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UGC Autonomous

Analog circuits

UNIT No: 1

BJT Biasing, Analysis and design of small signal low frequency BJT amplifiers

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

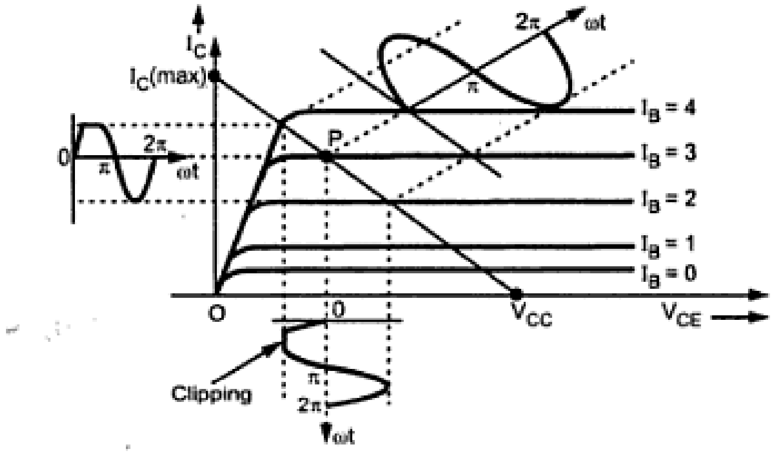
Transistor Voltage specifications For Various Operating Regions

Transistor	$V_{CE\,(sat)}$	$V_{BE\,(sat)}$	$V_{BE\,(active)}$	$V_{BE\,(cut\text{-}in)}$	$V_{BE\,(cut\text{-}off)}$
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

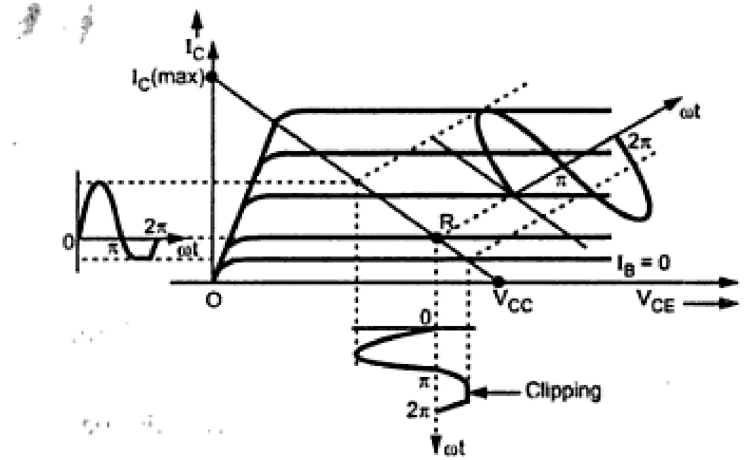
Condition for Active & Saturation Regions

For saturation : $$I_B > \frac{I_C}{\beta_{dc}}$$

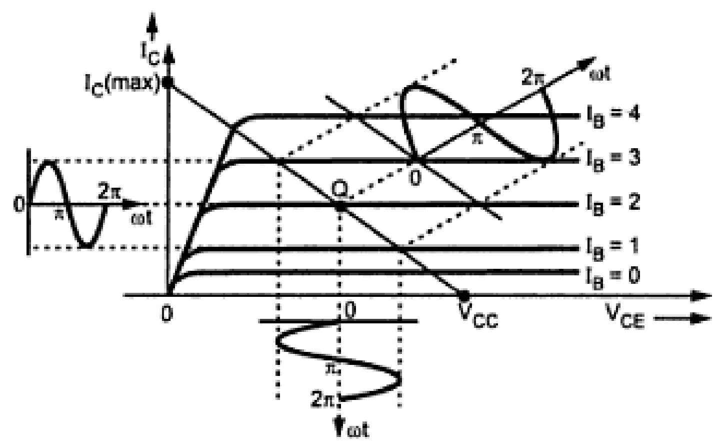
For active region : $$V_{CE} > V_{CE\,(sat)}$$



Operating point near saturation region gives clipping at the positive peaks

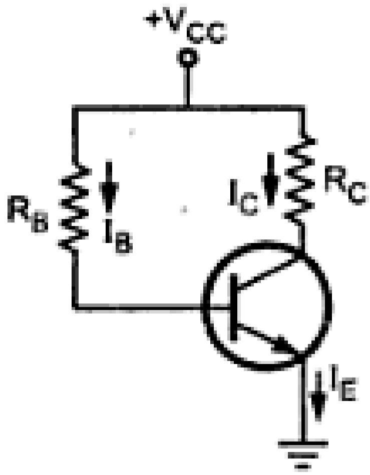


Operating point near cut-off region gives clipping at the negative peaks

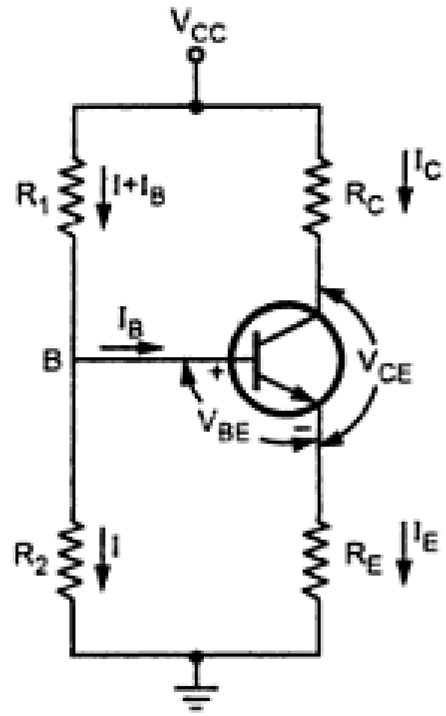


Operating point at the centre of active region is most suitable

Transistor Biasing

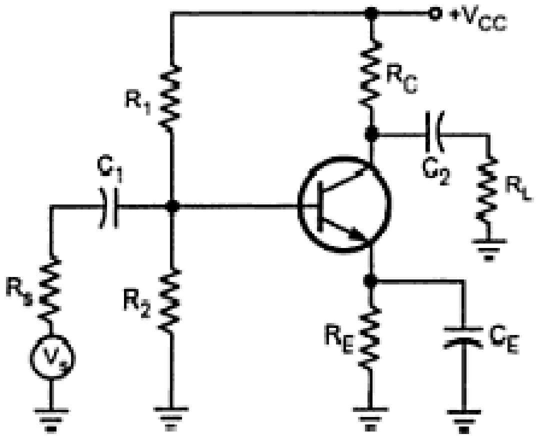


Fixed bias circuit

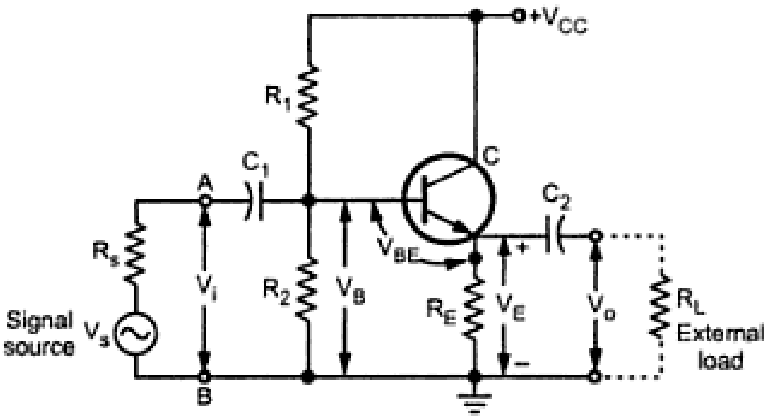


Voltage divider bias circuit

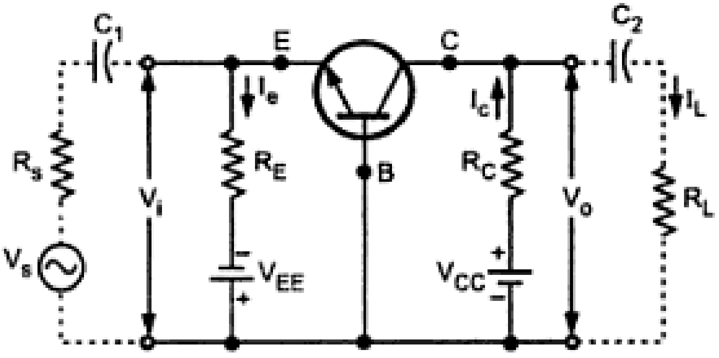
CE, CC, & CB Amplifiers



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 :

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

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

This parameter is ratio of similar quantities, hence unitless

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

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

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

a) With output short circuited :

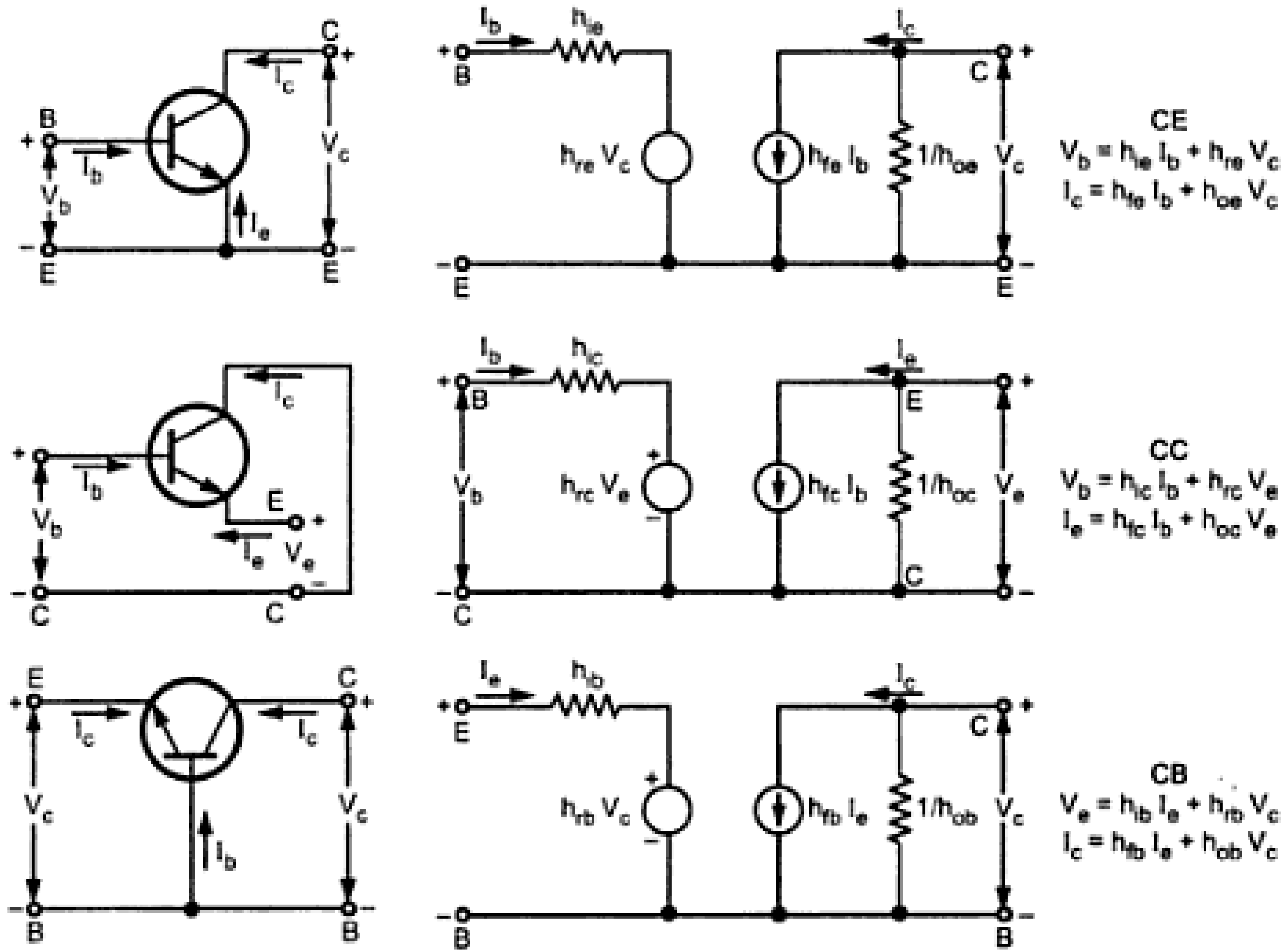
$h_{11} = h_i$: Input resistance

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

b) With input open circuited :

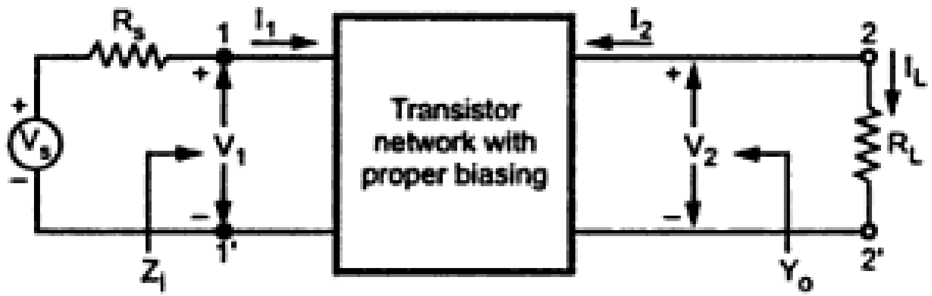
$h_{12} = h_r$: Reverse voltage transfer ratio

$h_{22} = h_o$: Output admittance

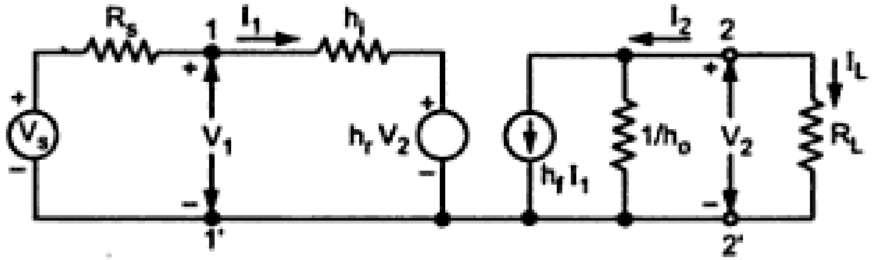


Transistor configurations and their hybrid models

Small Signal Analysis Of A Junction Transistor



Basic transistor amplifier



Transistor amplifier in its h-parameter model

small-signal analysis of a transistor amplifier

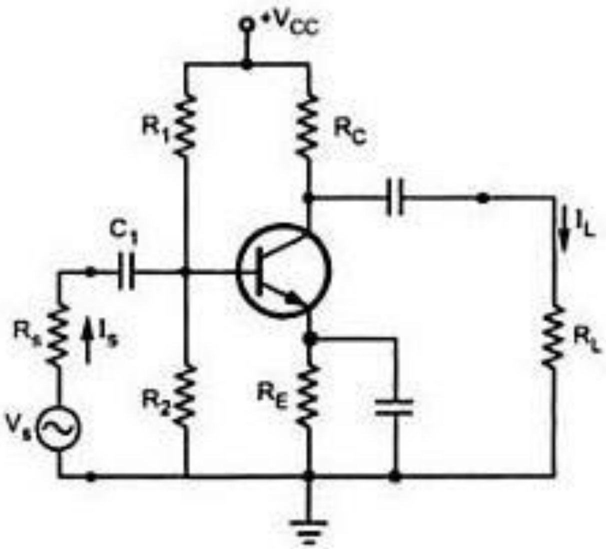
$A_i = -\frac{h_f}{1 + h_o R_L}$
$A_{is} = \frac{A_i R_s}{Z_i + R_s}$
$Z_i = h_i + h_r A_i R_L = h_i - \frac{h_f h_r}{h_o + Y_L}$
$A_v = \frac{A_i R_L}{Z_i}$
$A_{vs} = \frac{A_v R_i}{Z_i + R_s} = \frac{A_i R_L}{Z_i + R_s} = \frac{A_{is} R_L}{R_s}$
$Y_o = h_o - \frac{h_f h_r}{h_i + R_s} = \frac{1}{Z_o}$
$A_P = A_V A_i = A_i^2 \frac{R_L}{Z_i}$

Guidelines for Analysis of a Transistor Circuit

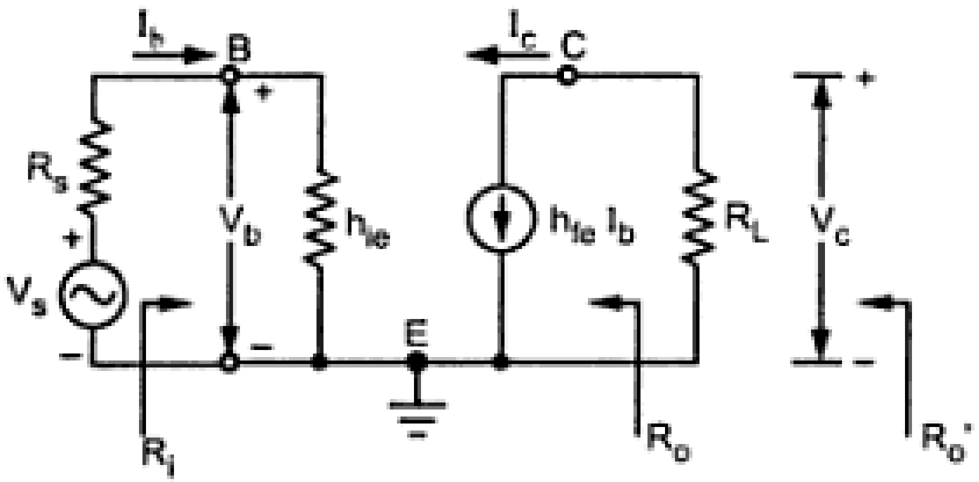
1. Draw the actual circuit diagram.
2. Replace coupling capacitors and emitter bypass capacitor by short circuit.
3. Replace dc source by a short circuit. In other words, short V_{CC} and ground lines.
4. Mark the points B(base), C(collector), E(emitter) on the circuit diagram and locate these points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

Problem

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



Approximate H-Model For CE Amplifier



Approximate CE model

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

Input Impedance $R_i \approx h_{ie}$

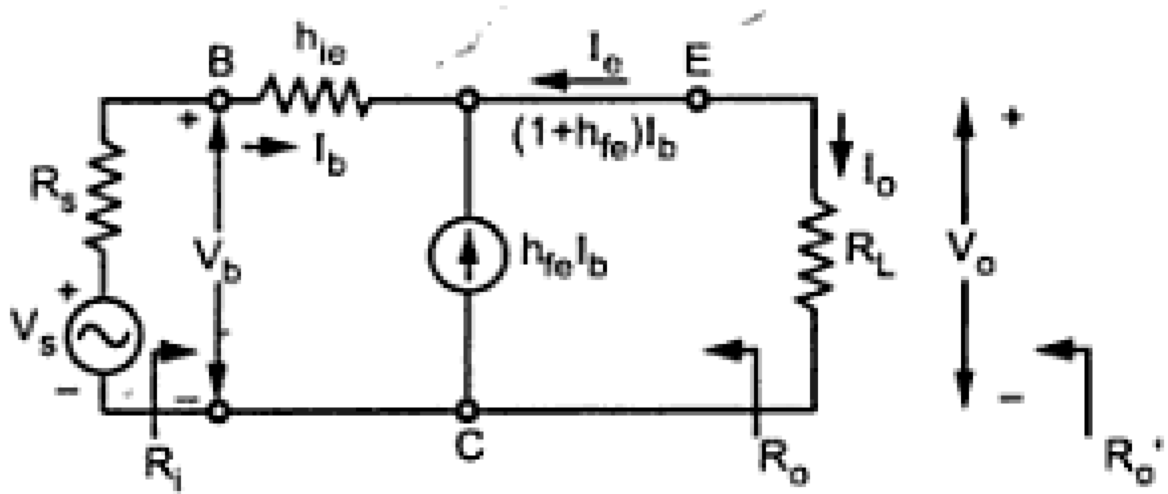
Voltage Gain : $A_v = \frac{A_i R_L}{R_i} = \frac{A_i R_L}{h_{ie}}$

