MODULE -2

Frequency Response of Amplifier

Frequency curve of an RC coupled amplifier:

A practical amplifier circuit is meant to raise the voltage level of the input signal. This signaL may be obtained from anywhere e.g. radio or TV receiver circuit. Such a signal is not of a single frequency. But it consists of a band of frequencies, e.g. from 20 Hz to 20 KHz. If the loudspeakers are to reproduce the sound faithfully, the amplifier used must amplify all the frequency components of signal by same amount. If it does not do so, the output of the loudspeaker will not be the exact replica of the original sound. When this happen then it means distortion has been introduced by the amplifier. Consider an RC coupled amplifier circuit shown in fig. 1.

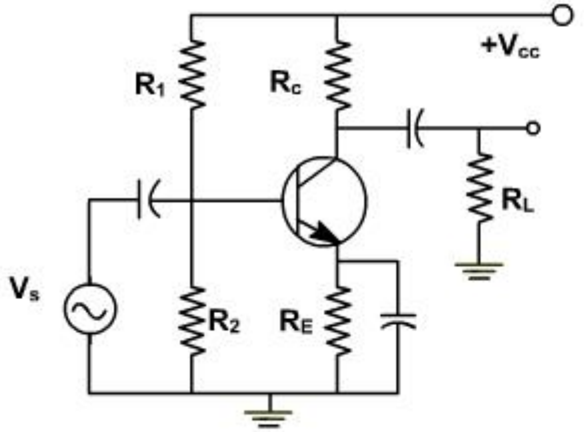


Fig. 1

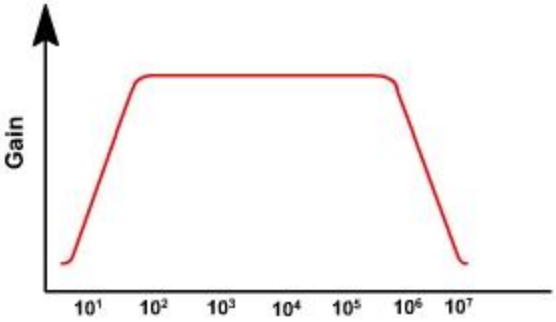


Fig. 2

Fig. 2, shows frequency response curve of a RC coupled amplifier. The curve is usually plotted on a semilog graph paper with frequency range on logarithmic scale so that large frequency range can be accommodated. The gain is constant for a limited band of frequencies. This range is called mid-frequency band and gain is called mid band gain. A_{VM}. On both sides of the mid frequency range, the gain decreases. For very low and very high frequencies the gain is almost zero.

In mid band frequency range, the coupling capacitors and bypass capacitors are as good as short circuits. But when the frequency is low. These capacitors can no longer be replaced by the short circuit approximation.

$$X_C = \frac{1}{2\pi fc}$$

i.e. $X_C \propto \frac{1}{f}$

First consider coupling capacitor. The ac equivalent is shown in **fig. 3**, assuming capacitors are offering some impedance. In mid-frequency band, the capacitors are ac shorted so the input voltage appears directly across r'_e but at low frequency the X_C is significant and some voltage drops across X_C. The input v_{in} at the base decreases. Thus decreasing output voltage. The lower the frequency the more will be X_C and lesser will be the output voltage.

