180^\circ$.
- Class AB :Conduction angle is between 180° . and 360° .
- Class D: These are used in *transmitters because their efficiency is high: 100%*.
- Class S:Switching regulators are based on class'S' operation.

Class A power amplifier

- If the collector current flows at all times during the full cycle of the signal, the power amplifier is known as **class A power amplifier**.
- If the Q point is placed near the centre of the linear region of the dynamic curve, class A operation results. Because the transistor will conduct for the complete 360° , distortion is low for small signals and conversion efficiency is low.



Types of class-A power Amplifiers

1. Series fed

There is no transformer in the circuit. R_L is in series with V_{cc} . There is DC power drop across R_L . Therefore efficiency = 25% (maximum).

2. Transformer coupled

- The load is coupled through a transformer. DC drop across the primary of the transformer is negligible. There is no DC drop across R_L . Therefore efficiency = 50% maximum.

Series Fed class-A power Amplifier

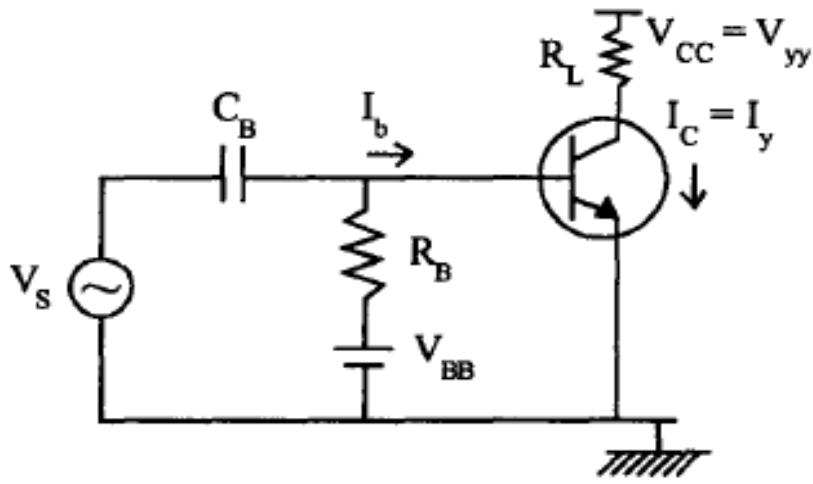


Fig.(a)Series fedClass A power amplifier circuit

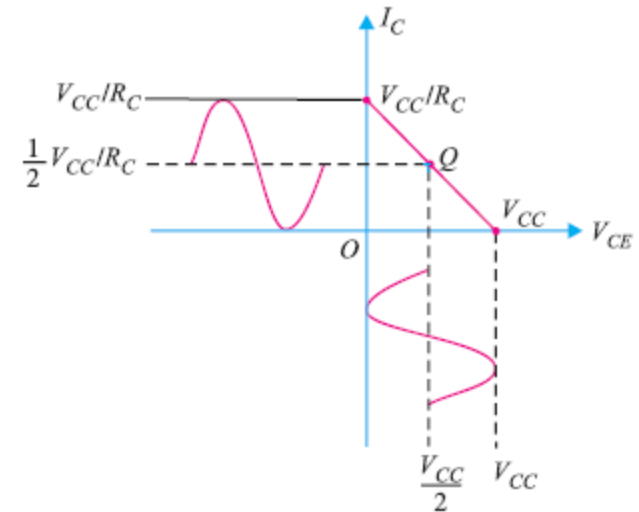


Fig.(b)Transter curve

Transformer Coupled class-A power Amplifier

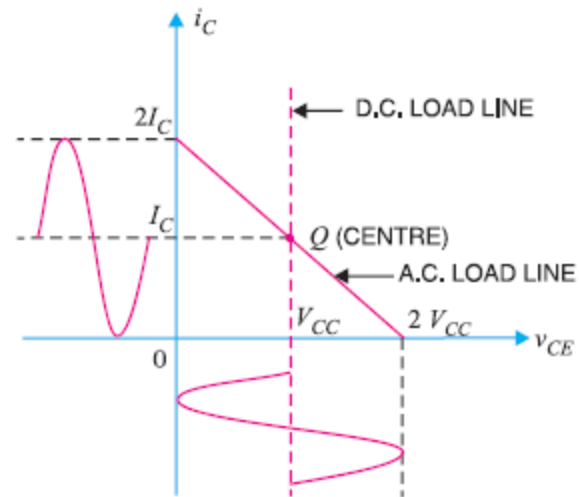
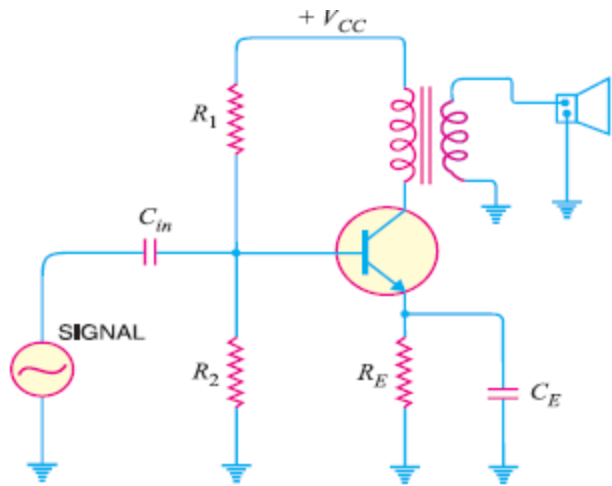