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 $A_i = \frac{I_o}{I_b} = \frac{-I_e}{I_b} = 1 + h_{fe}$

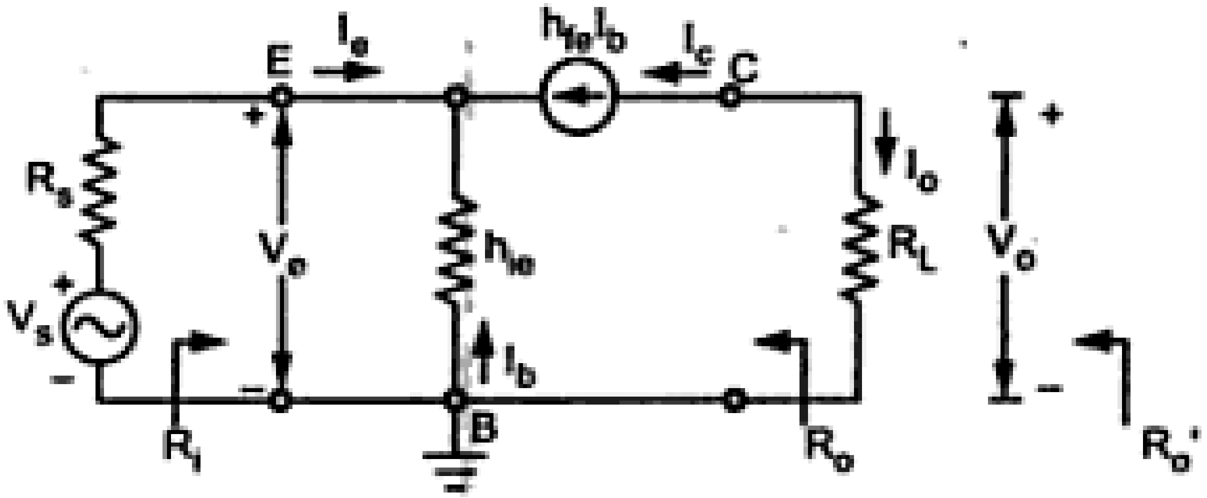
Input resistance : $R_i = \frac{V_b}{I_b} = h_{ie} + (1 + h_{fe})\, R_L$

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 $R_o = \frac{V_o}{I_e} = \frac{R_s + h_{ie}}{1 + h_{fe}}$

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

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)

$$A_v = \frac{\frac{h_{fe}}{1+h_{fe}} \times R_L}{\frac{h_{ie}}{1+h_{fe}}} \doteq \frac{h_{fe} R_L}{h_{ie}}$$

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

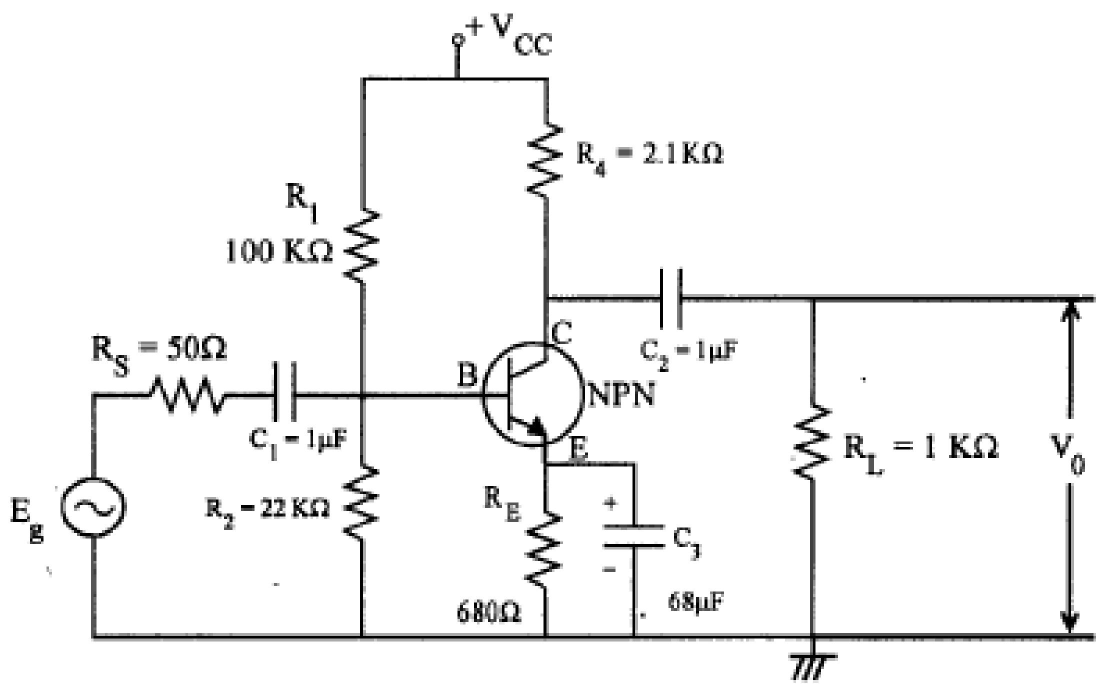
$$\underline{R'_o = R_o \parallel R_L = \infty \parallel R_L = R_L}$$

Problem

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

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

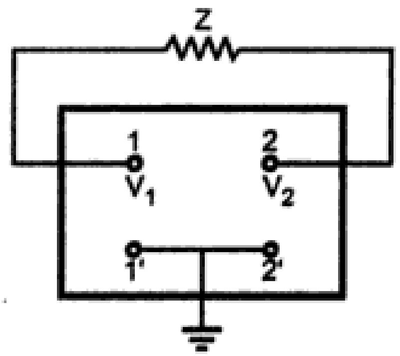
$I_b = 100\ \mu A$.



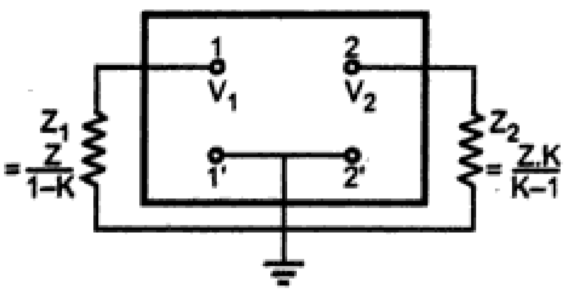
CE Amplifier Circuit

Miller's Theorem

Millers theorem is used to simplify the analysis of a circuit whenever there is a feedback connection in the circuit



(a)

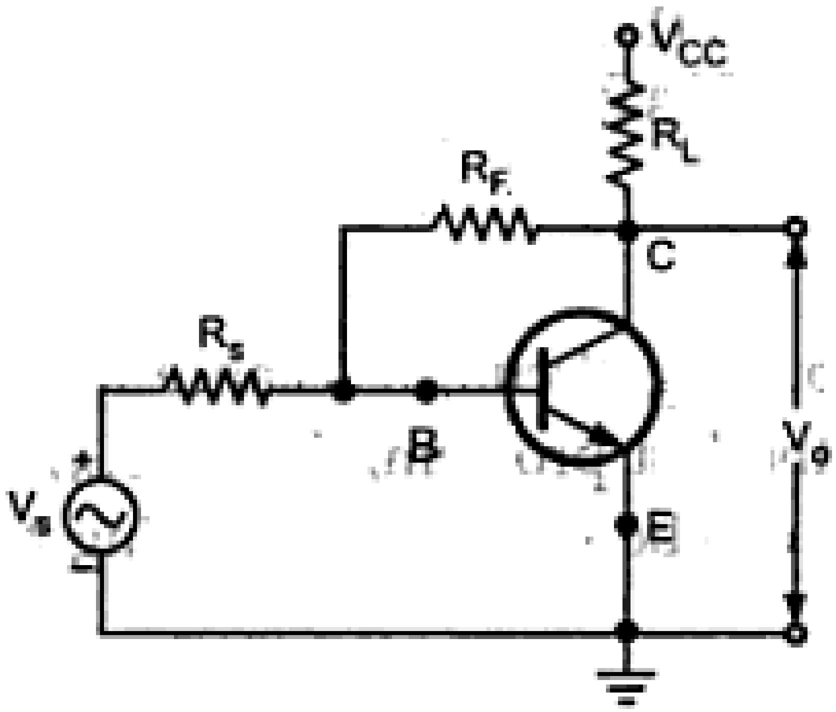


(b)

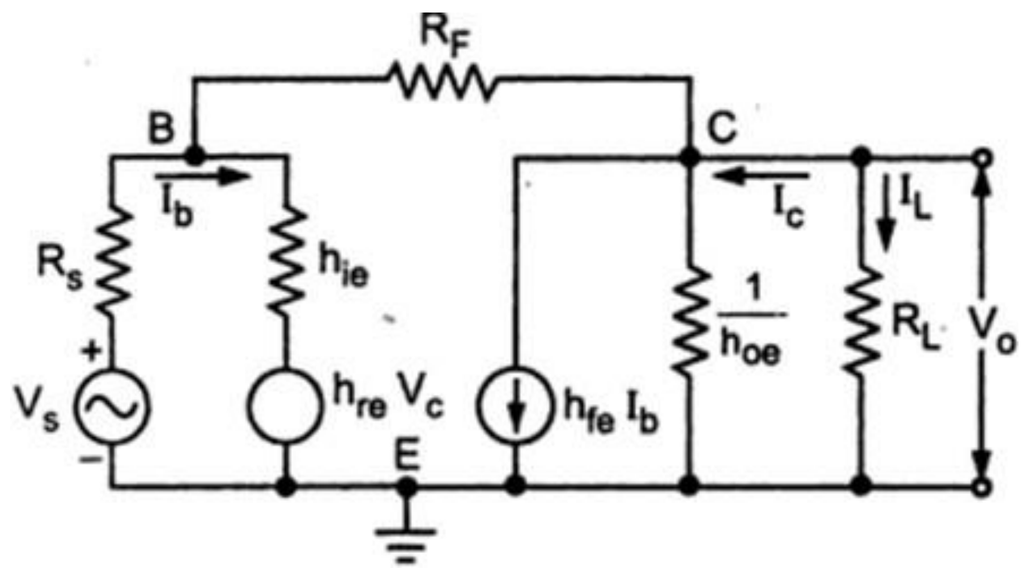
$$Z_1 = \frac{Z}{1-K}$$

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

Analysis of Common Emitter Amplifier with Collector to Base Bias

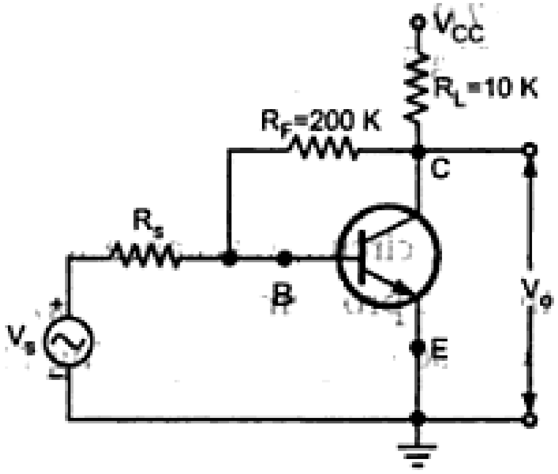


AC equivalent circuit



Problem

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



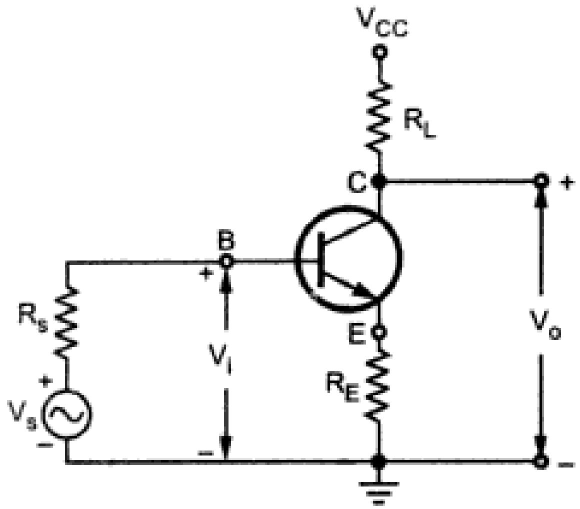
Problem

➡ 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 $R_2 = 0$?

$$h_{ie} = 1100\Omega \; ; \qquad h_{fe} = 50$$

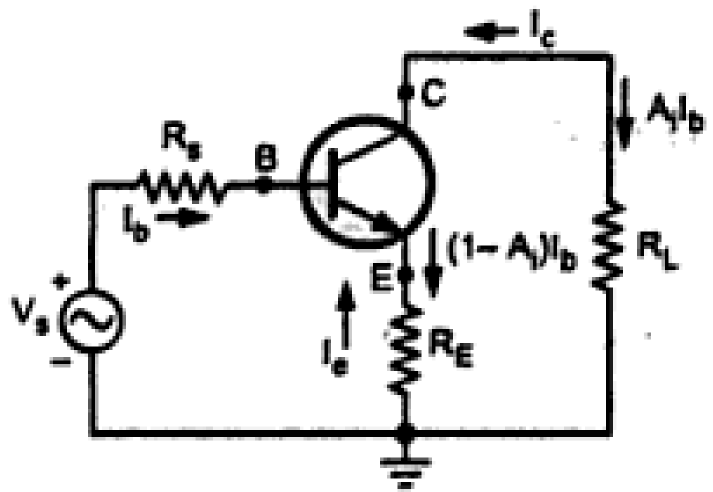
$$h_{re} = 2.50 \times 10^{-4} \; ; \qquad h_{oe} = 25\mu\, A/v$$

Analysis Of CE Amplifier With Unbypassed R_E

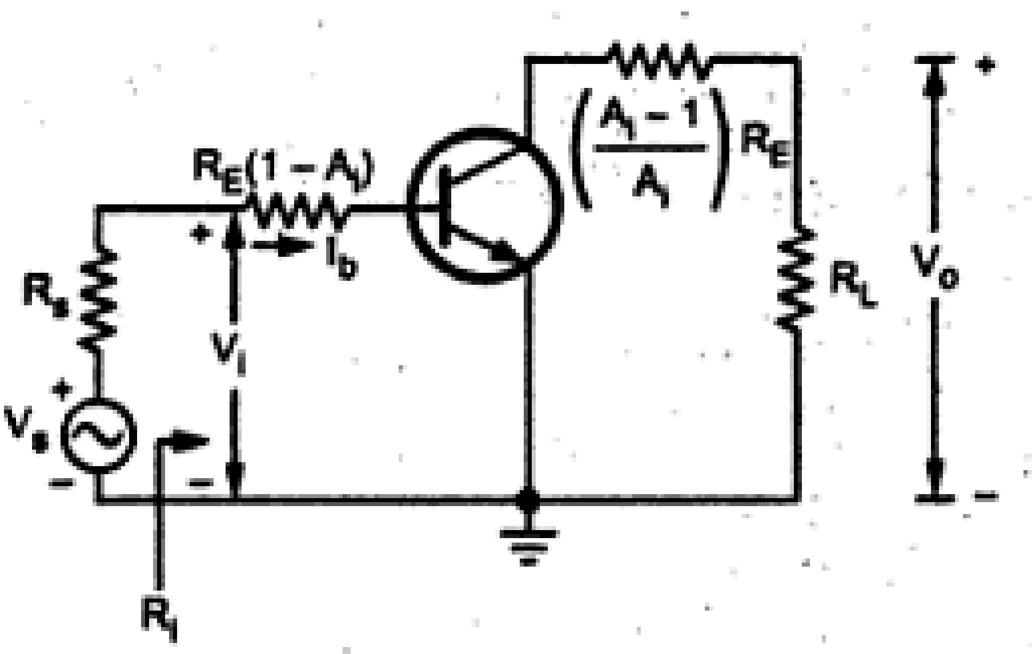


- R_E is added to stabilize the gain of the amplifier
- R_E acts as a feedback resistor
- The overall gain will reduce with unbypassed R_E

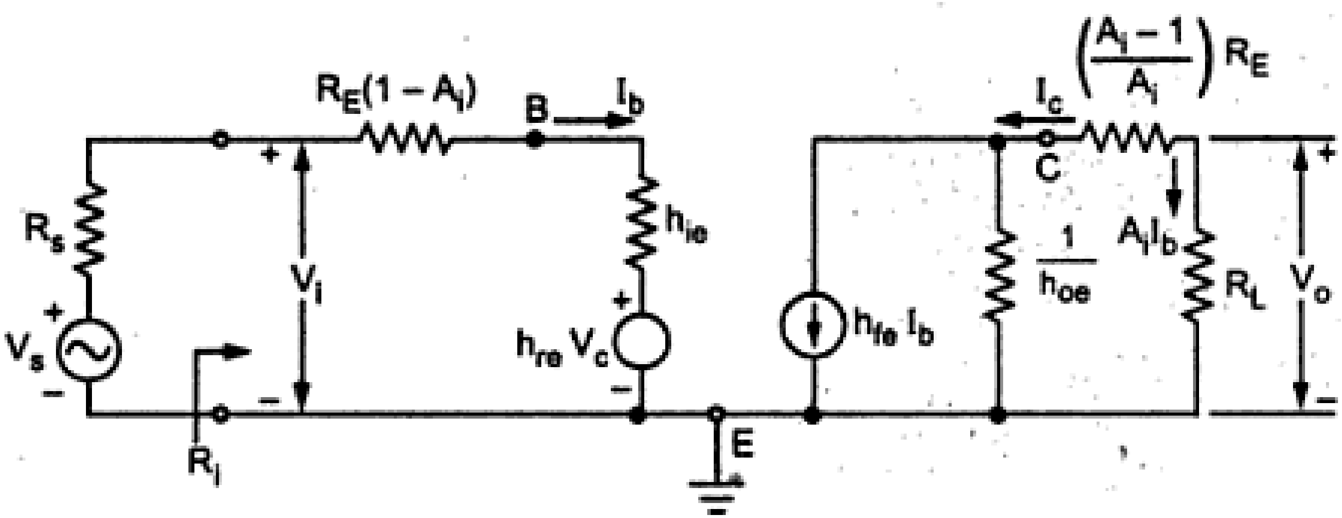
AC Equivalent Circuit For CE Amplifier with Unbypassed R_E