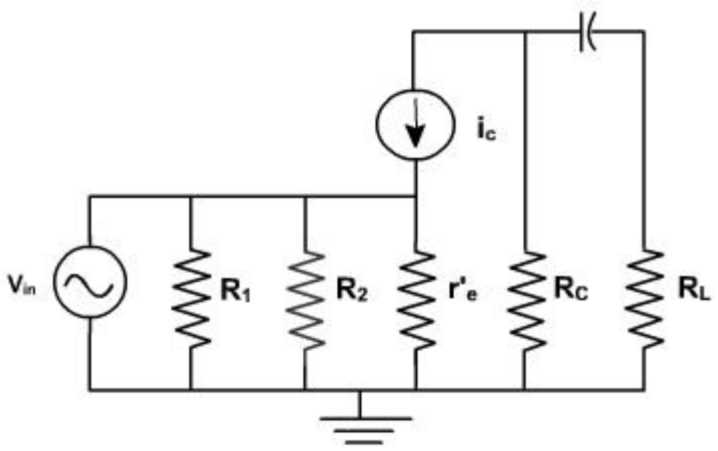
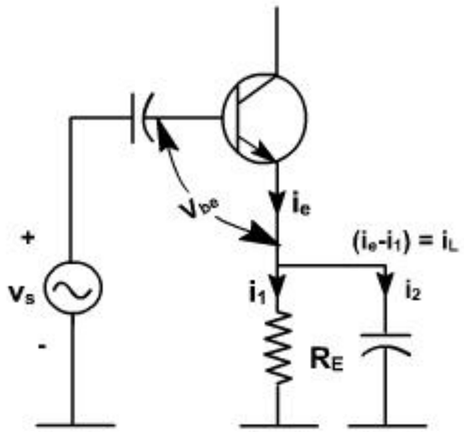


Fig. 3

Similarly at low frequency, output capacitor reactance also increases. The voltage across R_L also reduces because some voltage drop takes place across X_C. Thus output voltage reduces.

The X_C reactance not only reduces the gain but also change the phase between input and output. It would not be exactly 180^o but decided by the reactance. At zero frequency, the capacitors are open circuited therefore output voltage reduces to zero.



The other component due to which gain decreases at low frequencies is the bypass capacitor. The function of this capacitor is to bypass ac and blocks dc The impedence of this capacitor in mid frequency band is very low as compared to R_E so it behaves like ac short but as the frequency decrease the X_{CE} becomes more and no longer behaves like ac short. Now the emitter is not ac grounded. The ac emitter current i.e. divides into two parts i_1 and i_2, as shown in **fig. 4**. A current i_1 passes through R_E and rest of the current passes through C. Due to ac current i_1 in R_E, an ac voltage is developed $i_1 * R_E$. With the polarity marked at an instant. Thus the effective V_L voltage is given by

$V_{be} = V_s ? R_E$.

Thus the effective voltage input is reduced. The output also reduces. The lower the frequency, the lesser will be the gain. This reduction in gain is due to negative feedback.

As the frequency of the input signal increases, again the gain of the amplifier reduces. Firstly the □ of the transistor decreases at higher frequency. Thus reducing the voltage gain of the amplifier at higher frequencies as shown in **fig. 5**.

The other factor responsible for the reduction in gain at higher frequencies is the presence of various capacitors as shown in **fig. 6**. They are not physically connected but inherently present with the device.

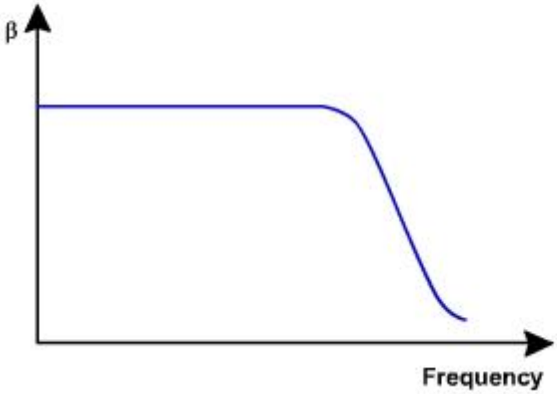


Fig. 5

The capacitor C_{bc} between the base and the collector connects the output with the input. Because of this, negative feedback takes place in the circuit and the gain decreases. This feedback effect is more, when C_{bc} provides a path for higher frequency ac currents

The capacitance C_{be} offers a low input impedance at higher frequency thus reduces the effective input signal and so the gain falls. Similarly, C_{ce} provides a shunting effect at high frequencies in the output side and reduces gain of the amplifier.