Fig.(a)Transformer Coupled Class A power amplifier circuit

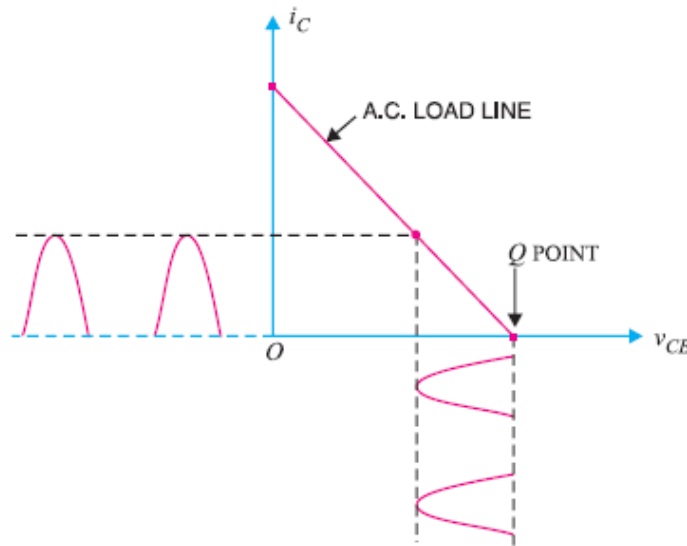
Fig.(b)Transfer curve

Important Points About Class A Power Amplifier

- A transformer coupled class A power amplifier has a maximum collector efficiency of **50%**
- The power dissipated by a transistor is given by :
$$P_{dis} = P_{dc} - P_{ac}$$
- When no signal is applied to a class A power amplifier, $P_{ac} = 0$.
$$\therefore P_{dis} = P_{dc}$$
- When a class A power amplifier is used in the final stage, it is called **single ended class A power amplifier**.

Class B power amplifier

- If the collector current flows only during the positive half-cycle of the input signal, it is called a **class B power amplifier**.
- For class B operation the Q point is set near cutoff. So output power will be more and conversion efficiency is more. Conduction is only for 180



Transfer curve

Types of class-B power Amplifiers

- **Push-Pull Amplifier**

The standard class B push-pull amplifier requires a centre tapped transformer

- **Complimentary Symmetry Circuits (Transformer Less Class B Power Amplifier)**

Complementary symmetry circuits need only one phase

They don't require a centre tapped transformer.

Advantages & Disadvantages of Class B power Amplifier

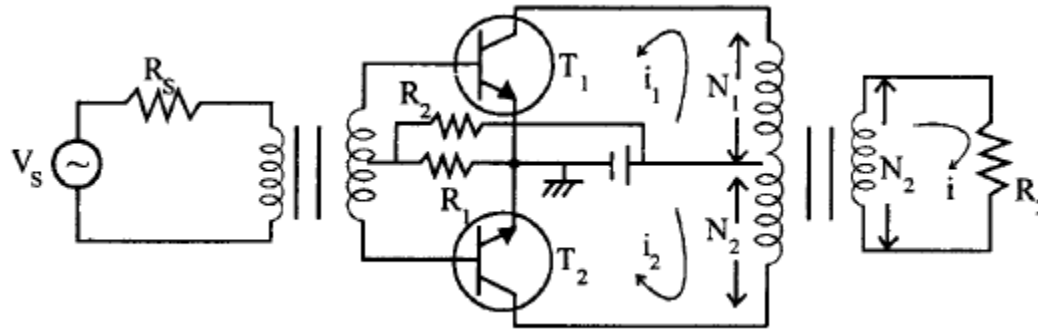
Advantages

1. More output power; efficiency = 78.5%. Max.
2. Efficiency is higher. Since the transistor conducts only for 180° , when it is not conducting, it will not draw DC current.
3. Negligible power loss at no signal.

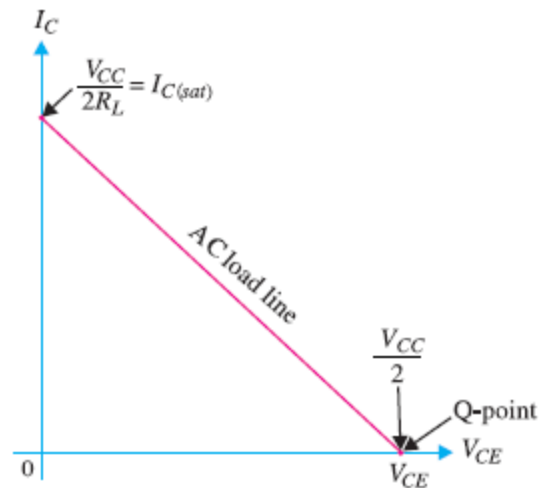
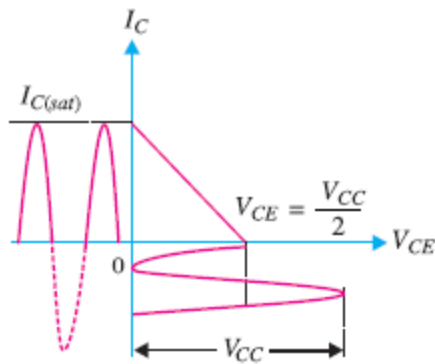
Disadvantages:

1. Supply voltage V_{cc} should have good regulation. Since if V_{cc} changes, the operating point changes (Since I_c changes). Therefore transistor may not be at cut off.
2. Harmonic distortion is higher. (This can be minimized by pushpull connection).