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

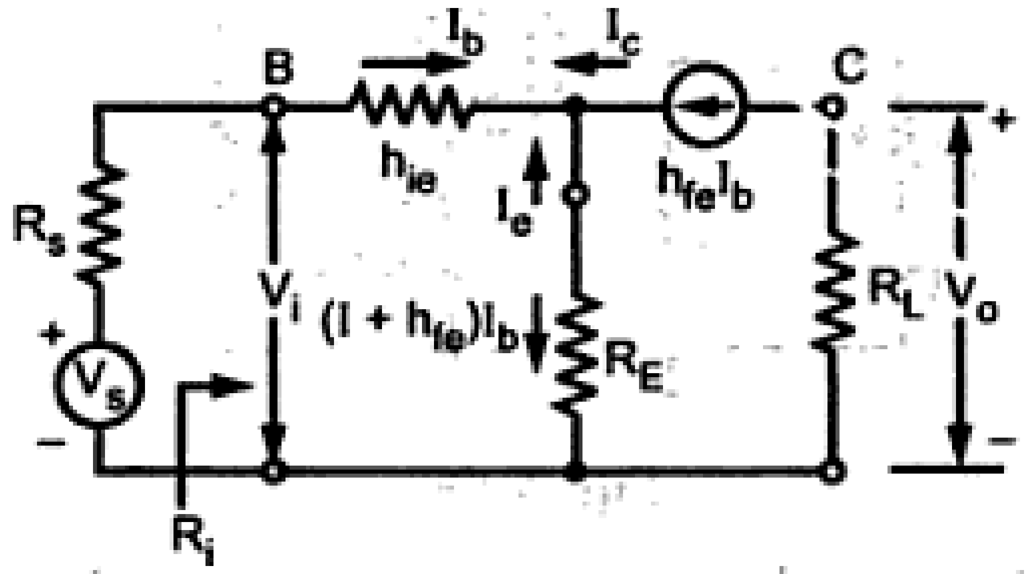


h-Parameter Equivalent Circuit (Exact Analysis)



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

h-Parameter Equivalent Circuit (Approximate Analysis)



Approximate model for CE amplifier with R_E

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

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

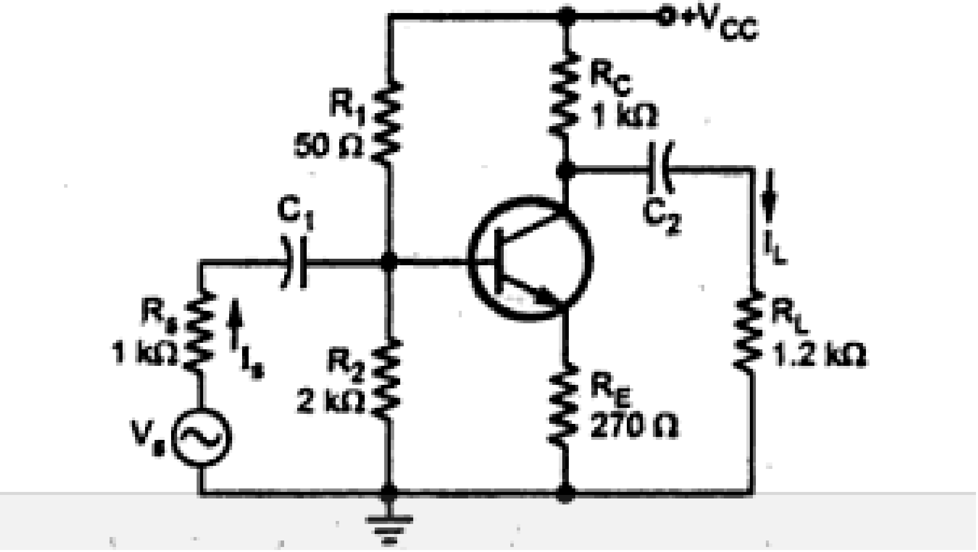
Voltage gain $A_v = \frac{A_i R_L}{R_i} = \frac{-h_{fe} R_L}{h_{ie} + (1 + h_{fe}) R_E}$

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

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

Problem

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*



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Analog circuits

UNIT No: 2

FET Amplifiers

FET BIASING

- Voltage controlled device
- General relationships that can be applied to the dc analysis of all FET amplifiers are

$$IG \cong 0A \quad \text{and} \quad I_D = I_S$$

- For JFETs and depletion – type MOSFET and MESFET , Shockley's equation is applied to relate the input and output quantities

$$I_D = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$

- For enhancement-type MOSFETs and MOSFETs

$$I_D = k_n (V_{GS} - V_P)^2$$

- Different biasing circuit of FET are

  Fixed Bias

  Self Bias

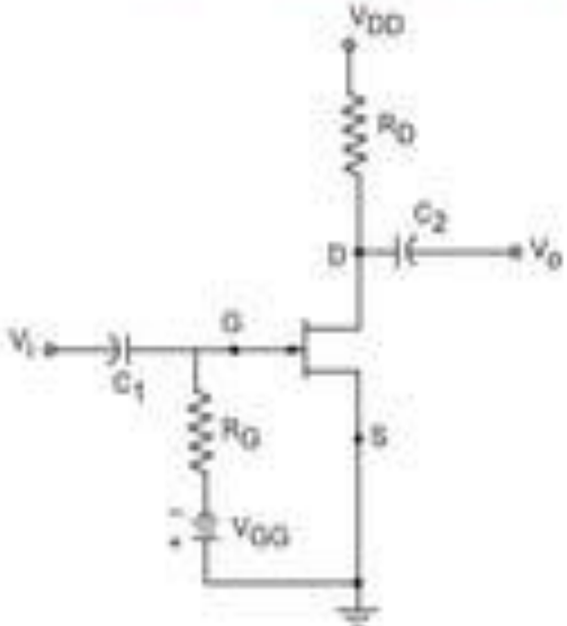
FIXED BIAS

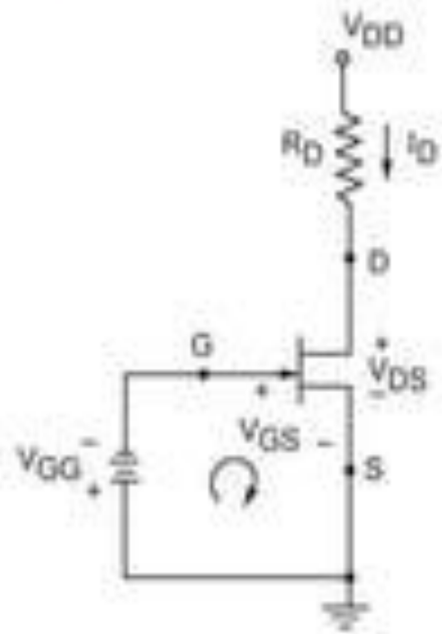
- For dc analysis

  ac input signal = 0

  C1 and C2 – open circuit (∵f = 0)

  $I_G \approx 0A$, $V_{RG} = I_G R_G = 0\,V$





VOLTAGE DIVIDER BIAS

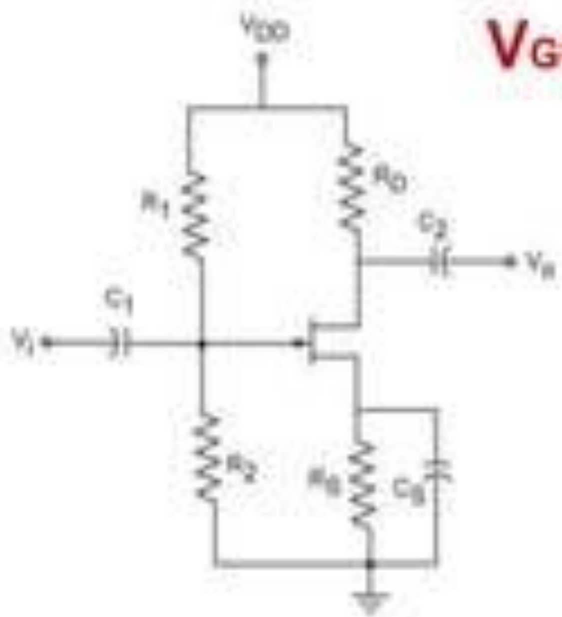
- For dc analysis

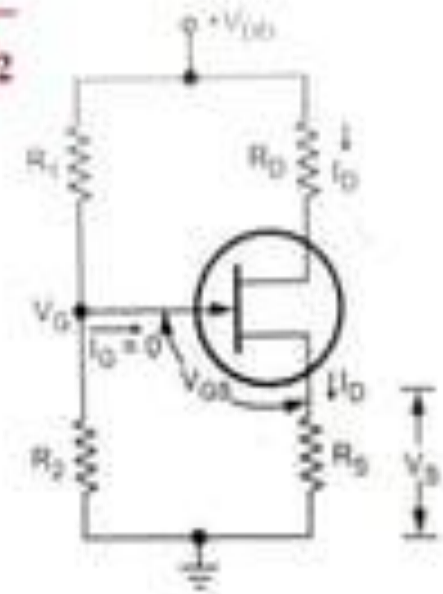
ac input signal = 0

C_1 and C_2 – open circuit ($\because f = 0$)

$I_G \approx$ 0A , $V_{RG} = I_G R_G = 0$ V

$$V_G = V_{DD}\frac{R_2}{R_1 + R_2}$$





Problems

For the circuit shown in the figure calculate V_{GSQ}, I_{DQ} and V_{DSQ} and draw dc load line.

Given data:

$V_{DD} = 8V$

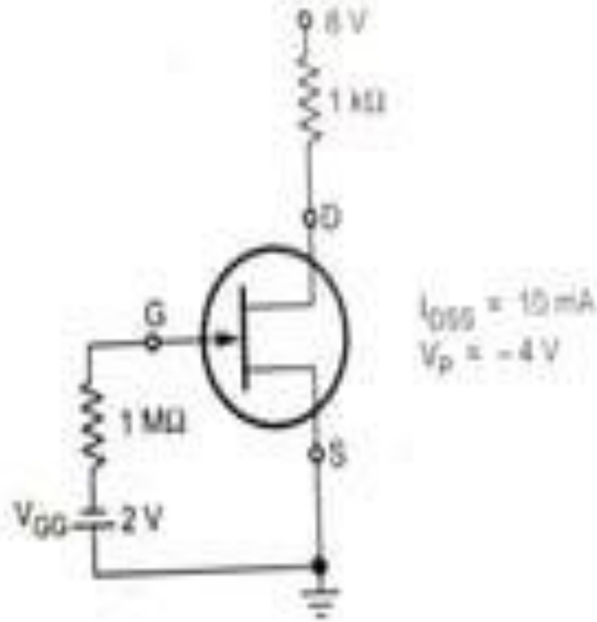
$R_D = 1k\Omega$

$V_{GG} = 2V$

$R_G = 1M\Omega$

$I_{DSS} = 10mA$

$V_P = -4V$



FET small signal model

⇒ The linear small signal model is same as the BJT.

⇒ We can formally express as

$$i_D = f(v_{GS}, v_{DS})$$

Transconductance g_m and Drain Resistance r_d

⇒ If both v_{GS} and v_{DS} both are variable.

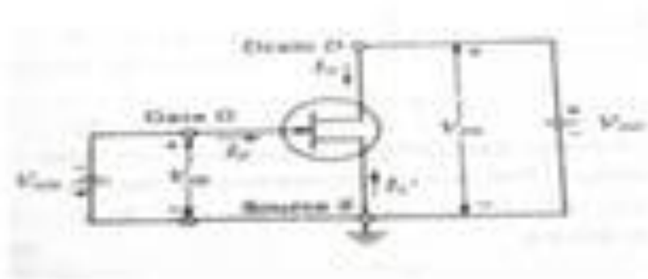
$$\triangle i_D = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{v_{DS}} \triangle v_{GS} + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{v_{GS}} \triangle v_{DS}$$

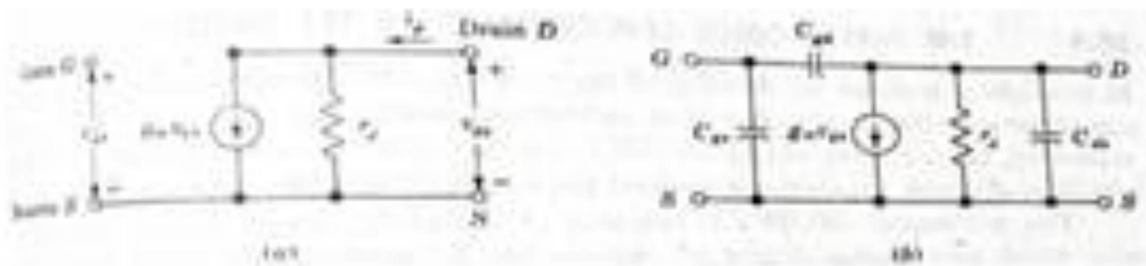
⇒ In small signal model, $\triangle i_D = i_d$, $\triangle v_{GS} = v_{gs}$, $\triangle v_{DS} = v_ds$

⇒ From above relation,

$$i_d = g_m v_{gs} + \frac{1}{r_d} v_{ds}$$

FET Model





⇒ (a) The low-frequency small-signal FET model.

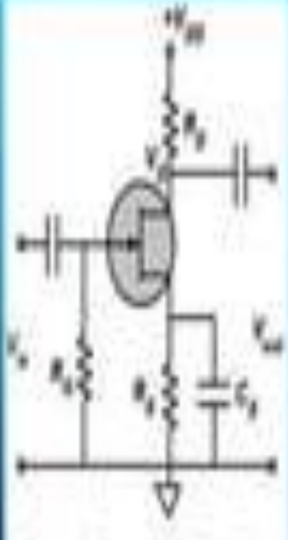
⇒ (b) The high-frequency model, taking node capacitors into account

CS AMPLIFIER

Common source FET configuration is probably the most widely used of all the FET circuit configurations.

Like its bipolar counterpart the common emitter circuit, the FET common source amplifier provides a good level of all round performance for many applications.

The common source circuit provides a medium input and output impedance levels. Both current and voltage gain can be described as medium, but the output is the inverse of the input, i.e. 180° phase change. This provides a good overall performance and as such it is often thought of as the most widely used configuration.



Common Sorce JFET Amplifier

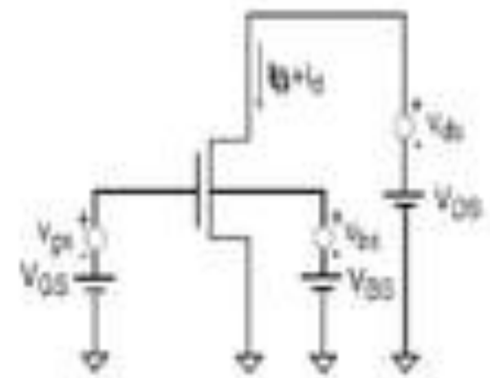
DESIGN OF CS AMPLIFIER

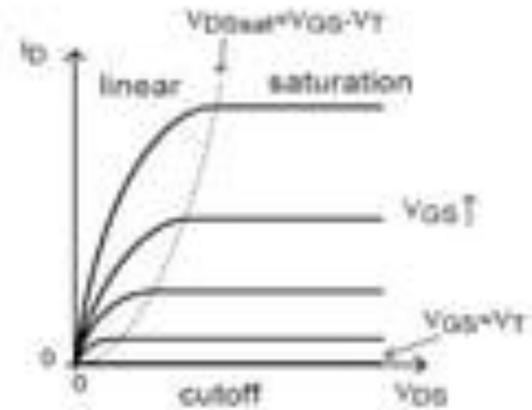
Following Design Specification are generally given :

- Desired voltage gain
- DC supply Vdd
- Frequency response
- Signal source impedance
- Load Impedance

Low-Frequency Small-Signal Equivalent Circuit Model

Regimes of Operations of MOSFET





Analog Circuits

UNIT No: 3

Multistage amplifiers

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

Distortion in amplifiers

There are 3 types of distortion in amplifiers

1. Amplitude Distortion or Non linear distortion

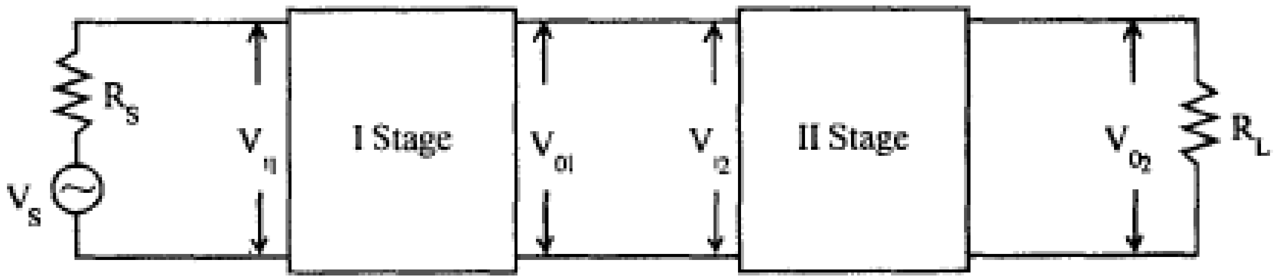
2. Frequency distortion

3. Phase distortion

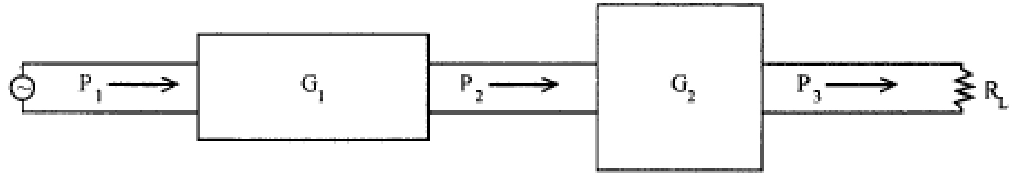
Need For Cascading

- 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



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

Overall gain $$G = \frac{P_3}{P_1}$$

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

$$\mathbf{G = G_1 G_2}$$

Decibel Voltage Gain

Cascaded Stages

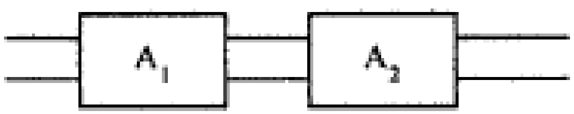


Fig. 2.23 Cascaded stages

$A = A_1 \times A_2$

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

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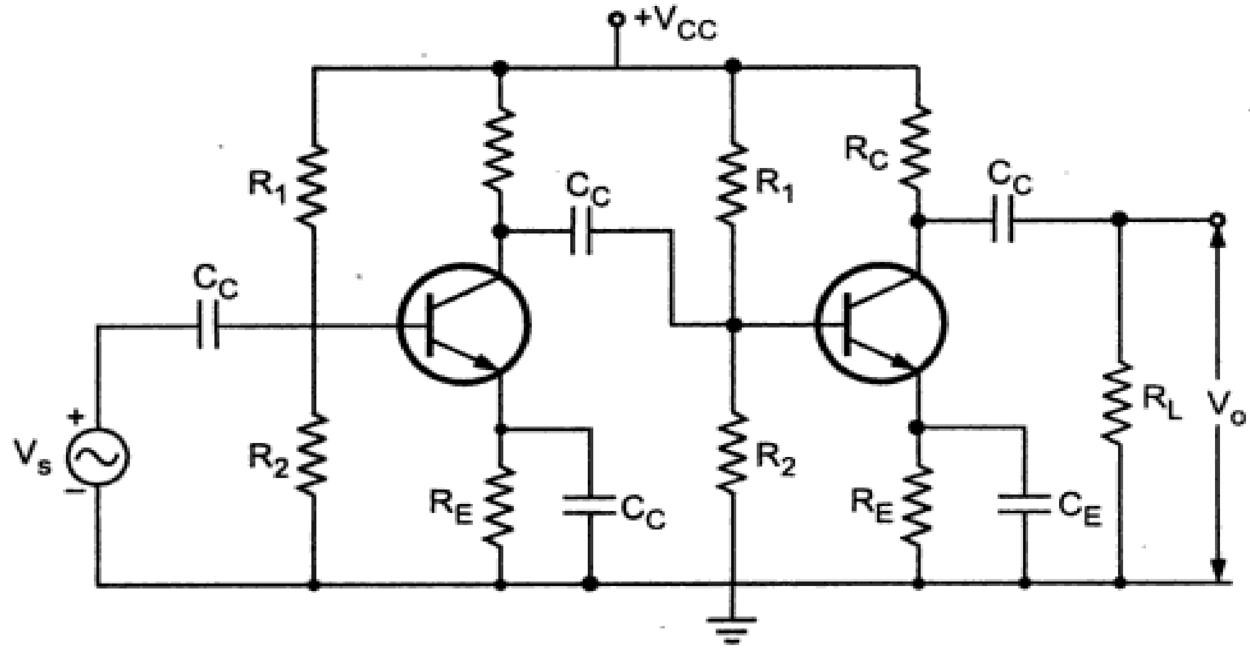
Electronic circuit analysis
UNIT No: 1
Topic :Methods of interstage coupling
K.Lakshmi