Besides these junction capacitances there are wiring capacitance C_{W1} and C_{W2}. These reactance are very small but at high frequencies they become 5 to 20 p.f. For a multistage amplifier, the effect of the capacitances C_{ce},C_{W1} and C_{W2} can be represented by single shunt capacitance.

$C_S = C_{W1} + C_{W2} + C_{ce}$.

At higher frequency, the capacitor C_S offers low input impedance and thus reduces the output.

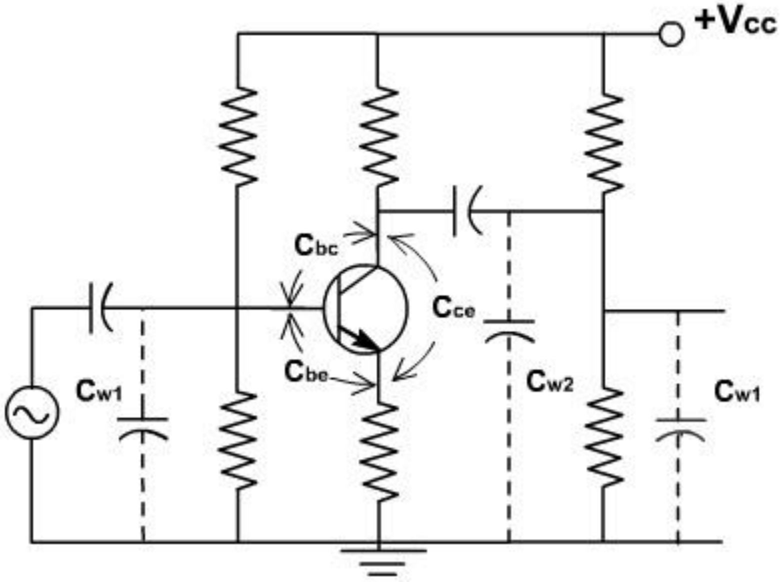


Fig. 6

Bandwidth of an amplifier:

The gain is constant over a frequency range. The frequencies at which the gain reduces to 70.7% of the maximum gain are known as cut off frequencies, upper cut off and lower cut off frequency. **fig. 7**, shows these two frequences. The difference of these two frequencies is called Band width (BW) of an amplifier.

BW = f_2 ? f_1.

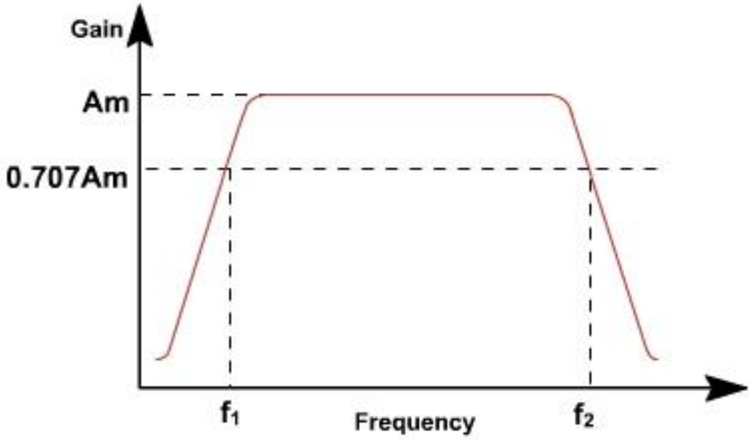


Fig. 7

At f_1 and f_2, the voltage gain becomes 0.707 Am(1 / □ 2). The output voltage reduces to 1 / □ 2 of maximum output voltage. Since the power is proportional to voltage square, the output power at these frequencies becomes half of maximum power. The gain on dB scale is given by

$20 \log_{10}(V_2 / V_1) = 10 \log 10 (V_2 / V_1)^2 = 3$ dB.

$20 \log_{10}(V_2 / V_1) = 20 \log_{10}(0.707) = 10 \log_{10} (1 /$ □ $2)^2 = 10 \log_{10}(1 / 2) = -3$ dB.