Class B Push-Pull Amplifier



Push Pull amplifier circuit



Complimentary Symmetry Circuits (Transformer Less Class B Power Amplifier)

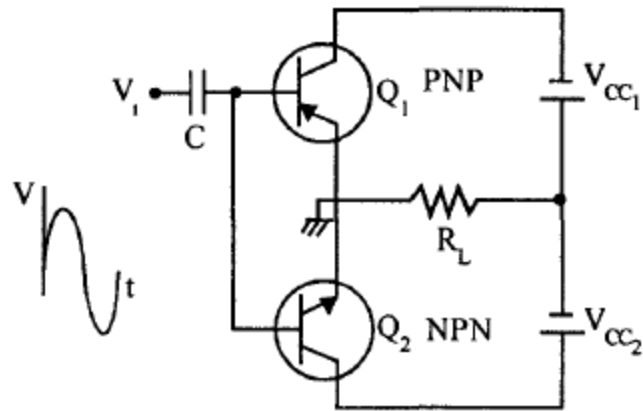


Fig. Complimentary Symmetry circuit

Advantages & Disadvantages of Class B complementary power Amplifier

- **Advantages**

- (i) This circuit does not require transformer. This saves on weight and cost.
- (ii) Equal and opposite input signal voltages are not required.

- **Disadvantages**

- (i) It is difficult to get a pair of transistors (nnp and pnp) that have similar characteristics.
- (ii) We require both positive and negative supply voltages.

Differences between class-A & B power Amplifiers

Class A	Class B
Less power	More power
Lesser η	More η upto 78.5%
Less Harmonic distortion	Harmonic distortion is more

Heat Sinks

- The metal sheet that serves to dissipate the additional heat from the power transistor is known as **heat sink**.
- The purpose of heat sinks is to keep the operating temperature of the transistor low, to prevent thermal breakdown.
- Almost the entire heat in a transistor is produced at the collector-base junction. If the temperature exceeds the permissible limit, this junction is destroyed and the transistor is rendered useless.
- Most of power is dissipated at the collector-base junction. This is because collector-base voltage is much greater than the base-emitter voltage, although currents through the two junctions are almost the same.

Mathematical Analysis Of Heat Sinks

$$\theta_{ja} = \theta_{jc} + \theta_{cn} + \theta_{na}$$

$$\theta_{jc} = (T_j - T_c) / P$$

$$\theta_{cs} = (T_c - T_s) / P$$

$$\theta_{sa} = (T_s - T_a) / P$$

θ_{ja} = Junction to ambient thermal resistance

θ_{jc} = Junction to casing thermal resistance

θ_{cs} = Casing to heat sink thermal resistance

θ_{sa} = Heat sink to ambient thermal resistance

T_j = Average junction temperature

T_c = Average case temperature

T_{sa} = Average heat sink temperature

T_a = Ambient temperature

P = Power dissipated in Watts.

Classification of heat Sinks

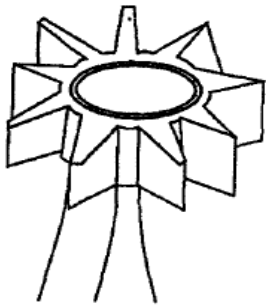
1. Low Power Transistor Type.
2. High Power Transistor Type.

Low Power Transistor Type.

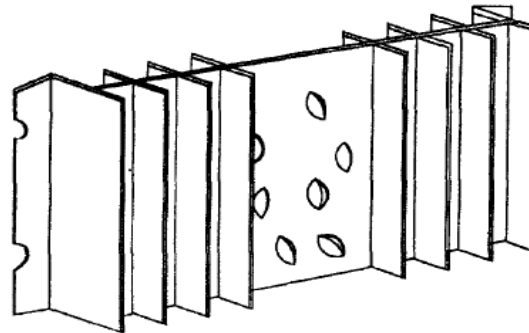
- Low Power Transistors can be mounted directly on the metal chassis to increase the heat dissipation capability. The casing of the transistor must be insulated from the metal chassis to prevent shorting.
- Beryllium oxide insulating washers are used for insulating casing from the chassis. They have good thermal conductivity.
- Zinc oxide film silicon compound between washer and chassis, improves the heat transfer from the semiconductor device to case to the chassis.

High Power Transistor Type.

- re TO-3 and TO-66 types. These are diamond shaped. For power transistors, usually, the ease itself in the collector convention and radiation
- Finned aluminium heat sinks yield the best heat transfer per unit cost.



Fin-type heat sink



Power transistor heat sink

Alternate Methods to prevent Thermal breakdown

- It should be realized that the use of heat sink alone may not be sufficient to prevent thermal runaway under all conditions. In designing a transistor circuit, consideration should also be given to the choice of
 - (i) operating point
 - (ii) ambient temperatures which are likely to be encountered and
 - (iii) the type of transistor e.g. metal case transistors are more readily cooled by conduction than plastic ones.

UNIT – V

TUNED AMPLIFIERS Introduction, Q Factor, Small signal Tuned Amplifiers, Effect of Cascading Single tuned Amplifiers on bandwidth, Effect of Cascading Double Tuned Amplifiers on Bandwidth, Stagger Tuned Amplifiers, Stability of tuned amplifiers.

Tuned Amplifiers

- Amplifiers which amplify a specific frequency or narrow band of frequencies are called **tuned amplifiers**.
- Tuned amplifiers are mostly used for the amplification of high or radio frequencies.
- It offers a very high impedance at *resonant frequency* and very small impedance at all other frequencies.