Methods of Inter Stage Coupling

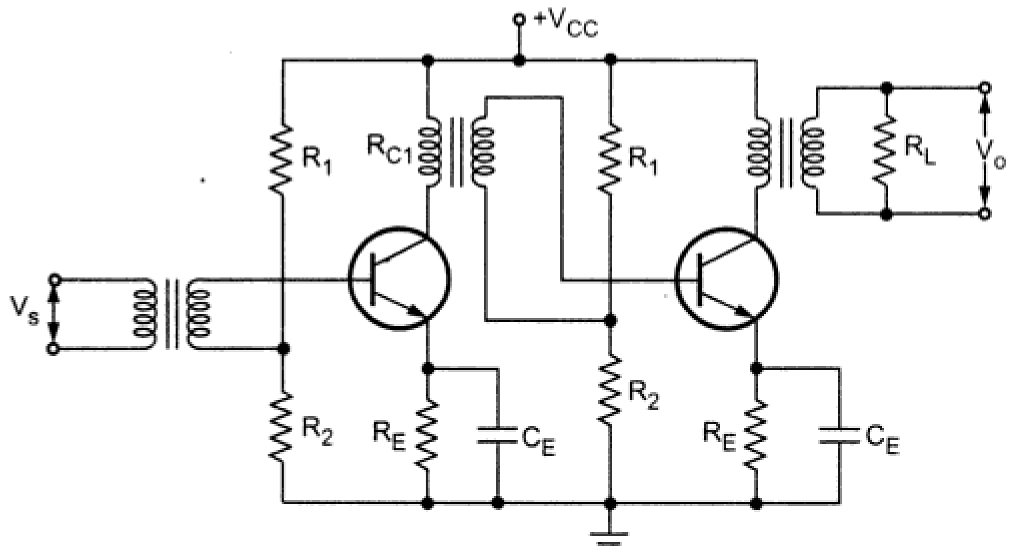
In multistage amplifier, the output signal of preceding stage is to be coupled to the input circuit of succeeding stage. For this interstage coupling, different types of coupling elements can be employed. These are :

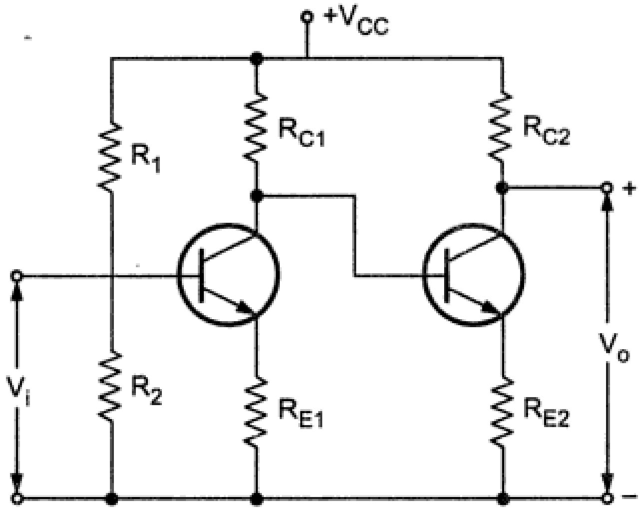
1. RC coupling
2. Transformer coupling
3. Direct coupling



Two stage RC coupled amplifier using transistors

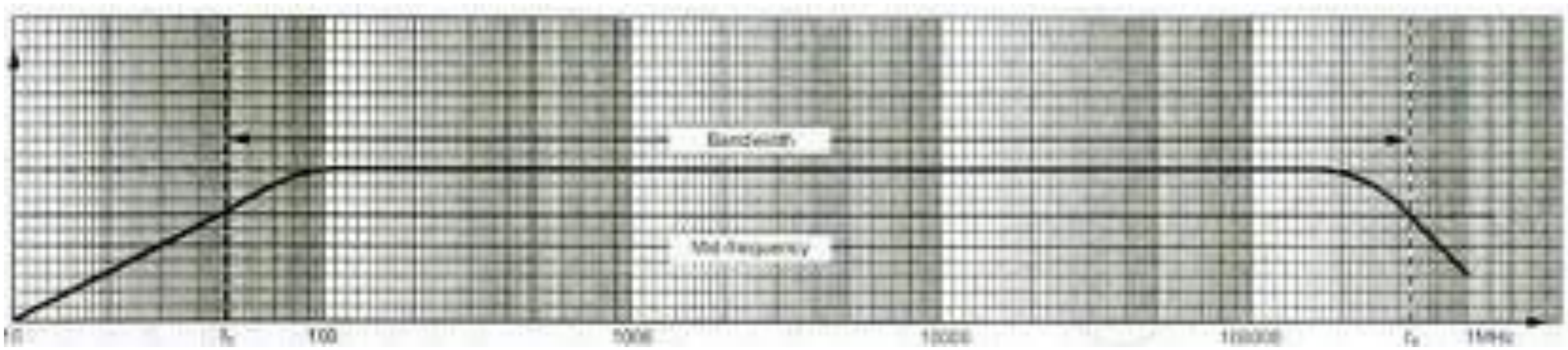
Two stage transformer coupled amplifier using transistors





Two stage directly coupled amplifier using transistors

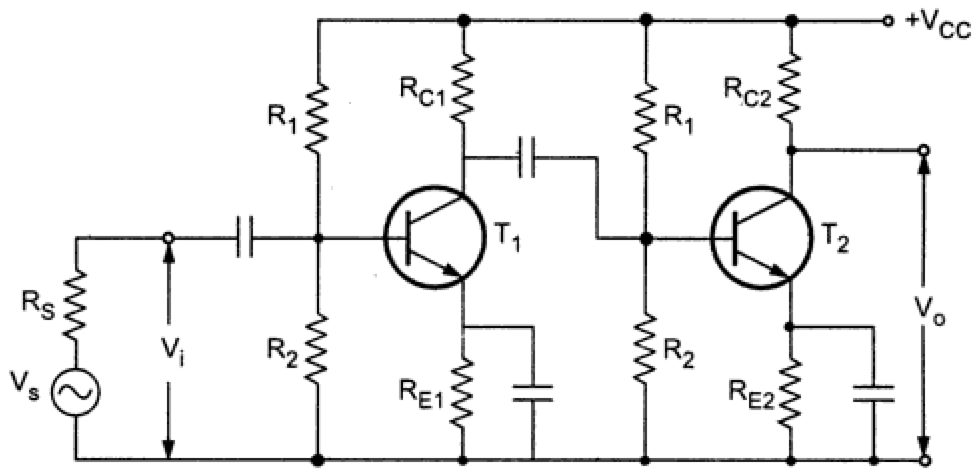
Frequency Response of 2-Stage RC Coupled Amplifier



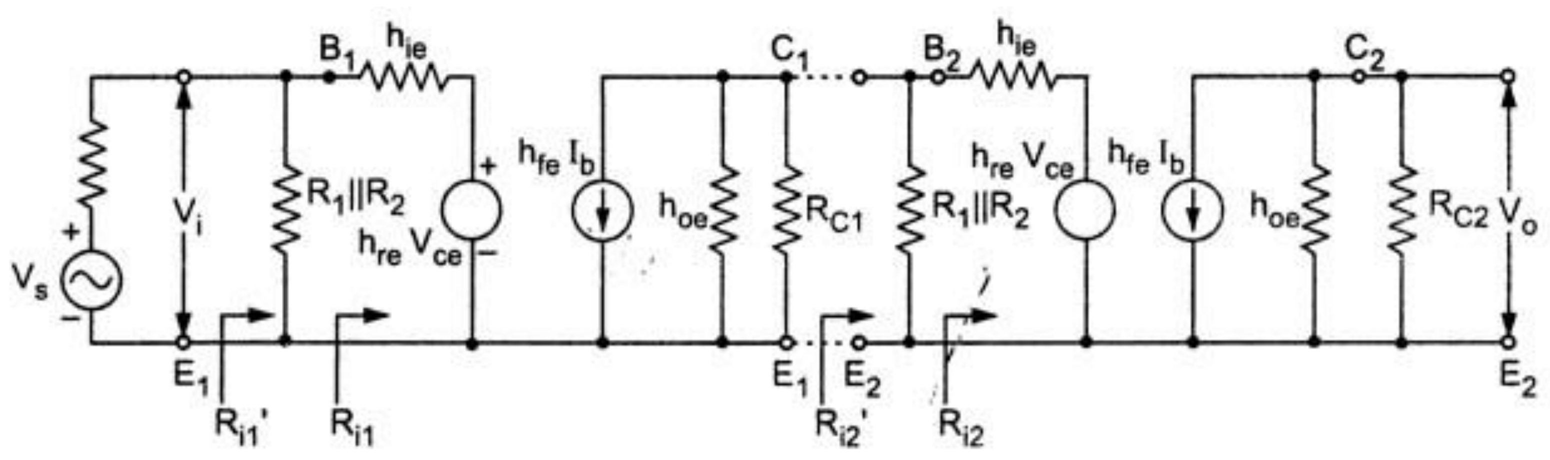
Comparison Between Coupling Method

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 pubic 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.

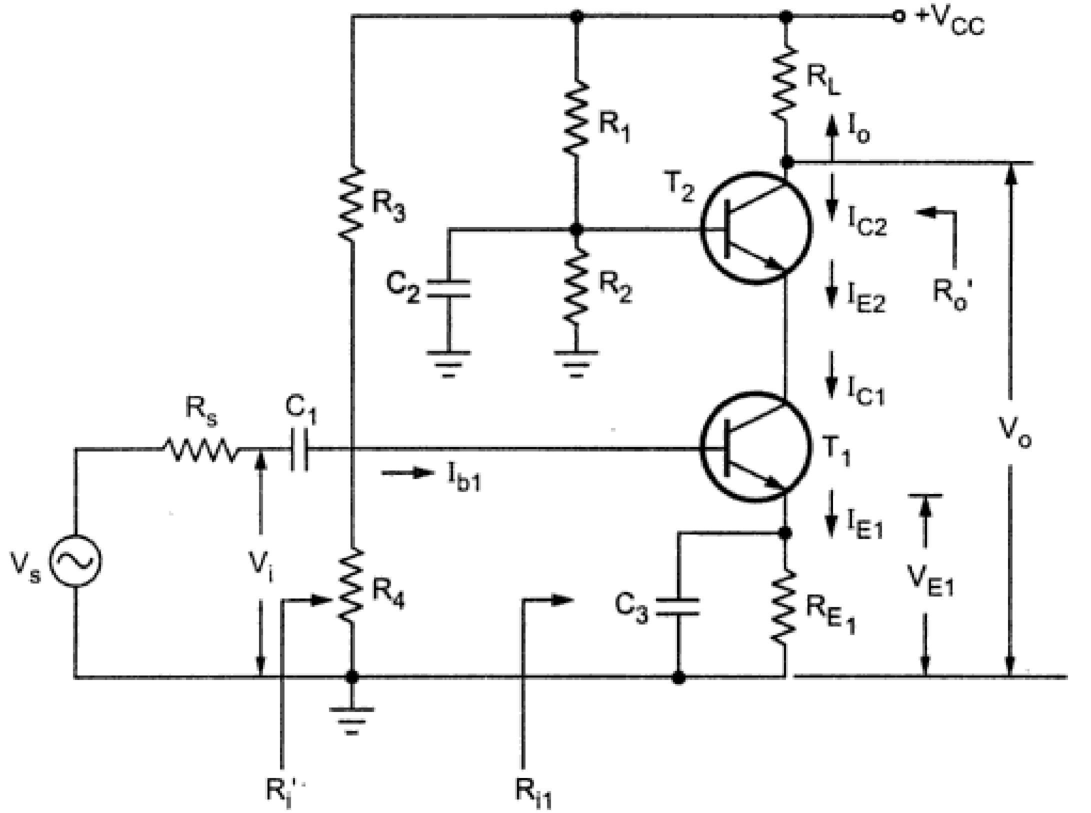
CE-CE Cascade Amplifier



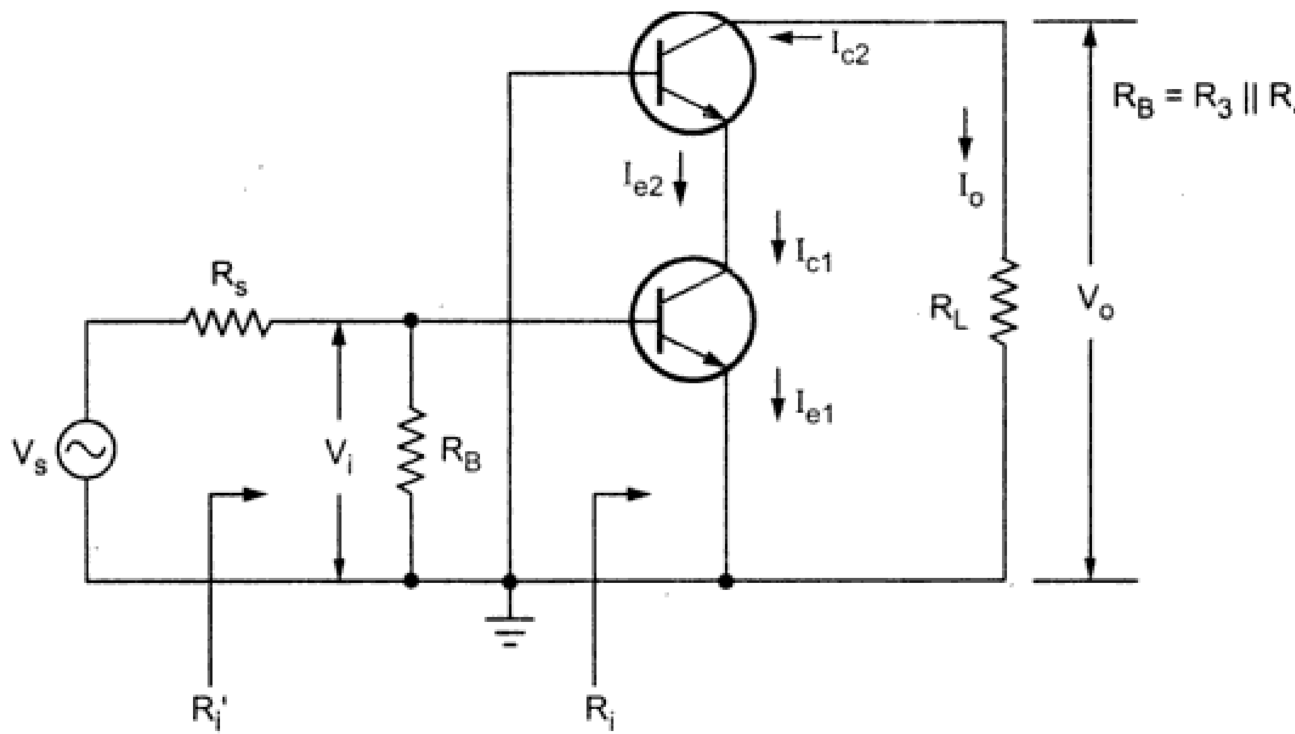
h-parameter equivalent circuit for CE-CE cascade amplifier



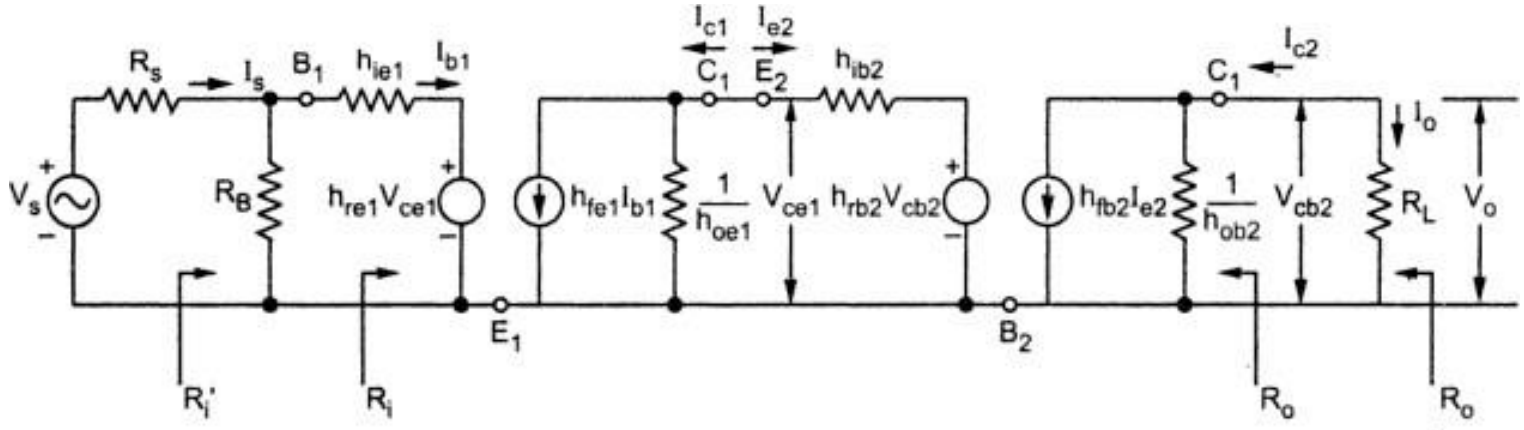
Cascode Amplifier



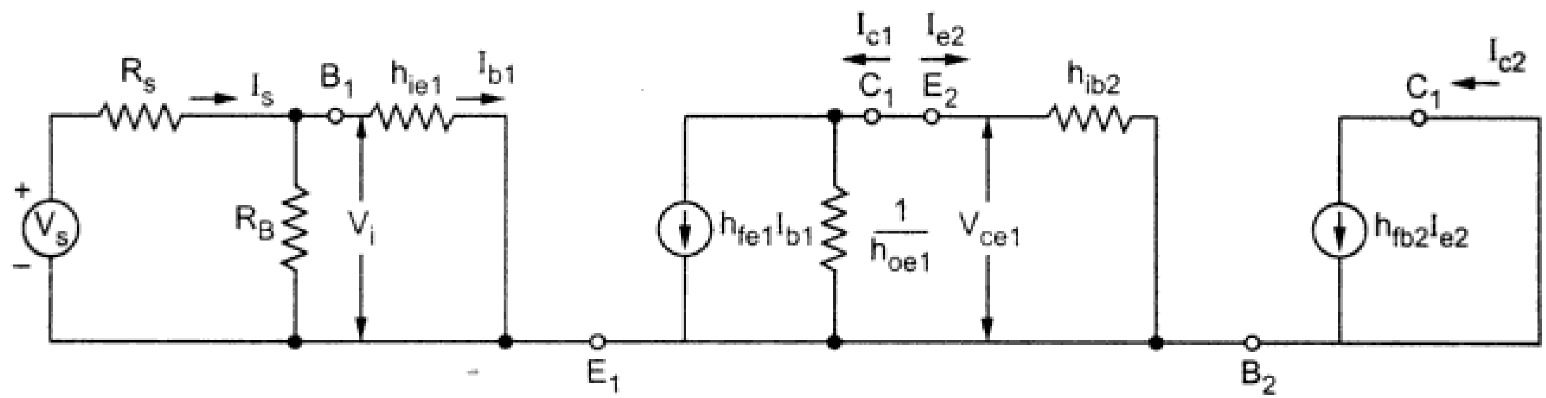
AC equivalent circuit



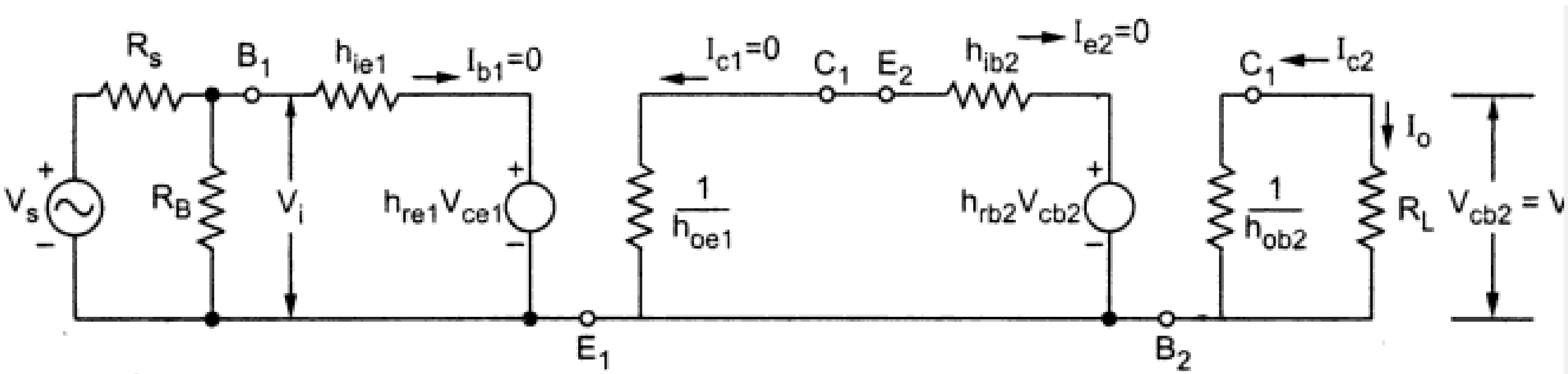
h-parameter equivalent circuit for cascode amplifier