If the difference in gain is more than 3 dB, then it can be detected by human. If it is less than 3 dB it cannot be detected.

Direct Coupling:

For applications, where the signal frequency is below 10 Hz, coupling and bypass capacitors cannot be used. At low frequencies, these capacitors can no longer be treated as ac short circuits, since they offer very high impedance. If these capacitors are used then their values have to be extremely large e.g. to bypass a 100 ohm emitter resistor at 10 Hz, we need a capacitor of approximately 1600□ F. The lower the frequency the worse the problem becomes.

To avoid this, direct coupling is used. This means designing the stages without coupling and bypass capacitors, so that the direct current is coupled as well as alternating current. As a result, there is no lower frequency limit. The amplifier enlarges the signal no matter have low frequency including dc or zero frequency.

One Supply Circuit:

Fig. 8, shows a two stage direct coupled amplifier, no coupling or bypass capacitors are used.
With a quiescent input voltage 1.4 V, emitter voltage = 1.4 - 0.7 = 0.7 V

$$\text{Emitter current } I_{E1} = \frac{0.7}{680\,\Omega} \approx 1\text{mA}. \therefore \; I_{C1} \approx I_{E1} = 1\text{ mA}$$

$$V_{C1} = 30 - 1*27 = 3\text{V}$$

$$\therefore V_{E2} = 3 - 0.7 = 2.3\text{V}$$

$$\therefore I_{E2} = \frac{2.3}{2.4\text{K}} \approx 1\text{mA} \approx I_{C2}$$

$$\therefore V_{C2} = 30 - 1*24 = 6\text{V}$$

The gain of first stage is given by $A_1 = -\frac{2700}{680} \approx -40$

The gain of the second stage is given by

$$A_2 = -\frac{24000}{2400} = -10$$

$$A = A_1 A_2 = 400$$

If $V_{in} = 6\text{mV}$,

$$V_{out} = 5 * 400\text{mV} = 2\text{V}$$

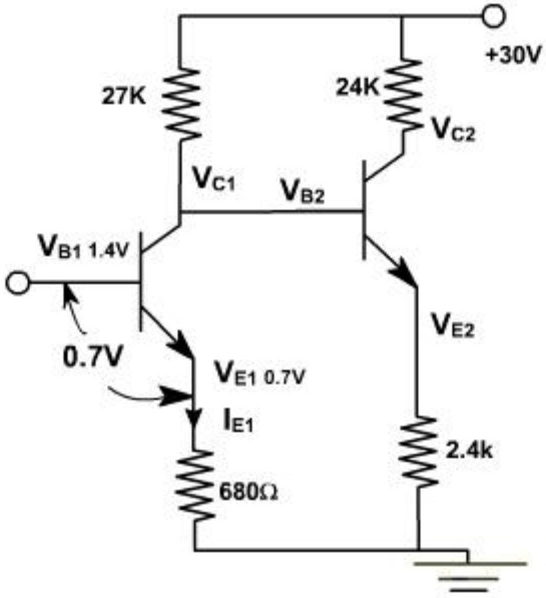


Fig. 8

The output varies from +6V to +8V.

The main disadvantage is variation in transistor characteristic with variation in temperature. This causes I_C and V_C to change. Because of the direct coupling the voltage changes are coupled from one stage to next stage, appearing at the final output as an amplified voltage. The unwanted change is called drift.

Grounded Reference Input

For the above amplifier, we need a quiescent voltage of 1.4V. In most applications, it is necessary to have grounded reference input one where the quiescent input voltage is 0 V, as shown in **fig. 9**.