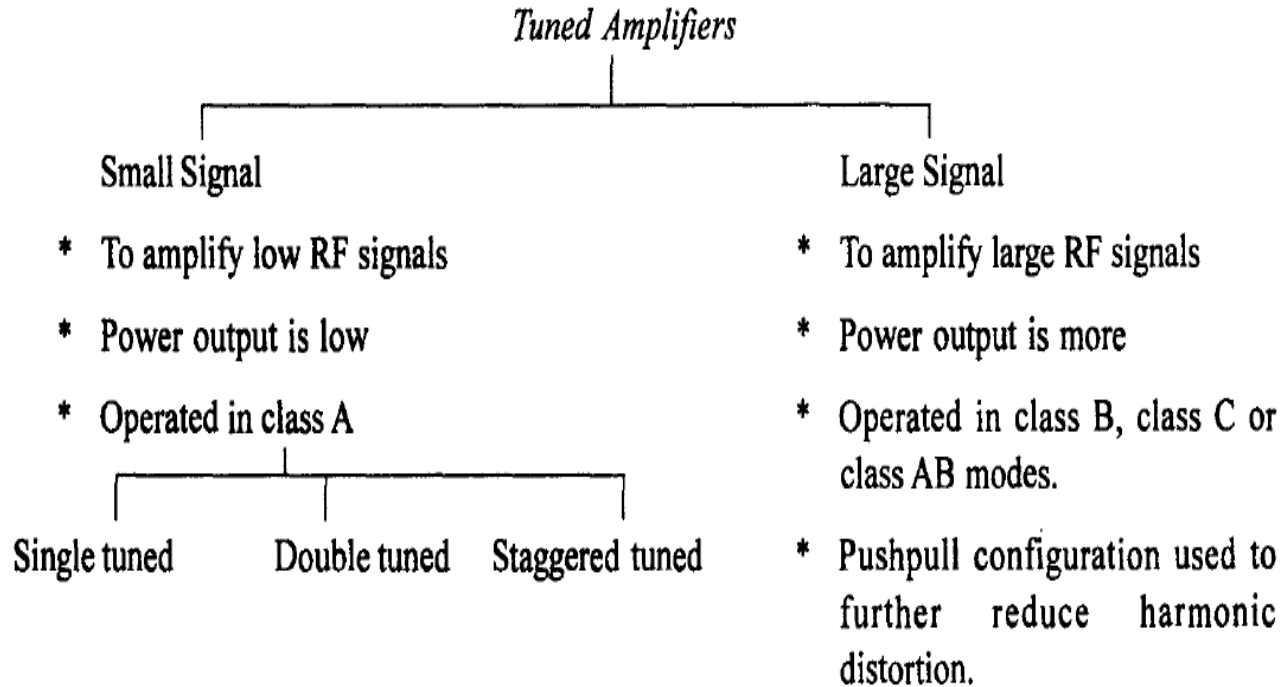
Advantages of Tuned Amplifiers

- 1. Small power loss.**
- 2. High selectivity**
- 3. Smaller collector supply voltage**
- 4. Used in RF amplifiers,
Communication receivers, Radar ,
Television ,I.F amplifiers**
- 5. harmonic distortion is very small**

Why not Tuned Circuits for Low Frequency Amplification?

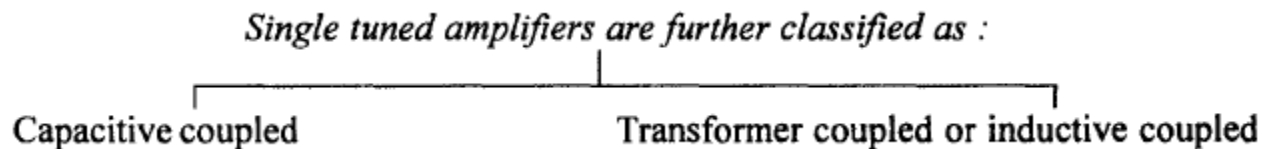
- *Low frequencies are never single*
- *High values of L and C.*