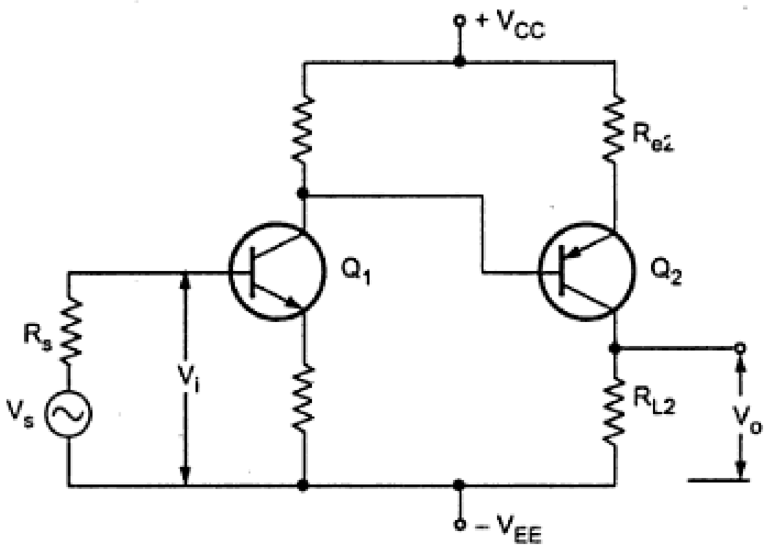
h-parameter equivalent circuit when output shorted



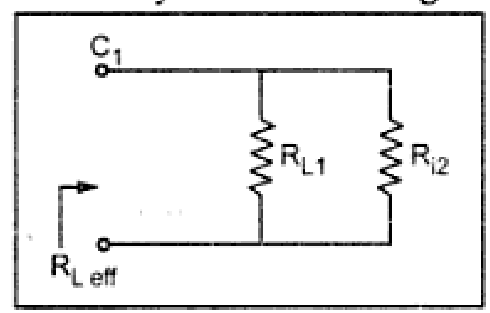
h-parameter equivalent circuit when $I_b = 0$



CE-CC Amplifier

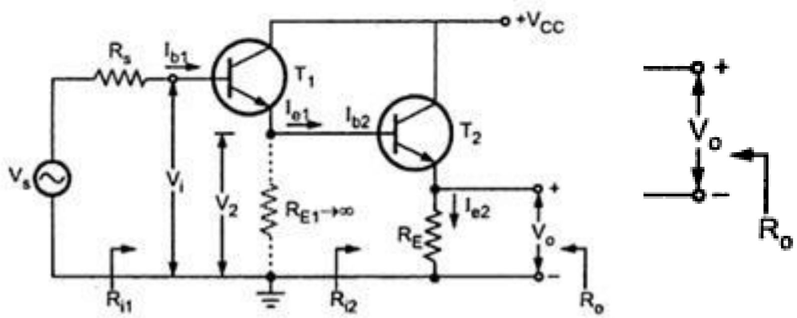


Analysis for first stage

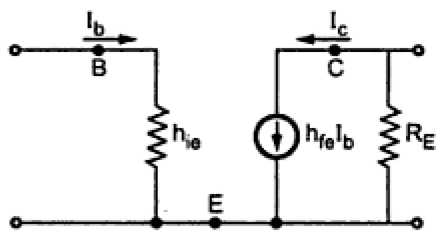


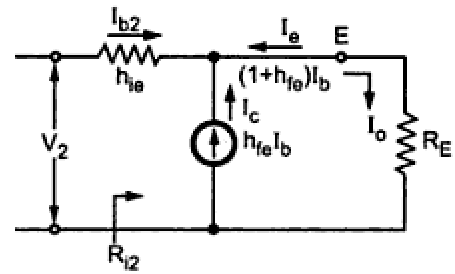
Darlington Transistors

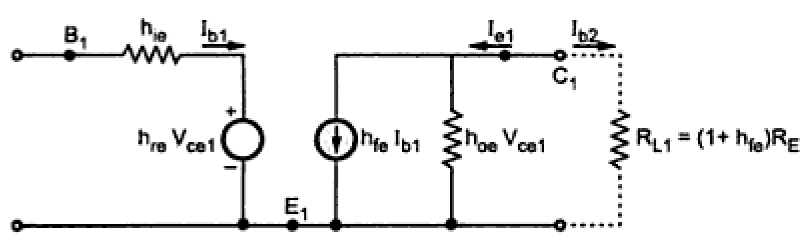
Darlington Transistors $+V_{CC}$

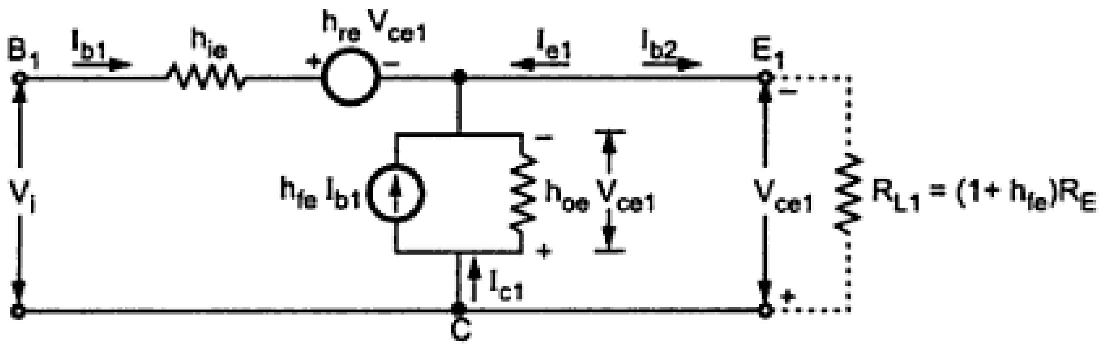


AC Equivalent Circuit :



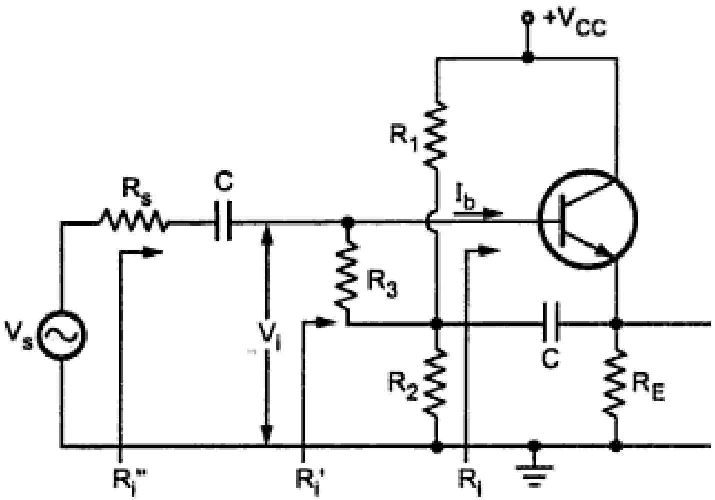


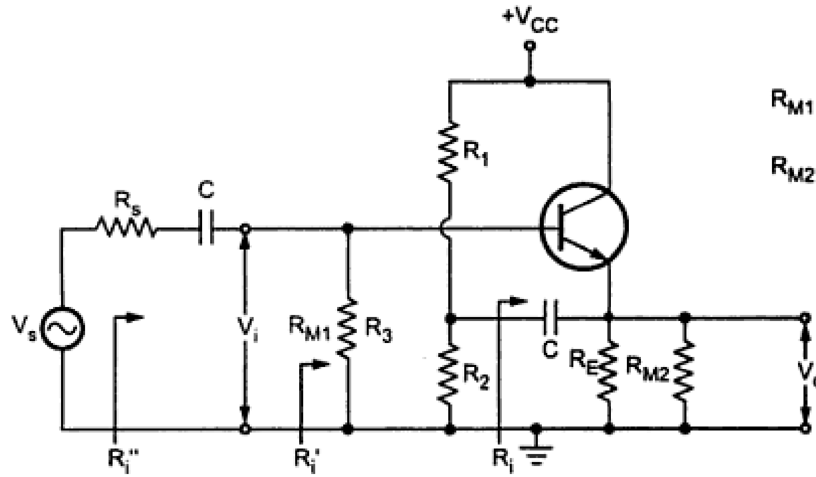




Parameter	Single stage	Darlington
Input Resistance	$R_i = (1 + h_{fe})\, R_E = 168.3\ k\,\Omega$	$R_i = \frac{(1+h_{fe})^2 R_E}{1+h_{oe}\,(1+h_{fe})\,R_E} \approx 1.65\ M\,\Omega$
Current Gain	$A_i = 1 + h_{fe} = 51$	$A_i = \frac{(1+h_{fe})^2}{1+h_{oe}\,(1+h_{fe})\,R_E} \approx 500$