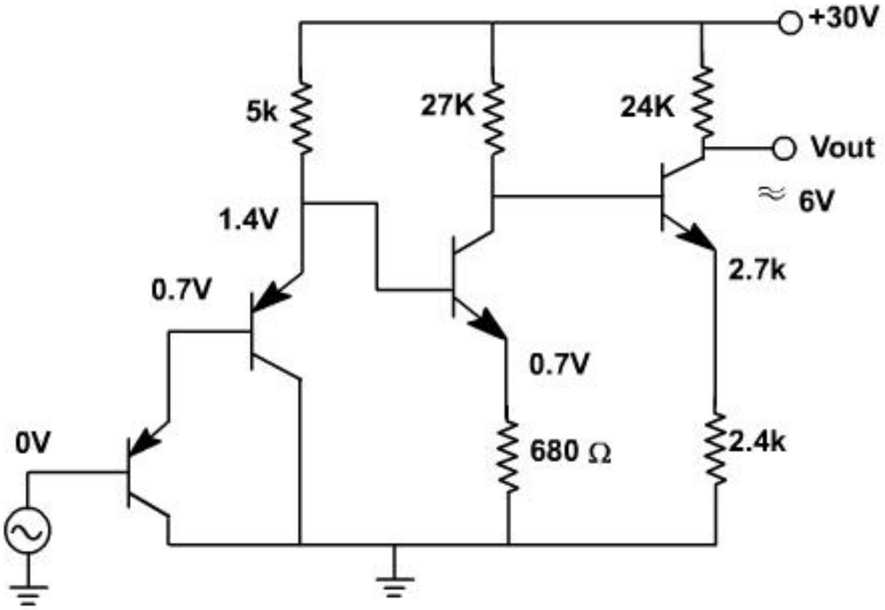


Fig. 9

The quiescent V_{CE} of the first transistor is only 0.7V and the quiescent of the second transistor is only 1.4V. Both the transistors are operating in active region because $V_{CE(sat)}$ is only 0.1 volt. The input is only in mV, which means that these transistors continue to operate in the active region when a small signal is present.

h-Parameters

Small signal low frequency transistor Models:

All the transistor amplifiers are two port networks having two voltages and two currents. The positive directions of voltages and currents are shown in **fig. 1**.

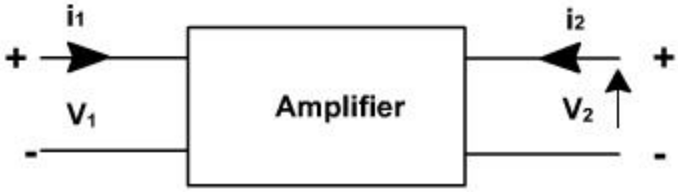


Fig. 1

Out of four quantities two are independent and two are dependent. If the input current i_1 and output voltage v_2 are taken independent then other two quantities i_2 and v_1 can be expressed in terms of i_1 and V_2.

$$v_1 = f_1(i_1, v_2)$$
$$i_2 = f_2(i_1, v_2)$$

The equations can be written as

$$v_1 = h_{11} i_1 + h_{12} v_2$$
$$i_2 = h_{21} i_1 + h_{22} v_2$$

where h_{11}, h_{12}, h_{21} and h_{22} are called h-parameters.

$$h_{11} = \left.\frac{v_1}{i_1}\right|_{v_2 = 0}$$

$= h_i =$ input impedance with output short circuit to ac.

$$h_{12} = \left.\frac{v_1}{v_2}\right|_{i_2 = 0}$$

=h_r = fraction of output voltage at input with input open circuited or reverse voltage gain with input open circuited to ac (dimensions).

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2 = 0}$$

= h_f = negative of current gain with output short circuited to ac.

The current entering the load is negative of I_2. This is also known as forward short circuit current gain.

$$h_{22} = \left.\frac{i_2}{i_1}\right|_{i_2 = 0}$$

= h_o = output admittance with input open circuited to ac.

If these parameters are specified for a particular configuration, then suffixes e,b or c are also included, e.g. h_{fe} ,h_{ib} are h parameters of common emitter and common collector amplifiers

Using two equations the generalized model of the amplifier can be drawn as shown in **fig. 2**.