Classification

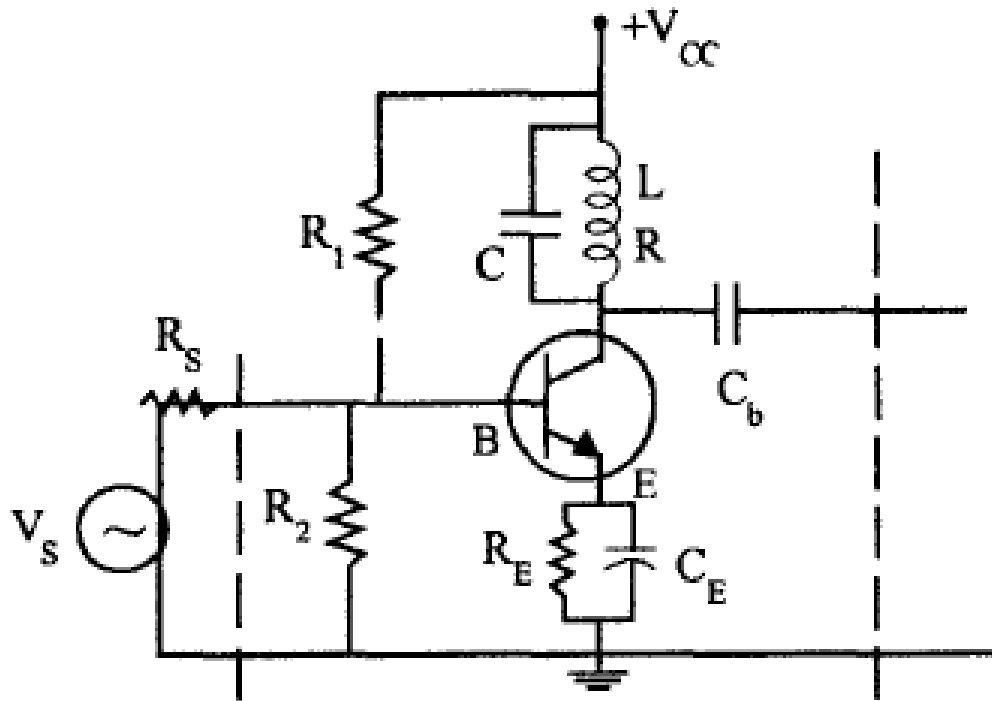


Single Tuned Amplifier

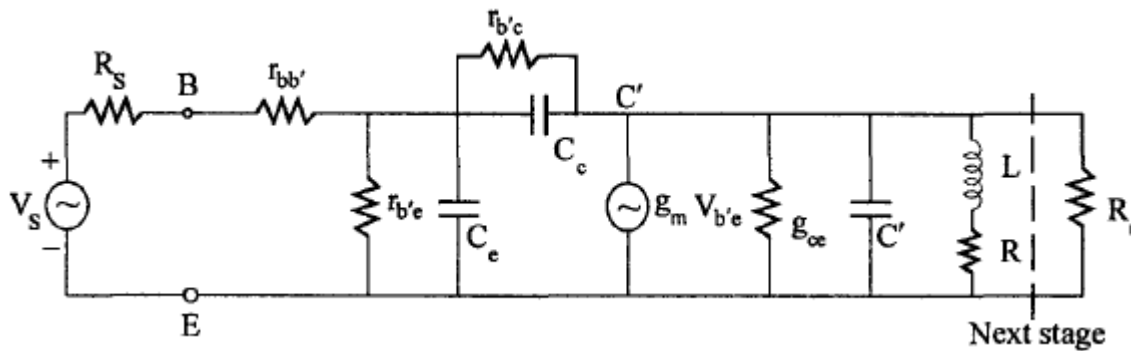
•Uses one parallel tuned circuit as the load IZI in each stage and all these tuned circuits in different stages are tuned to the same frequency. To get large A_v or A_p , multistage amplifiers are used. But each stage is tuned to the same frequency, one tuned circuit in one stage.



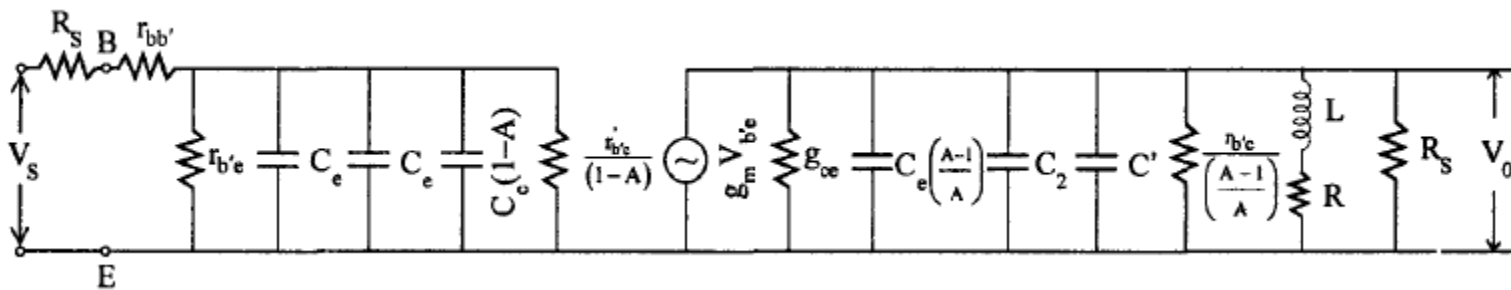
Single Tuned Capacitive Coupled Amplifier



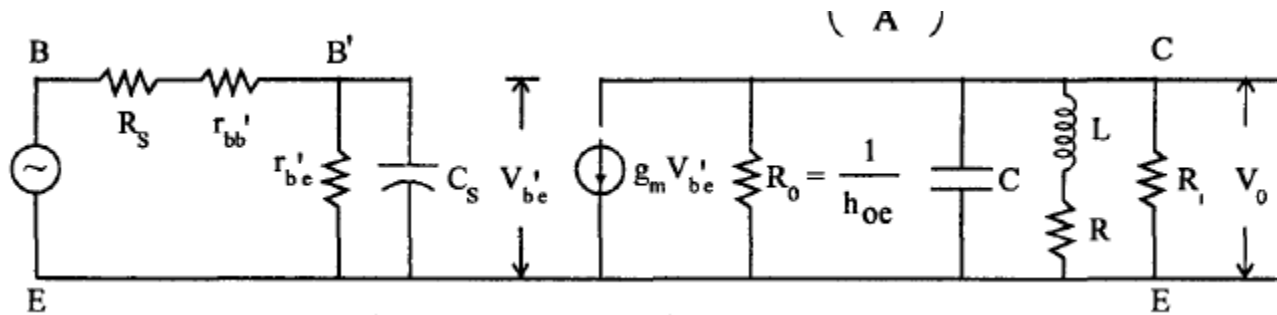
Equivalent circuit of Single Tuned Capacitive Coupled Amplifier



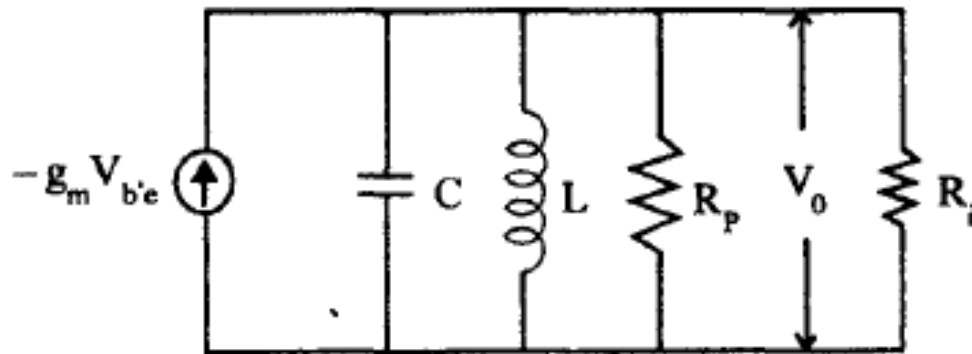
Equivalent circuit of Single Tuned Capacitive Coupled Amplifier (applying Miller's Theorem)