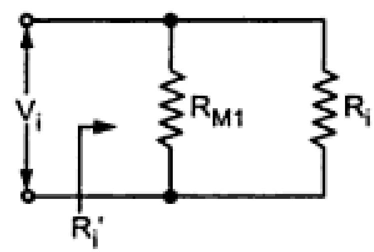
Bootstrap Emitter Follower



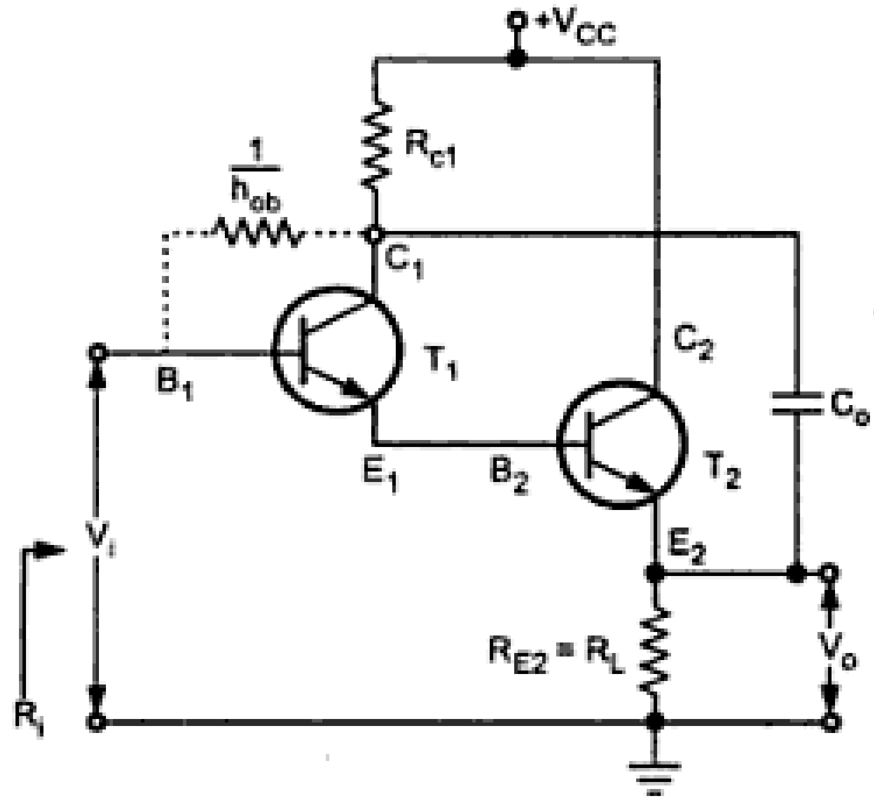


$$R_{M1} = \frac{R_3}{1 - A_v}$$

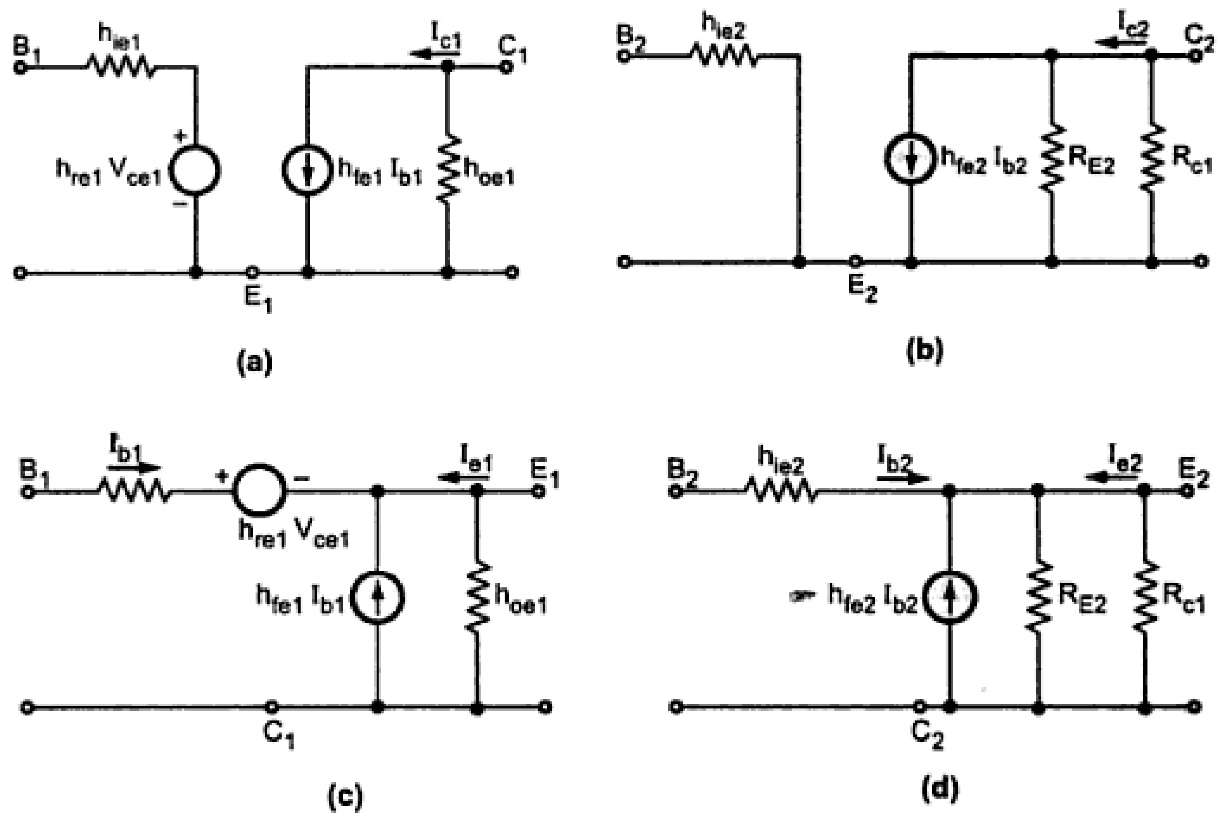
$$R_{M2} = \frac{R_3 A_v}{A_v - 1}$$

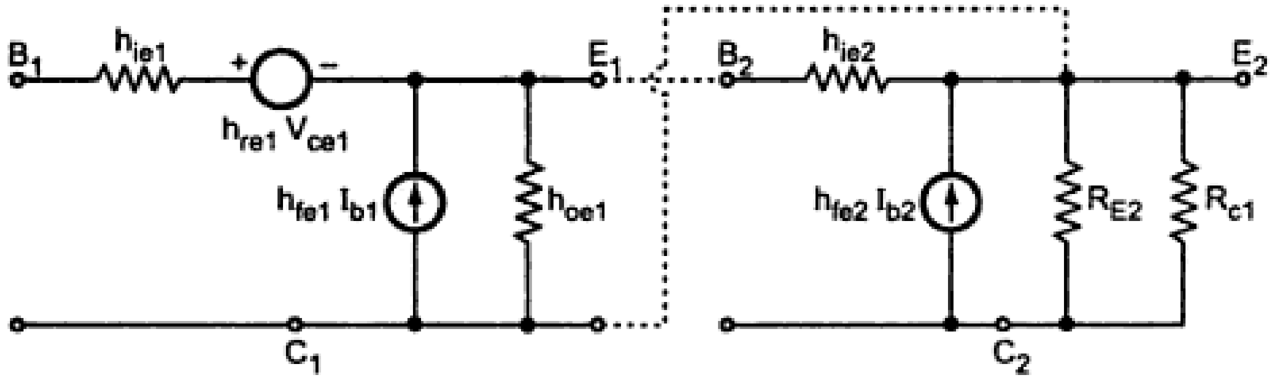


Bootstrapped Darlington circuit

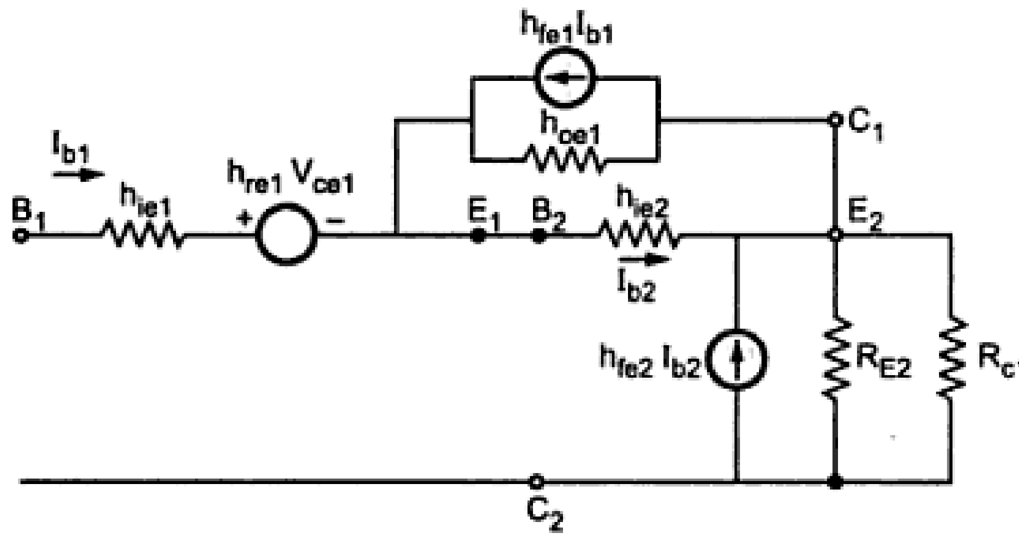


AC Equivalent circuit for bootstrapped Darlington circuit



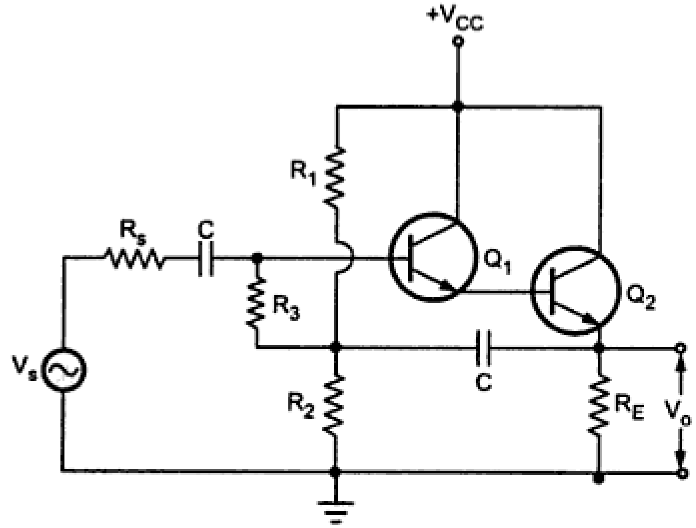


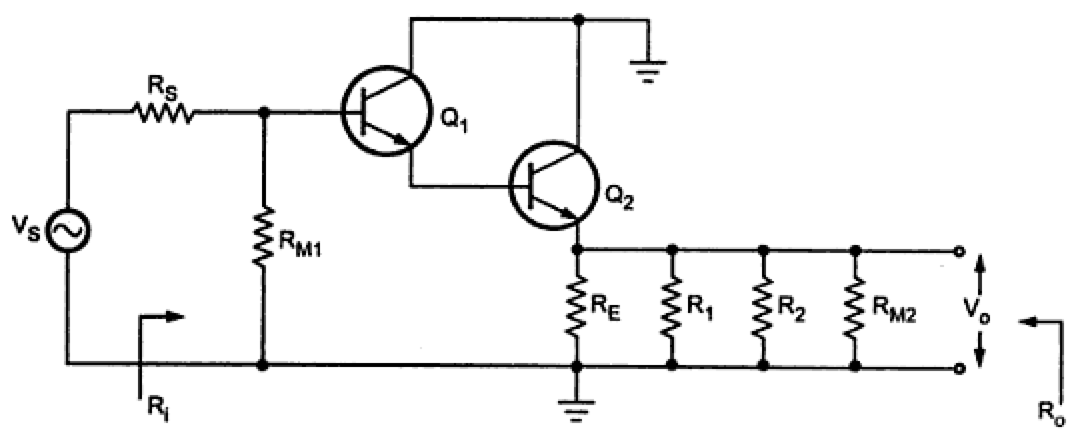
B_1
h_{ie1}
+
−
$h_{re1}\ V_{ce1}$
E_1
B_2
h_{ie2}
E_2
$h_{fe1}\ I_{b1}$
h_{oe1}
$h_{fe2}\ I_{b2}$
R_{E2}
R_{c1}
C_1
C_2



$h_{fe1}I_{b1}$
C_1
h_{oe1}
I_{b1}
$h_{re1}\ V_{ce1}$
h_{ie1}
B_1
+
−
E_1
B_2
h_{ie2}
E_2
I_{b2}
$h_{fe2}\ I_{b2}$
R_{E2}
R_{c1}
C_2

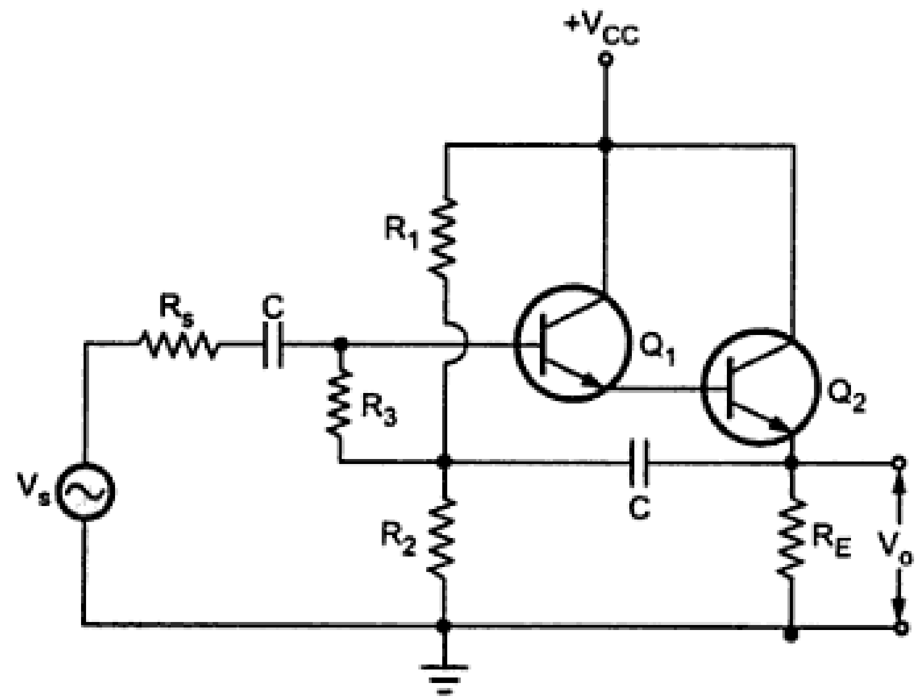
Bootstrapped Darlington Circuit Alternative Approach

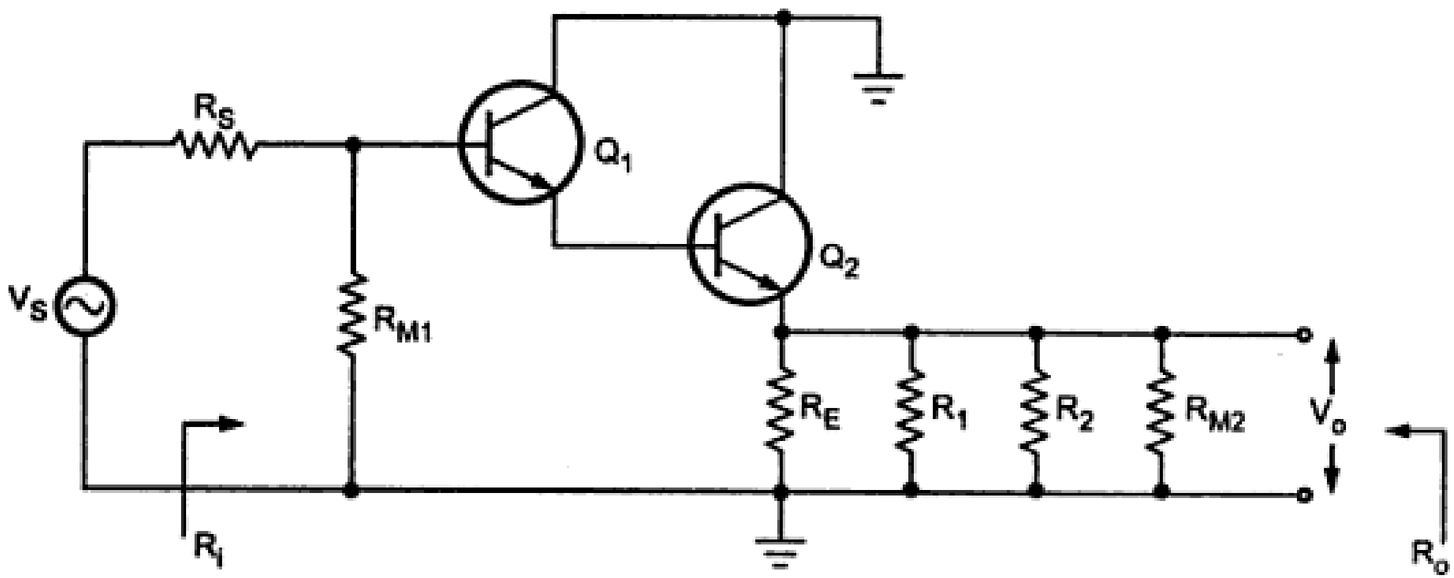




AC equivalent circuit

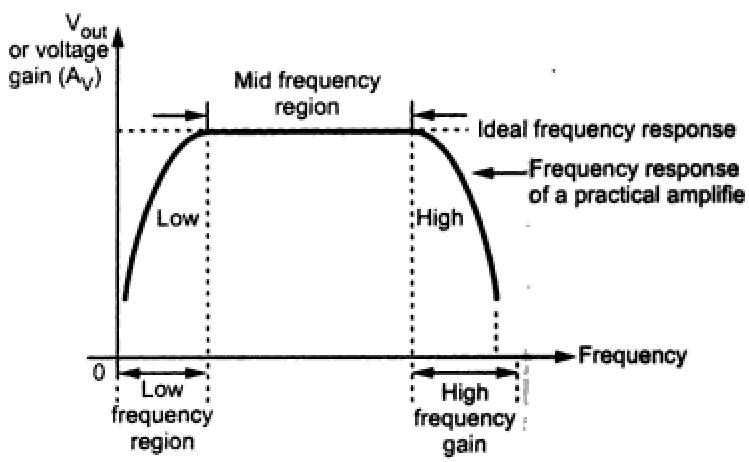
Bootstrapped Darlington Circuit Alternative Approach



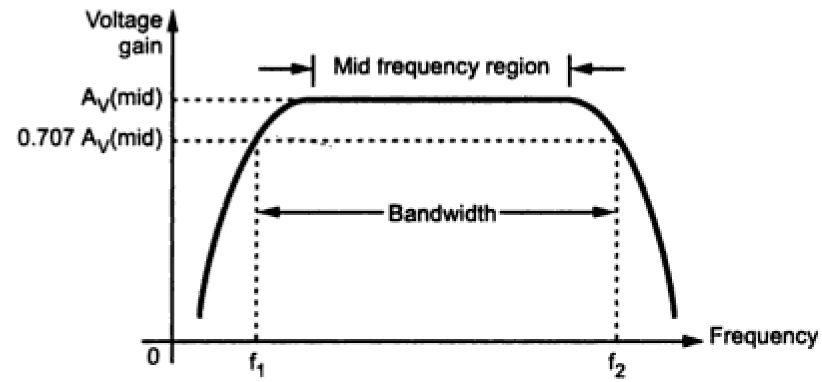


AC equivalent circuit

Frequency Response of an RC Coupled Amplifier

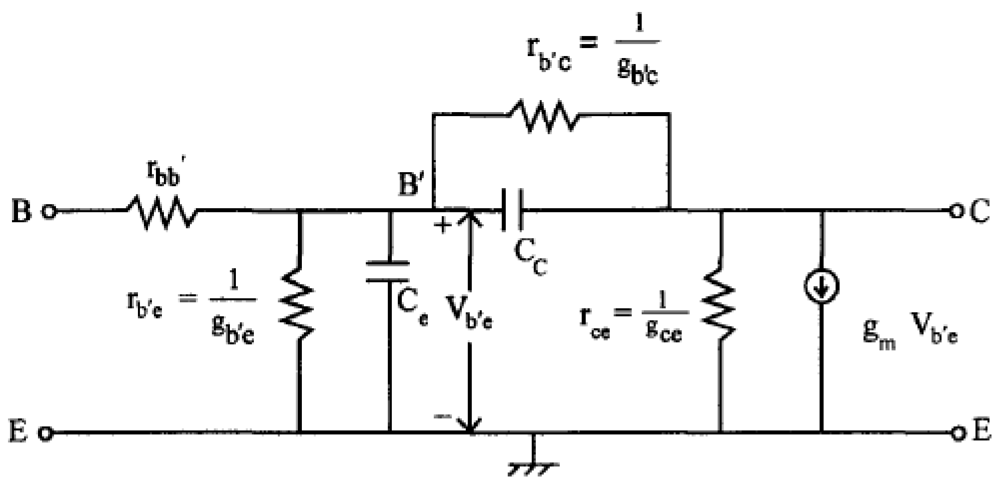


Bandwidth of an Amplifier



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

Hybrid – π   Common Emitter Transc onductance Model



Hybrid - π C.E BJT Model

The High frequency model parameters of a BJT in terms of low frequency hybrid parameters is given below

Transconductance $g_m = I_c/V_t$

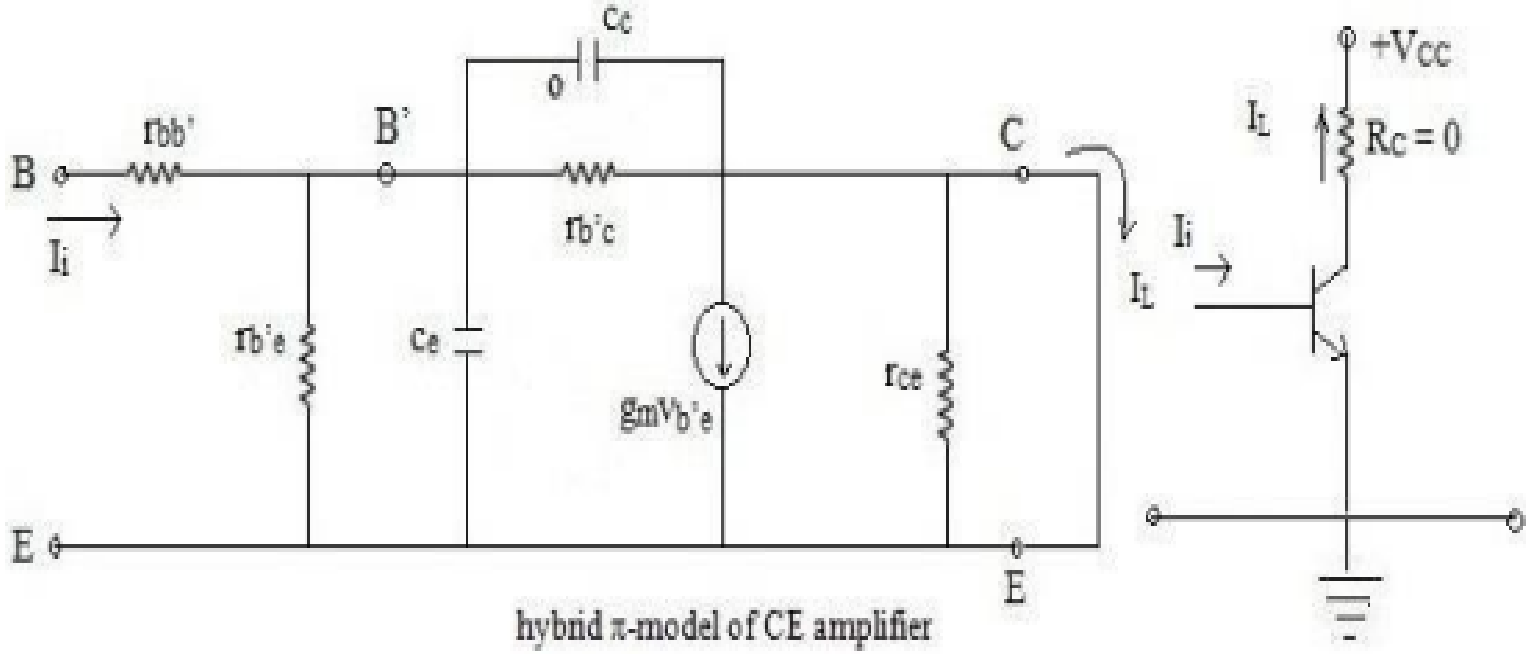
Internal Base node to emitter resistance $r_{b'e} = h_{fe}/ g_m = (h_{fe} * V_t)/ I_c$

Internal Base node to collector resistance rb'e = (hre* rb'c) / (1- hre) assuming hre << 1 it reduces to rb'e = (hre* rb'c)

Base spreading resistance rbb' = hie – rb'e = hie – (hfe* Vt)/ Ic

Collector to emitter resistance rce = 1 / (hoe – (1+ hfe)/rb'c)

The C_E short circuit current gain (A_i)



hybrid π-model of CE amplifier

$$g_m = \frac{|I_C|}{V_T}, \quad r_{b'e} = \frac{h_{fe}}{g_m}, \quad r_{b'c} = \frac{r_{b'e}}{h_{re}}$$

$$\frac{1}{r_{ce}} \cong h_{oe} - \frac{(1 + h_{fe})}{r_{b'c}}, \quad C_C = 3p_F, \; C_e = \frac{g_m}{2\pi F_T}$$

$$A_i = \frac{I_L}{I_i}$$

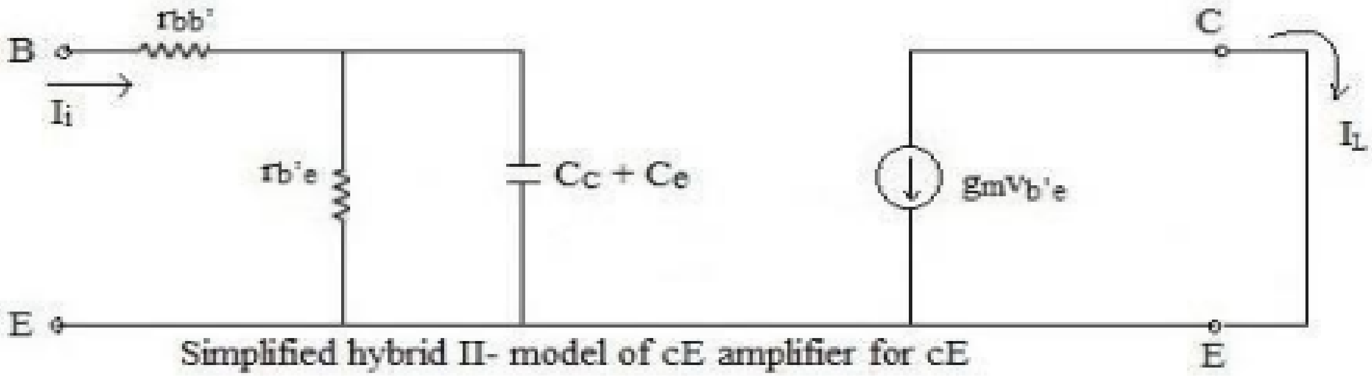
(1) is in shunt with short circuit and behaves as open circuit and hence is removed from the equivalent circuit.

(2) $r_{b'e} \,||\, r_{b'c} \, r_{b'e}$

$C_C \,||\, C_e = C_C + C_e$

(3) Current delivered directly to the output from input though $r_{b'c}$ & C_C is negligibly sma
compared to dependent
current source $g_m V_{b'e}$

Under these assumptions the simplified hybrid model of C_E amplifier.