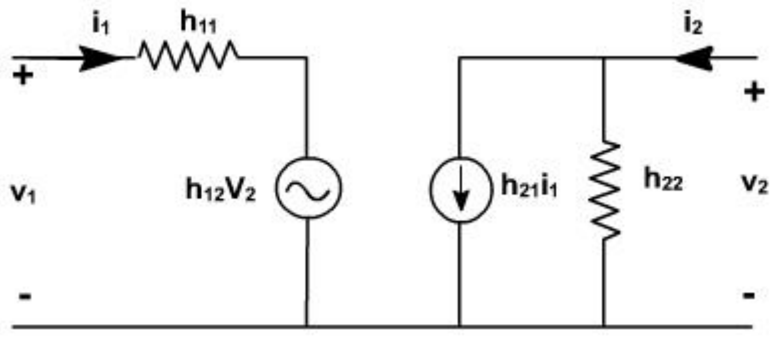


Fig. 2

The hybrid model for a transistor amplifier can be derived as follow:

Let us consider CE configuration as show in **fig. 3**. The variables, i_B, i_C ,v_C, and v_B represent total instantaneous currents and voltages i_B and v_C can be taken as independent variables and v_B, I_C as dependent variables.

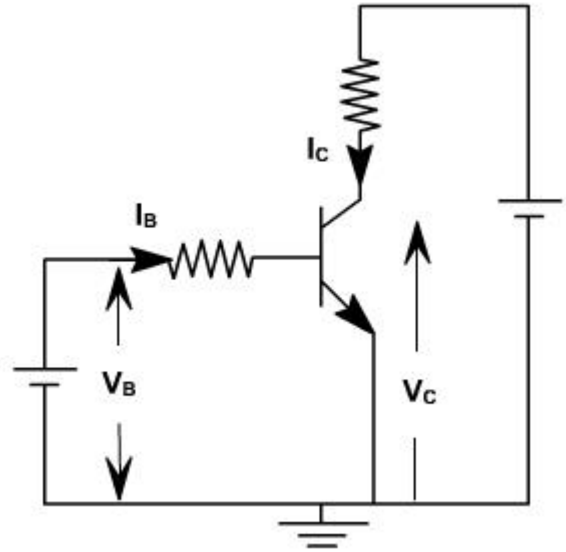


Fig. 3

$v_B = f_1 (i_B ,v_C)$

$I_C = f_2 (i_B , v_C)$.

Using Taylor 's series expression, and neglecting higher order terms we obtain.

$$\Delta v_B = \left.\frac{\partial f_1}{\partial i_B}\right|_{v_C} \Delta i_B + \left.\frac{\partial f_1}{\partial v_C}\right|_{i_B} \Delta v_C$$

$$\Delta i_C = \left.\frac{\partial f_2}{\partial i_B}\right|_{v_C} \Delta i_B + \left.\frac{\partial f_2}{\partial v_C}\right|_{i_B} \Delta v_C$$

The partial derivatives are taken keeping the collector voltage or base current constant. The Δv_B, Δv_C, Δi_B, Δi_C represent the small signal (incremental) base and collector current and voltage and can be represented as v_b ,i_b ,v_C ,i_C.

$$\therefore v_b = h_{ie}\, i_B + h_{re}\, v_C$$

$$i_C = h_{fe}\, i_B + h_{oe}\, v_b$$

where

$$h_{ie} = \left.\frac{\partial f_1}{\partial i_B}\right|_{v_C} = \left.\frac{\partial v_B}{\partial i_B}\right|_{v_C} ; \qquad h_{re} = \left.\frac{\partial f_1}{\partial v_C}\right|_{i_B} = \left.\frac{\partial v_B}{\partial v_C}\right|_{i_B}$$

$$h_{fe} = \left.\frac{\partial f_2}{\partial i_B}\right|_{v_C} = \left.\frac{\partial i_C}{\partial i_B}\right|_{v_C} ; \qquad h_{oe} = \left.\frac{\partial f_2}{\partial v_C}\right|_{i_B} = \left.\frac{\partial v_B}{\partial v_C}\right|_{i_B}$$

The model for CE configuration is shown in **fig. 4**.