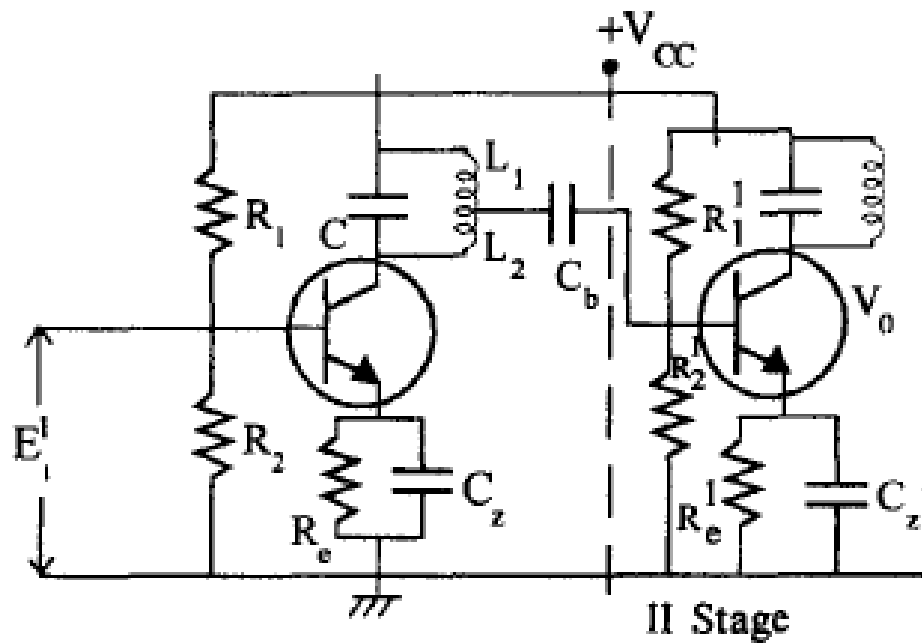
Simplified equivalent circuit



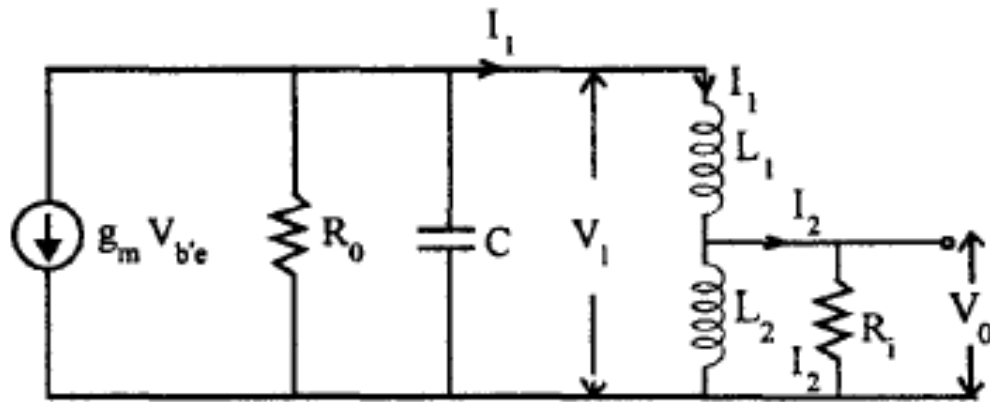
Simplified output circuit



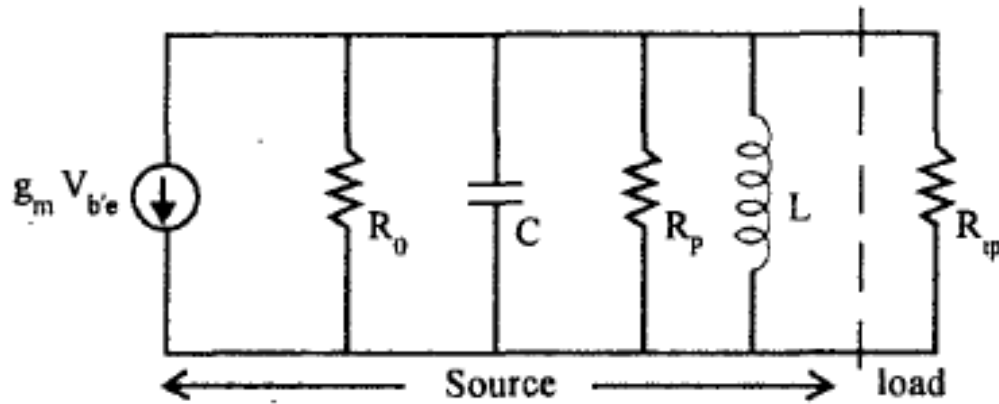
Tapped Single Tuned Capacitance Coupled Amplifier



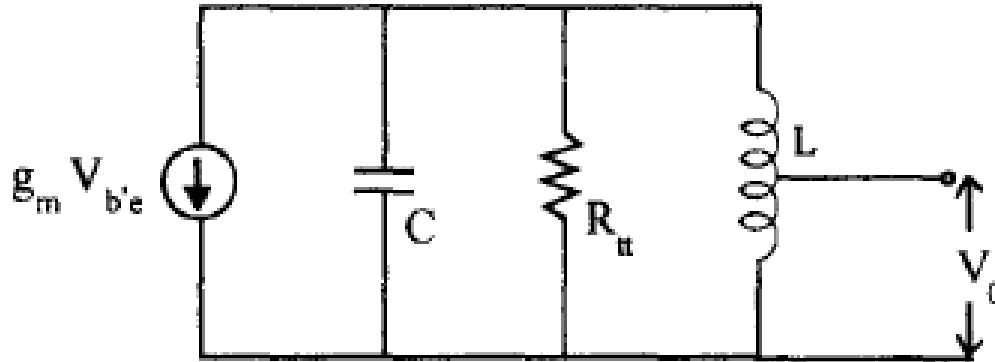
Equivalent Circuit on the Output Side of the I Stage