Simplified hybrid II- model of cE amplifier for cE

$$A_i = \frac{I_C}{I_i} = \frac{-g_m I_i}{\frac{1}{r_{b'e}} + j\omega(C_C + C_e)}$$

$$\frac{I_C}{I_i} = \frac{-g_m r_{b'e}}{1 + j\omega(C_C + C_e) r_{b'e}}$$

$$= \frac{-g_m r_{b'e}}{1 + jf/\frac{1}{2\pi r_{b'e}(C_C + C_e)}}$$

$$A_i = \frac{-h_{fe}}{1 + jf/f_B} \text{ - - - - - - (1)}$$

$$\text{where } f_B = \frac{1}{2\pi r_{b'e}(C_C + C_e)} \text{ - - - - - - - (2)}$$

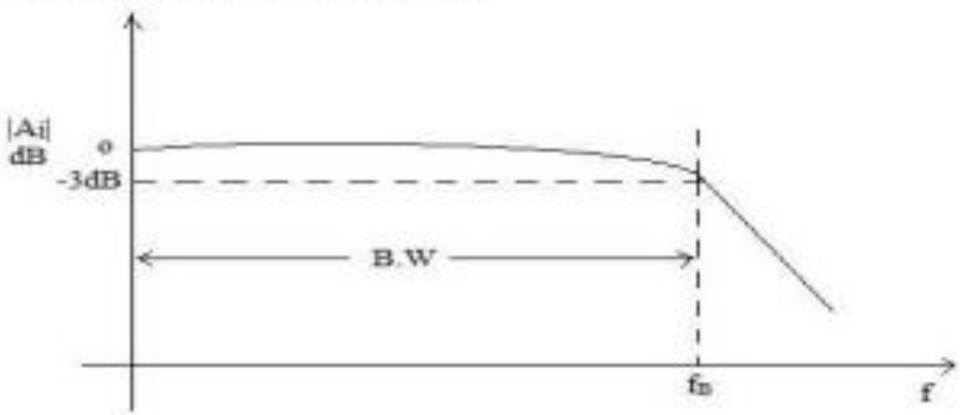
At $f = 0$, $A_i = -h_{fe}$

At $f = f_B$, $A_i = \frac{-h_{fe}}{1+j}$

Or $|A_i| = \frac{-h_{fe}}{\sqrt{2}} = \frac{\text{max}^{\underline{m}}\text{ current gain}}{\sqrt{2}}$

Thus at $f = f_B$, the short ckt current gain is $\frac{1}{\sqrt{2}}$ times the $\text{max}^{\underline{m}}$ short ckt. current gain available at low frequency.

$\frac{1}{\sqrt{2}}$ corresponds to -3dB and hence f_B in called 3dB frequency and the frequency range $0 - f_B$ *is* called bandwidth of the amplifier.



The parameter f_T: The frequency at which the magnitude short ckt. current gain of C_E amplifier reduces to unity is
defined as frequency f_T

f_T --> Gain bandwidth product of an amplifier.

$$A_i = \frac{-h_{fe}}{1 + jf/f_B}$$

$$|A_i| = \frac{h_{fe}}{[1 + (f/f_B)^2]^{\frac{1}{2}}}$$

$\therefore$ From above

$$1 = \frac{h_{fe}}{[1 + (f_T/f_B)^2]^{\frac{1}{2}}}$$

$$[1 + (f_T/f_B)^2]^{\frac{1}{2}} = h_{fe}$$

$$f_T = f_B\sqrt{h_{fe}{}^2 - 1}$$

$\because \quad h_{fe}{}^2 \gg 1$

$$\therefore \quad f_T = f_B\sqrt{h_{fe}{}^2}$$

$$\therefore \quad f_T = f_B h_{fe}$$

Also, $f_T = \dfrac{h_{fe}}{2\pi r_{b'e}(C_C + C_e)}$

$$f_T = \frac{g_m}{2\pi(C_C + C_e)}$$

$$C_C + C_e = \frac{g_m}{2\pi f_T}$$

$$\therefore \quad C_e = \frac{g_m}{2\pi f_T} - C_C$$

$$\because \quad g_m/2\pi f_T \gg C_C$$

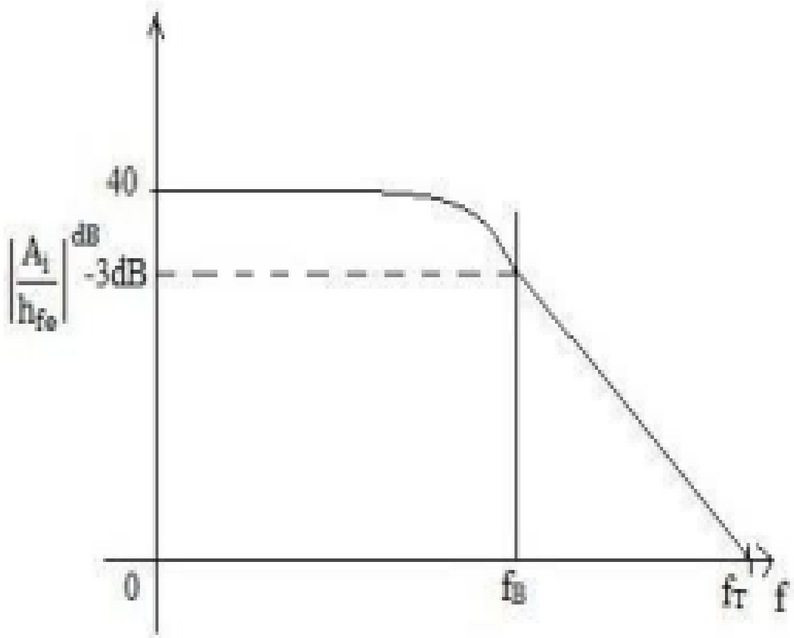
$$\boxed{C_e = \frac{g_m}{2\pi f_T}}$$

$$\frac{A_i}{h_{fe}} = \frac{1}{[1 + (f/f_B)^2]^{\frac{1}{2}}}$$

$$20\log 10\left|\frac{A_i}{h_{fe}}\right| = 20\log 10 \frac{1}{[1 + (f/f_B)^2]^{\frac{1}{2}}}$$

$$= -10\log 10\,[1 + (f/f_B)^2]$$

$|A_i|$ = at $f = f_T$ $$= -20\log 10\,(f/f_B)$$



40
$\left|\frac{A_i}{h_{fe}}\right|^{dB}$
-3dB
0
f_B
f_T
f

Gain Bandwidth product

It is defined as performance of an amplifier also known as Figure of merit

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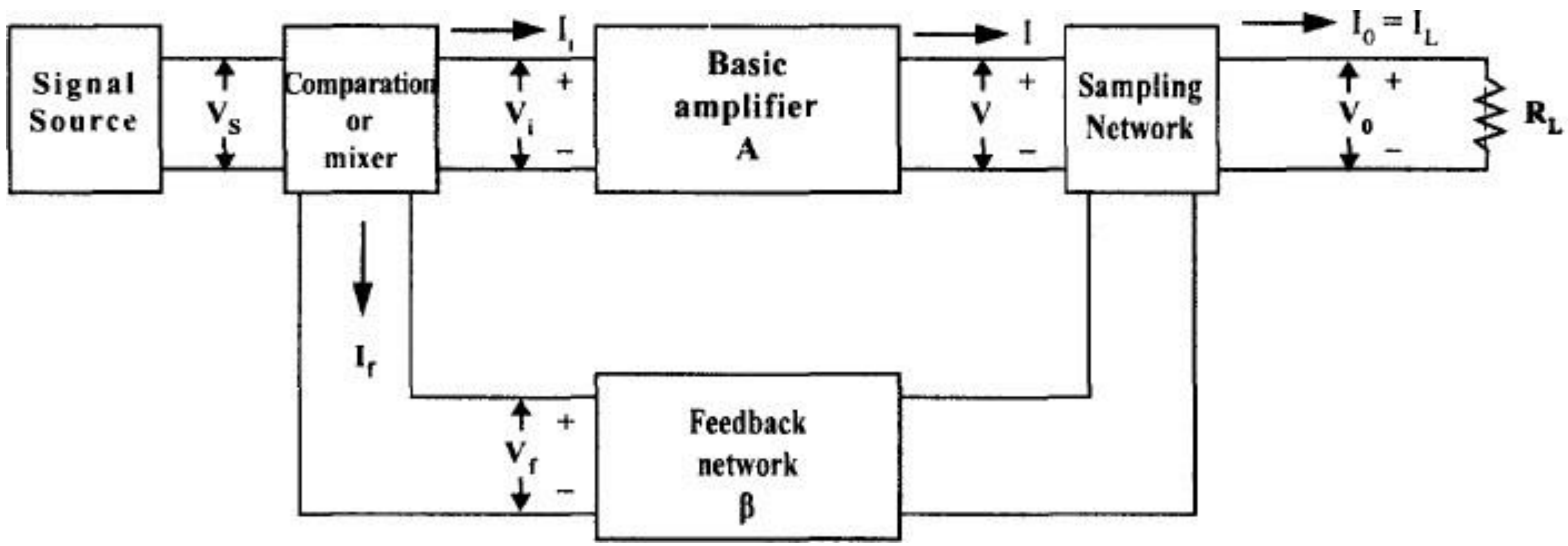
Analog Circuits

UNIT : 4

Feedback amplifiers

GENERALIZED BLOCK SCHEMATIC



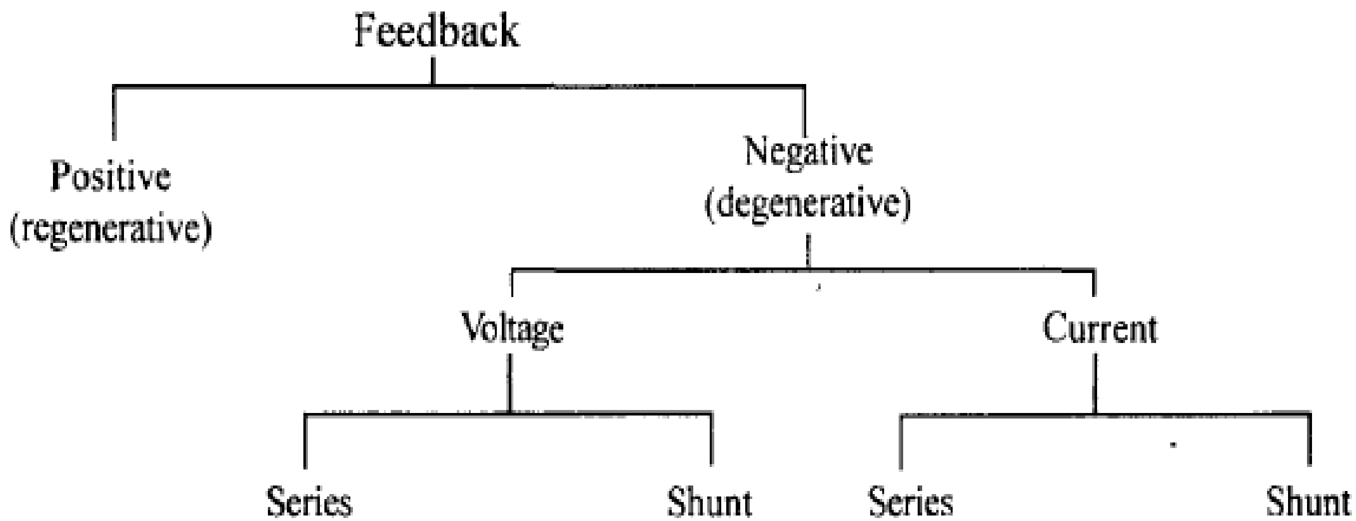
Introduction To Feedback

- 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 Vf to be in phase with the input signal Vin.*

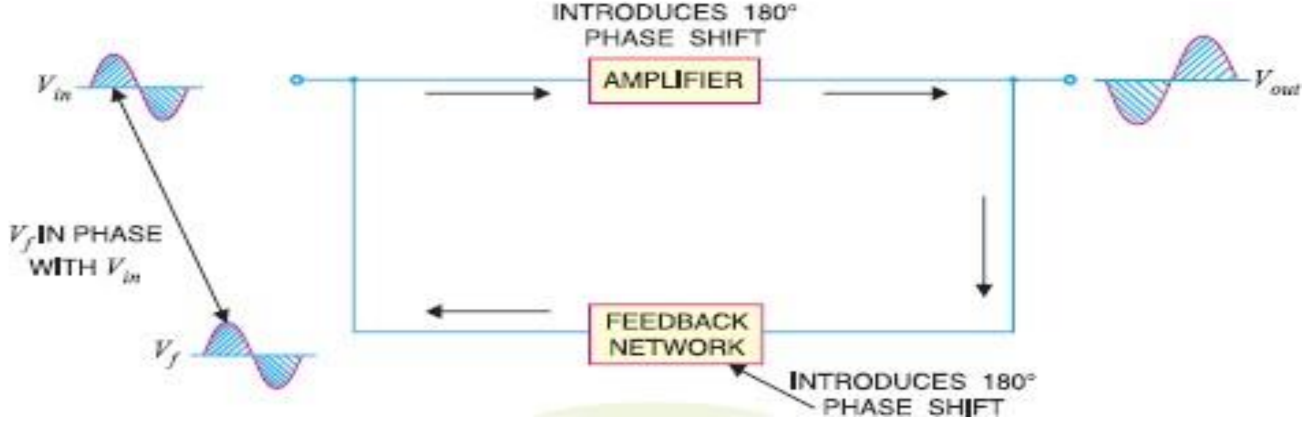


Fig. Block diagram for positive feedback

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.*

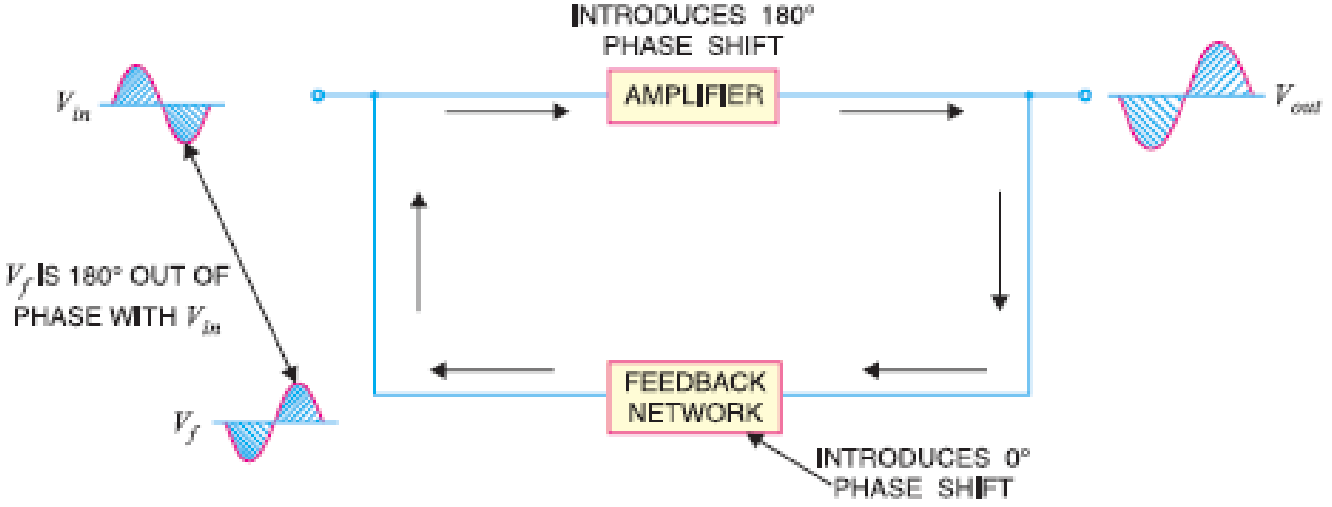
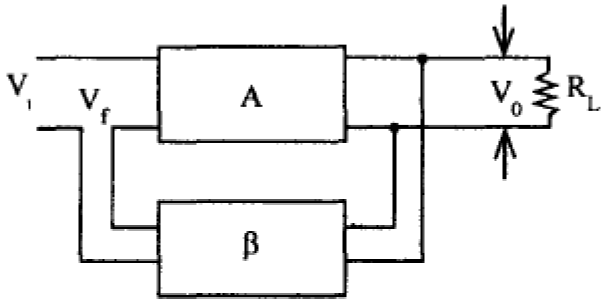
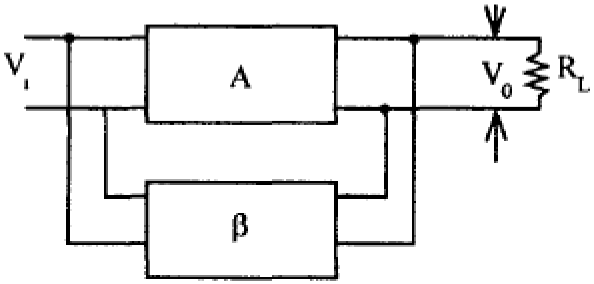


Fig.negative feedback amplifier

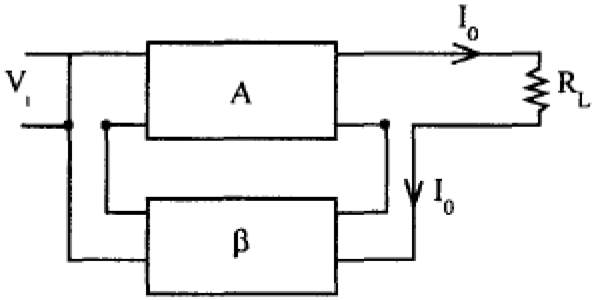
CLASSIFICATION OF FEEDBACK AMPLIFIERS



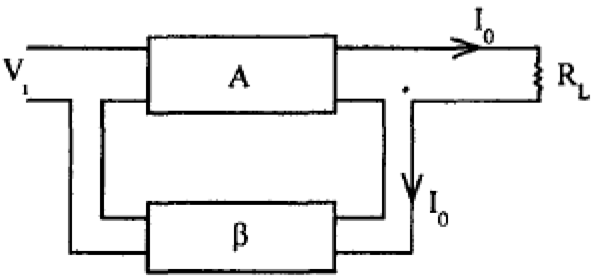
voltage series feedback.



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

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

❖ INCREASE IN BANDWIDTH

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

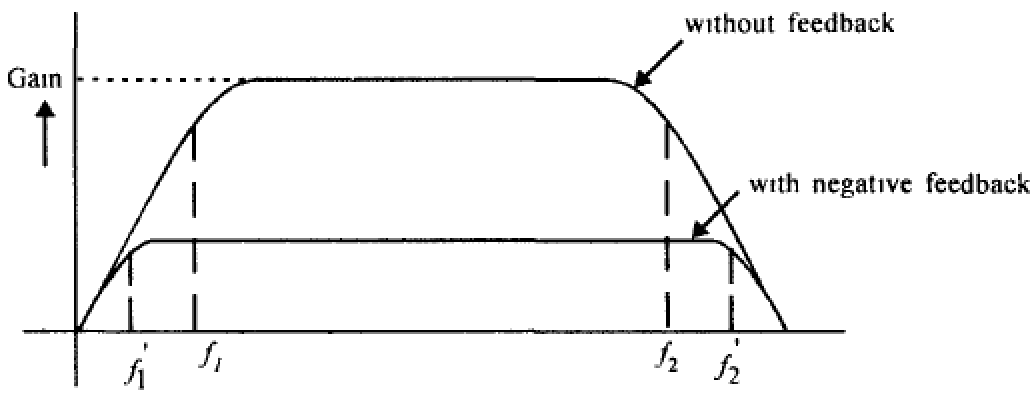
$$f_L' = \frac{f_L}{1+\beta_v A_{v(mid)}}$$

❖ 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

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

$$\textit{Densitivity} \quad \boxed{D = (1 + \beta A).}$$

- REDUCTION OF NONLINEAR DISTORTION

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

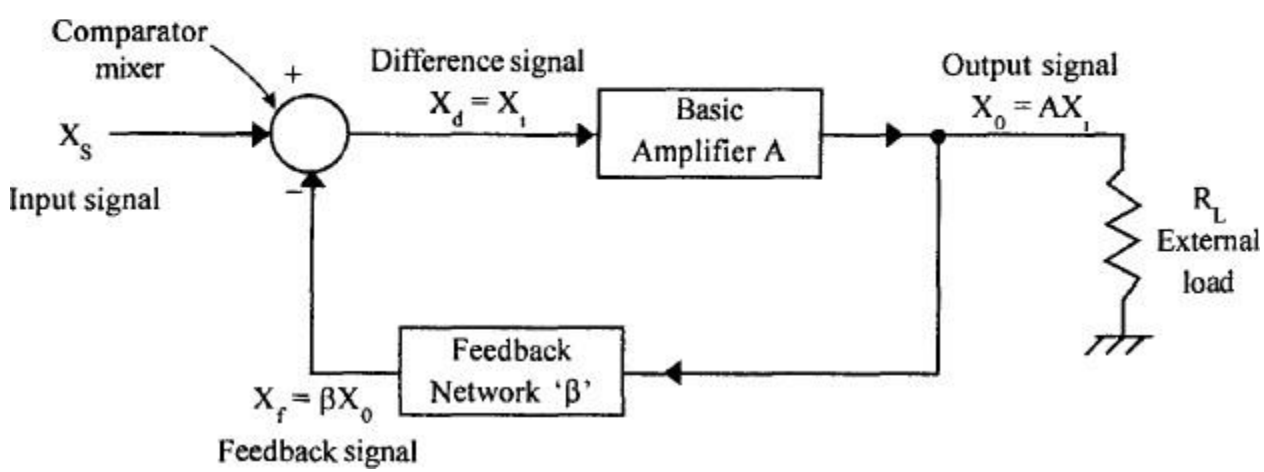
❖ REDUCTION OF NOISE

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

$N_F < N$. 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.*

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

Let us now tabulate the amplifier characteristics that get affected by different types of negative feedbacks.