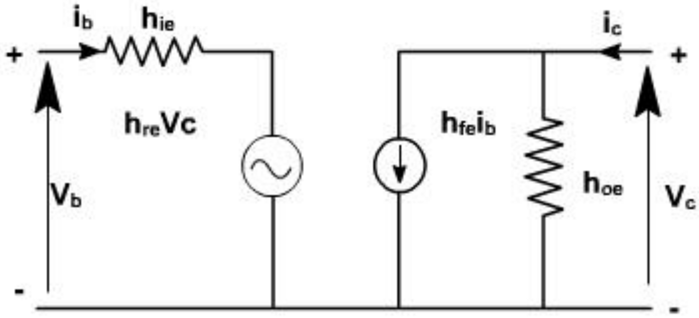


Fig. 4

Determination of h - parameters:

To determine the four h-parameters of transister amplifier, input and output characteristic are used. Input characteristic depicts the relationship between input voltage and input current with output voltage as parameter. The output characteristic depicts the relationship between output voltage and output current with input current as parameter. **Fig. 5**, shows the output characterisitcs of CE amplifier.

$$h_{fe} = \left.\frac{\partial i_C}{\partial i_B}\right|_{V_C} = \frac{i_{C2} - i_{C1}}{i_{b2} - i_{b1}}$$

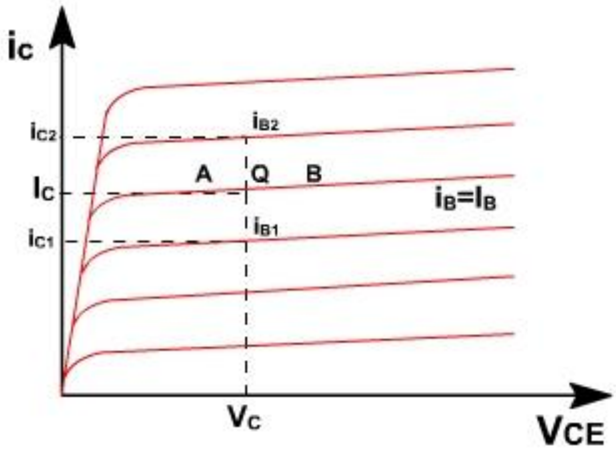


Fig. 5

The current increments are taken around the quiescent point Q which corresponds to $i_B = I_B$ and to the collector voltage $V_{CE} = V_C$

$$h_{oe} = \left.\frac{\partial i_C}{\partial V_C}\right|_{i_B}$$

The value of h_{oe} at the quiescent operating point is given by the slope of the output characteristic at the operating point (i.e. slope of tangent AB).

$$h_{ie} = \frac{\partial V_B}{\partial i_B} \approx \left.\frac{\Delta V_B}{\Delta i_B}\right|_{V_C}$$

h_{ie} is the slope of the appropriate input on **fig. 6**, at the operating point (slope of tangent EF at Q).

$$h_{re} = \frac{\partial V_B}{\partial V_C} = \left.\frac{\Delta V_B}{\Delta V_C}\right|_{I_B} = \frac{V_{B2} - V_{B1}}{V_{C2} - V_{C1}}$$

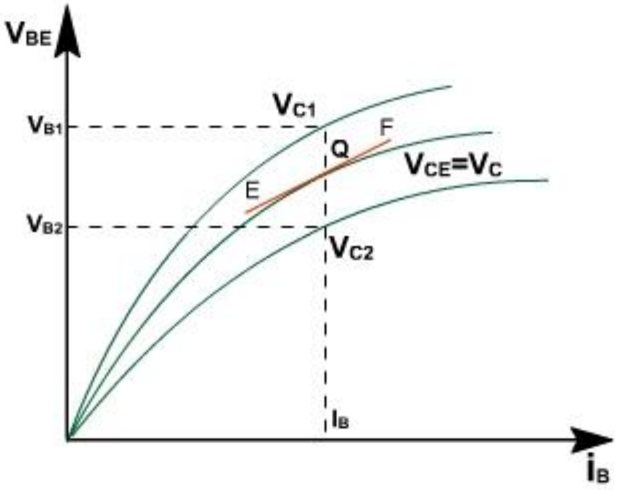


Fig. 6

A vertical line on the input characteristic represents constant base current. The parameter hre can be obtained from the ratio (V_{B2}? V_{B1}) and (V_{C2}? V_{C1}) for at Q.