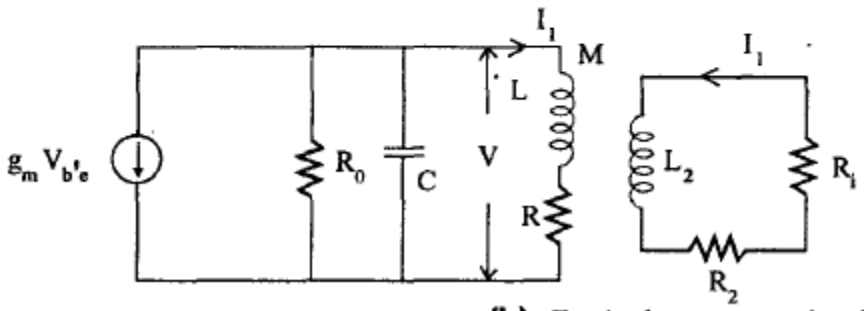
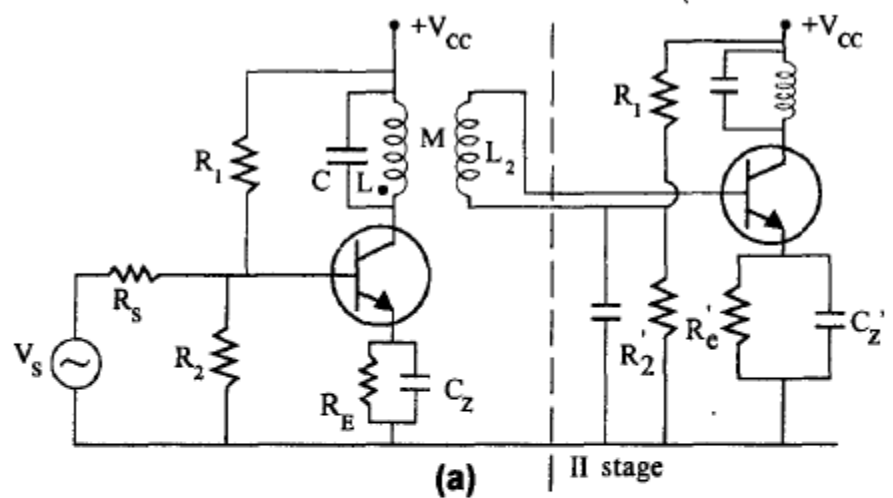
Equivalent circuit of Tapped Single Tuned Capacitance Coupled Amplifier



Equivalent circuit after simplification

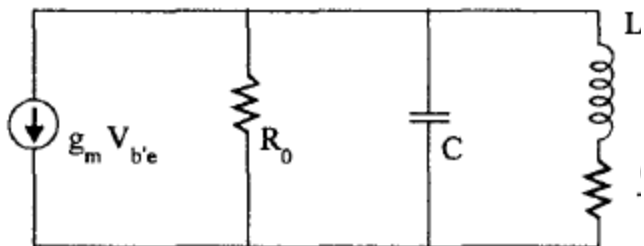


Single Tuned Transformer Coupled or Inductively Coupled Amplifier

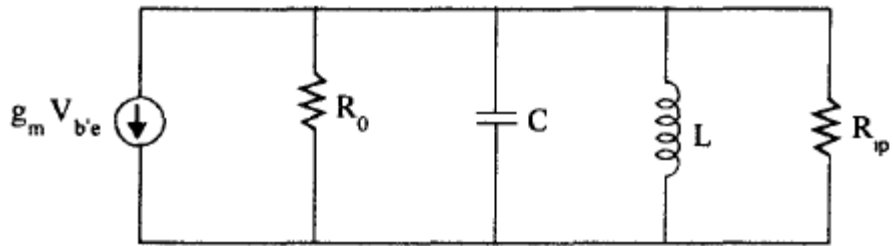


Inductive coupled amplifier circuit (a) and its equivalent (b)

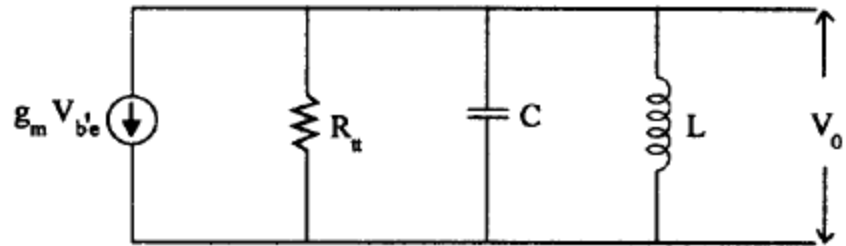
Single Tuned Transformer Coupled or Inductively Coupled Amplifier