Characteristics	Types of Feedback			
	Voltage-Series	Voltage-Shunt	Current-Series	Current-Shunt
Voltage Gain	Decreases	Decreases	Decreases	Decreases
Bandwidth	Increases	Increases	Increases	Increases
Input resistance	Increases	Decreases	Increases	Decreases
Output resistance	Decreases	Decreases	Increases	Increases
Harmonic distortion	Decreases	Decreases	Decreases	Decreases
Noise	Decreases	Decreases	Decreases	Decreases

UGC Autonomous

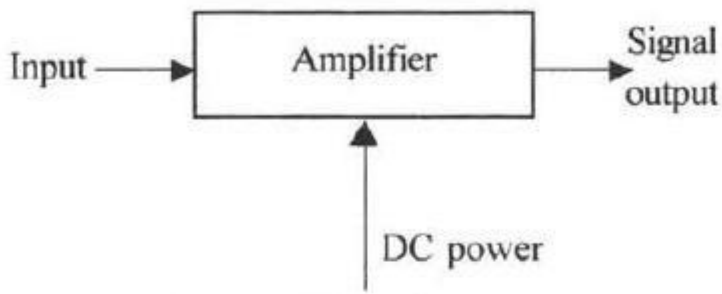
Analog Circuits

UNIT : 5

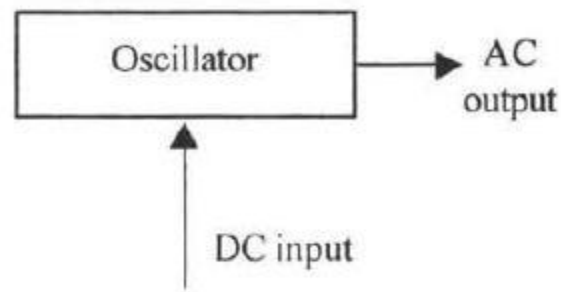
Oscillators

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 .

$$\frac{V_o}{V_s} = \frac{A}{1 - A\beta}$$

If $\beta A = 1$ then $V_o = \infty$; Very high output with zero input.

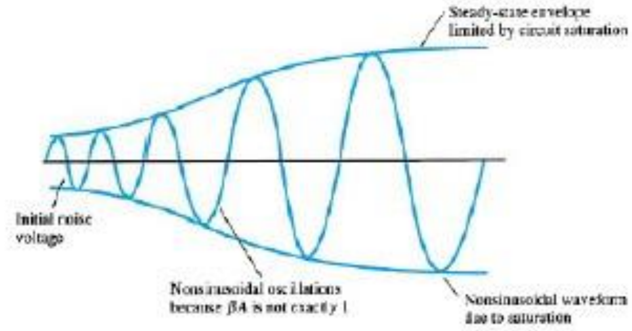
Use positive feedback through frequency-selective feedback network to ensure sustained oscillation at ω_0

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**

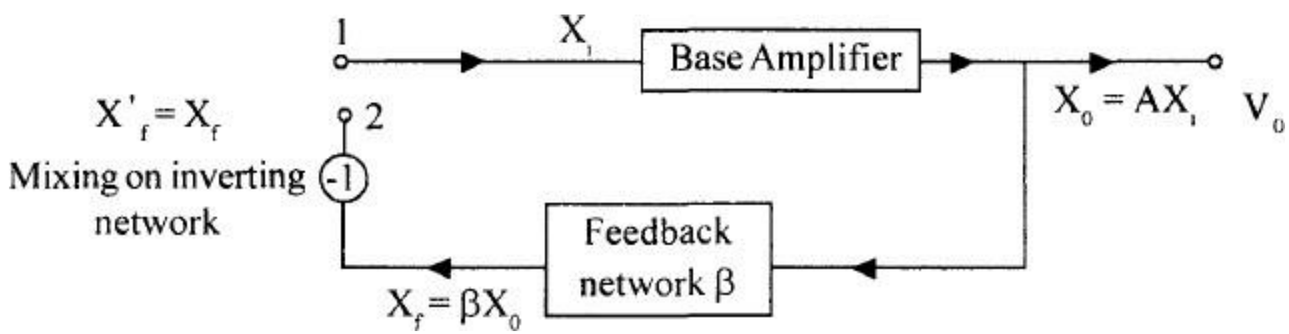
PERFORMANCE MEASURES OF OSCILLATOR CIRCUITS:

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

Total phase shift = 360^0 (180 + 180). Therefore, to get sustained oscillations,

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

SINUSOIDAL OSCILLATORS

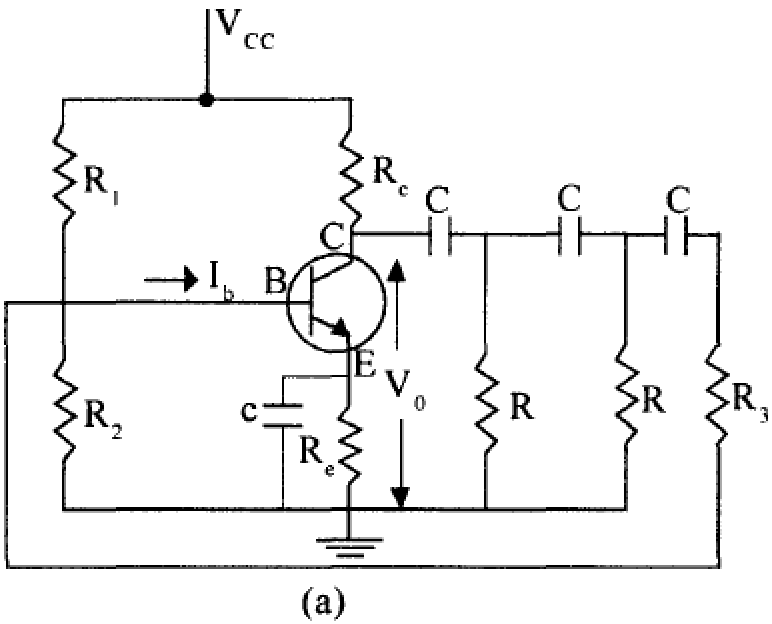


Block schematic

BARKHAUSEN CRITERION

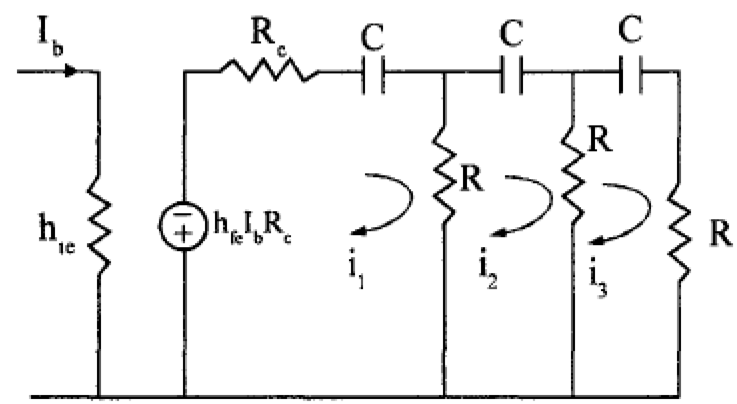
$|\beta A| = 1$ and phase of $-A\beta = 0$.

R - C PHASE-SHIFT OSCILLATOR



(a)

Transistor phase shift oscillator.



R - C Equivalent circuit.

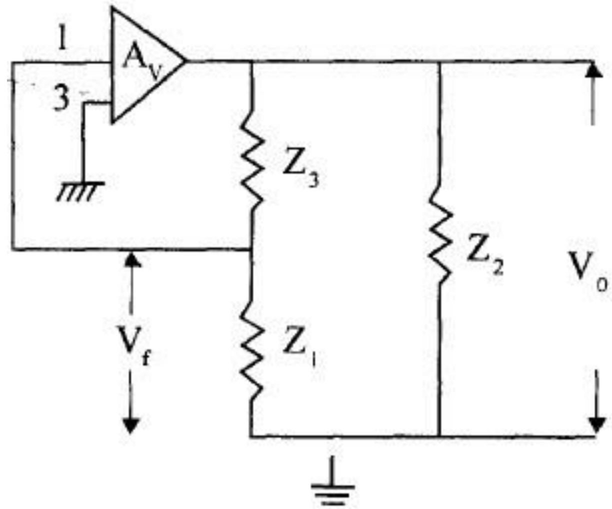
$$h_{fe}\,K > 4K^2 + 23K + 29$$

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

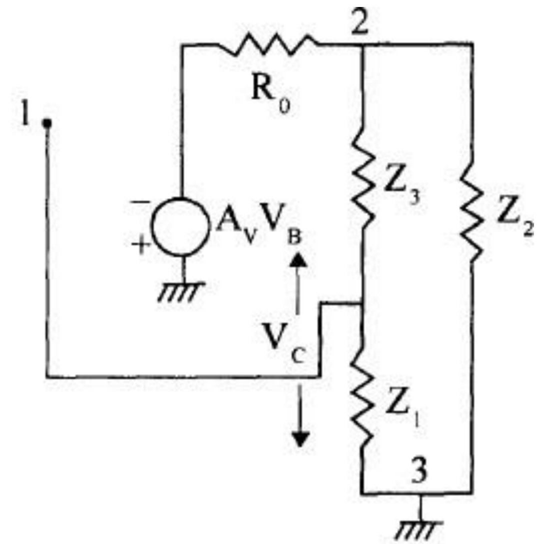
K < 2.7

$$h_{fe} > 44.5$$

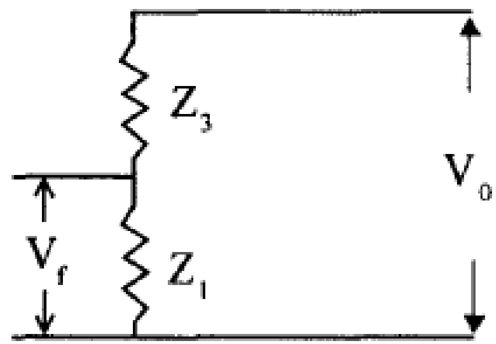
A GENERAL FORM OF LC OSCILLATOR CIRCUIT



(a)



(b)

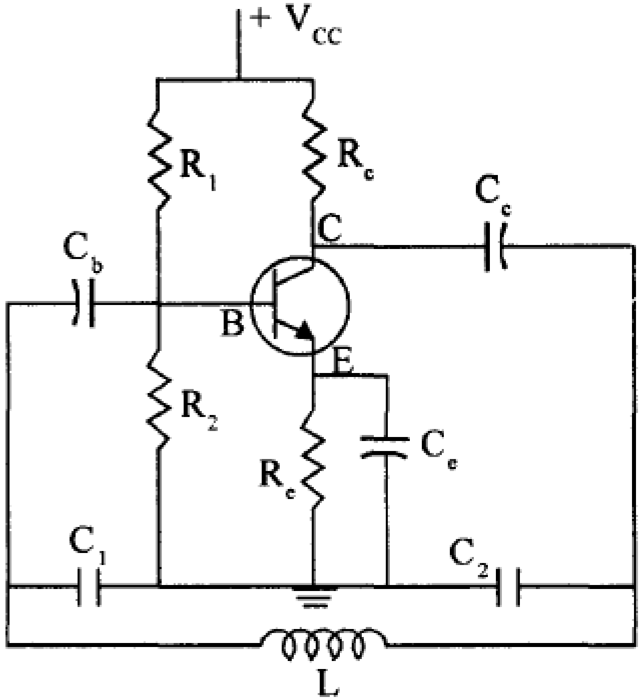


$$-A\beta = \frac{A_V X_1}{X_2}.$$

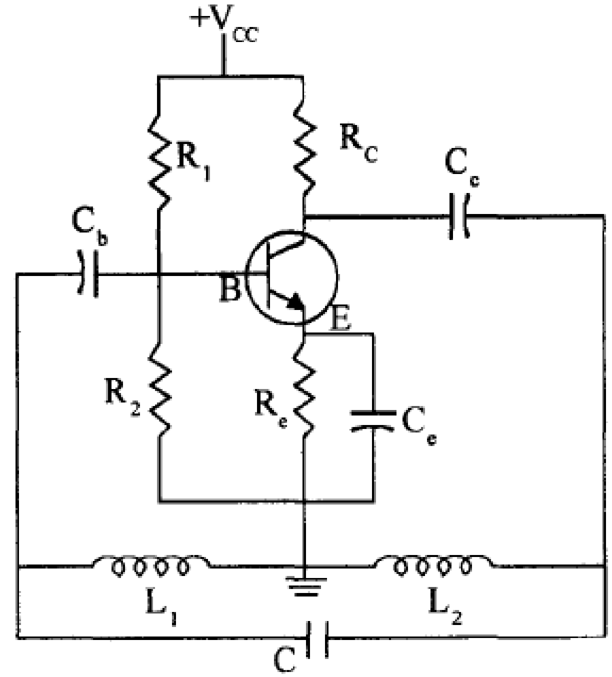
- Aβ must be positive, and at least unity in magnitude. Than XI and X2 must have the same sign.

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



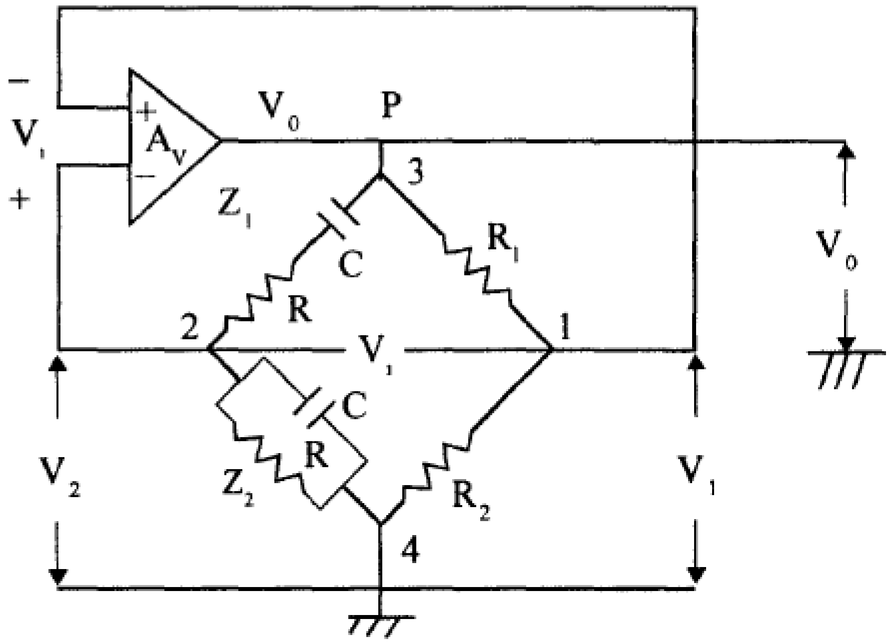
(b) Hartely oscillator circuit

$$f = \frac{1}{2\pi\sqrt{L\,C_T}}$$

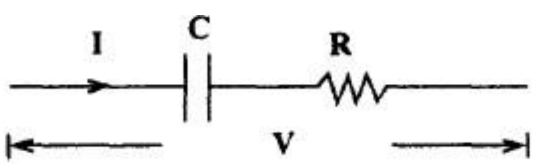
where $C_T = \frac{C_1 C_2}{C_1 + C_2}$

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

Wien bridge oscillator circuit.

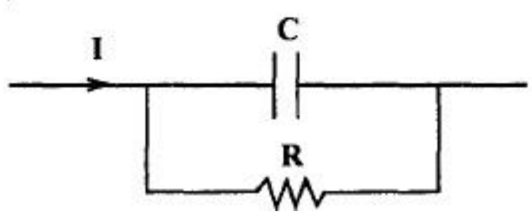


Lead Network :

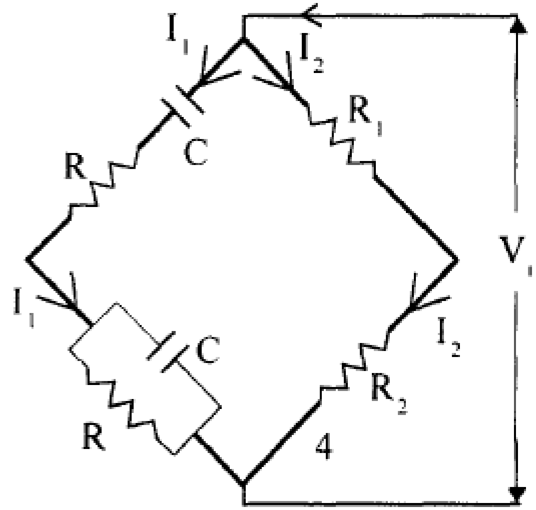


Same I is passing through C and R.
So I leads V.

Lag Network :



I lags with respect to V.

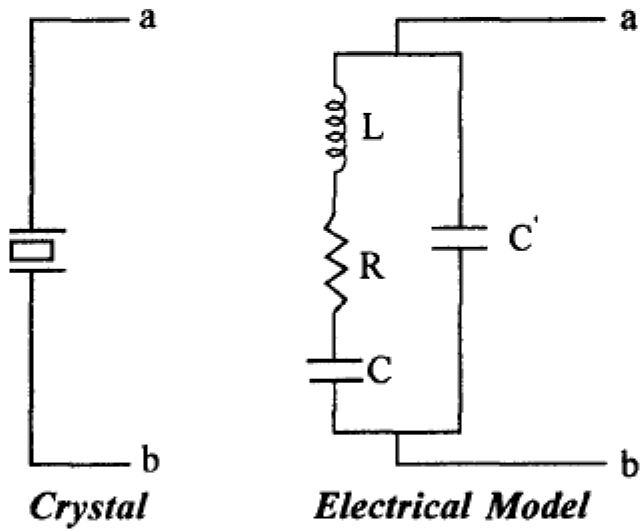


Wien Bridge oscillator circuit.

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

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

CRYSTAL OSCILLATORS



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