(a)Equivalent circuit



(b)Simplified circuit

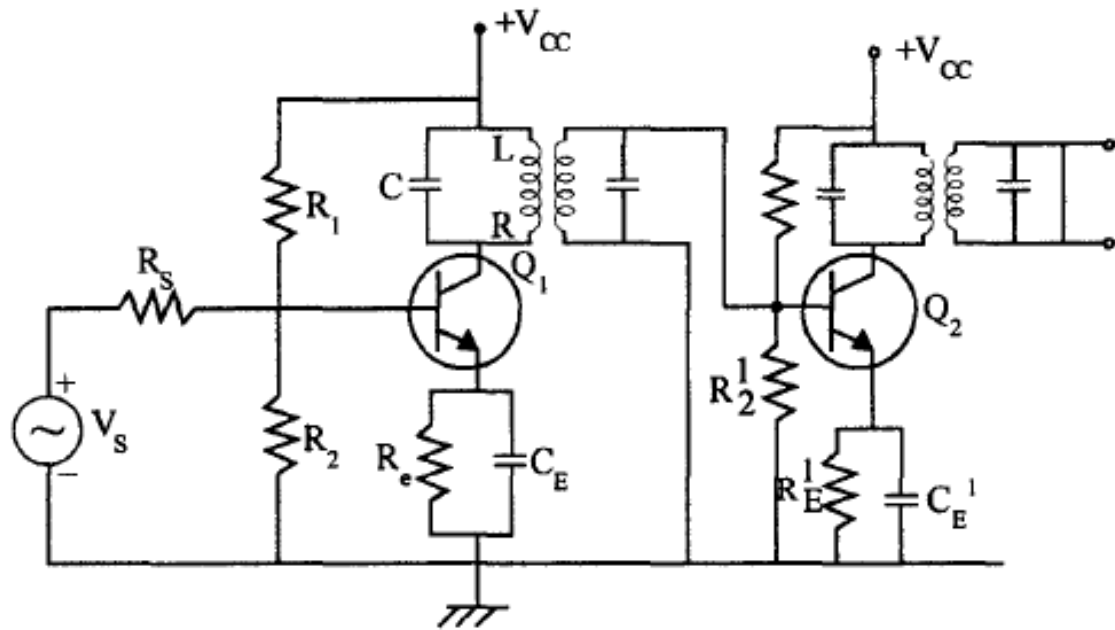


©Equivalent circuit

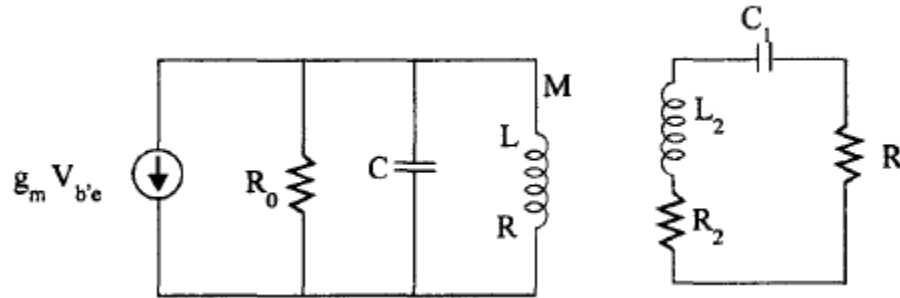
Double Tuned Amplifier

- It uses two inductively coupled tuned circuits, for each stage of the amplifier. Both the tuned circuits are tuned to the same frequency, two tuned circuits in one stage, to get sharp response.
- It provides larger 3-db band width than the single tuned amplifier. Therefore Gain x Bandwidth product is more.
- It provides gain - frequency curve having steeper sides and flatter top.

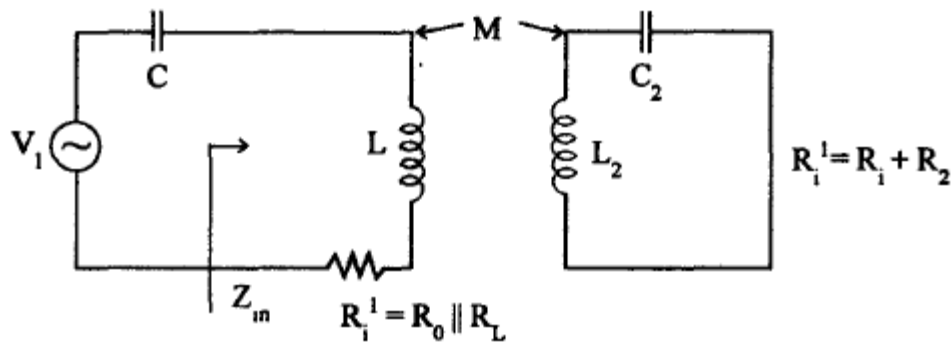
Double tuned amplifier circuit



Double tuned amplifier Equivalent circuit



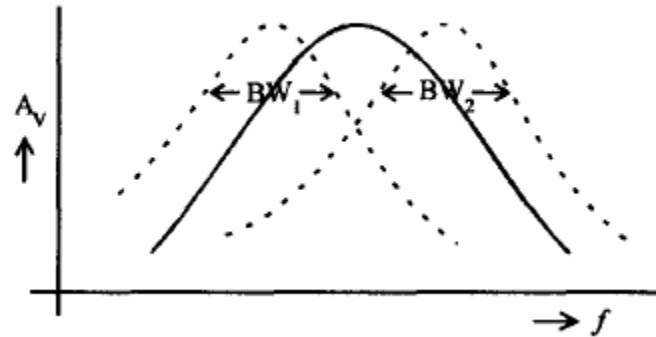
(a) Equivalent circuit



(b) Modified circuit

Stagger Tuned Amplifier

- This circuit uses number of single tuned stages in cascade. The successive tuned circuits are tuned to slightly different frequencies.



Variation of A_v with f

Stability Considerations

- Thermal Effects
- Bias Considerations: Distortion in Audio amplifiers and other types of circuits depends on :
 - (i) Input signal level (in mv)
 - (ii) Source Resistance
 - (iii) Bias Conditions
 - (iv) Type of output load and its impedance
 - (v) Loading effect