Typical CE h-parametersof transistor 2N1573 are given below:

h_{ie} = 1000 ohm.
h_{re} = 2.5 * 10 ?4
h_{fe} = 50
h_{oe} = 25 □A / V

Analysis of a transistor amplifier using h-parameters:

To form a transistor amplifier it is only necessary to connect an external load and signal source as indicated in **fig. 1** and to bias the transistor properly.

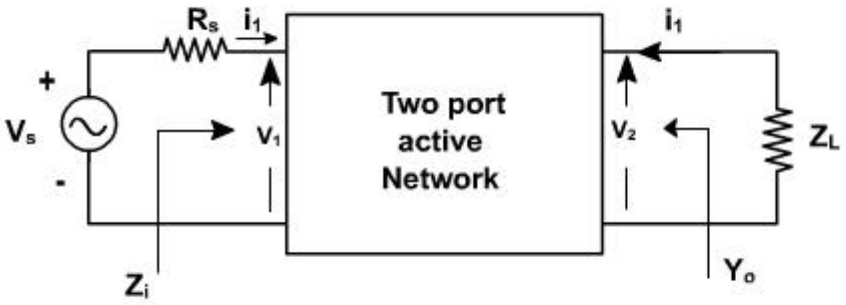


Fig. 1

Consider the two-port network of CE amplifier. R_S is the source resistance and Z_L is the load impedence h-parameters are assumed to be constant over the operating range. The ac equivalent circuit is shown in **fig. 2**. (Phasor notations are used assuming sinusoidal voltage input). The quantities of interest are the current gain, input impedence, voltage gain, and output impedence.

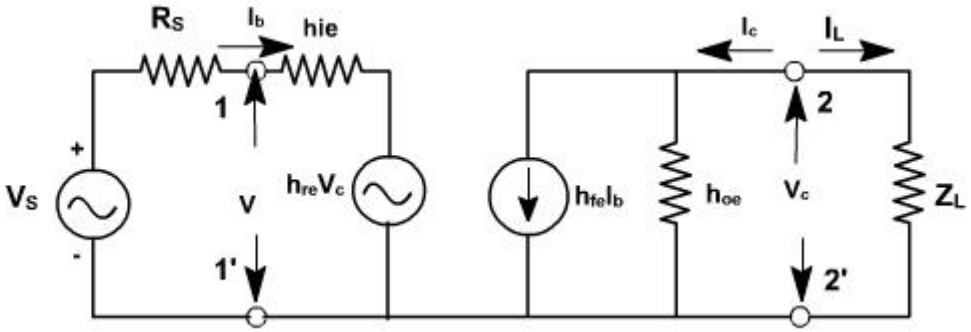


Fig. 2

Current gain:

For the transistor amplifier stage, A_i is defined as the ratio of output to input currents.

$$A_i = \frac{I_L}{I_b} = \frac{-I_C}{I_b} \qquad (I_L + I_c = 0. \quad \therefore I_L = -I_c)$$

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

$$V_c = I_L Z_L = -I_c Z_L$$

$$\therefore I_c = h_{fe} I_b + h_{oe} (-I_c Z_L)$$

$$\text{or } \frac{I_c}{I_b} = \frac{h_{fe}}{1 + h_{oe} Z_L}$$

$$\therefore A_i = - \frac{h_{fe}}{1 + h_{oe} Z_L}$$

Input Impedence:

The impedence looking into the amplifier input terminals (1,1') is the input impedence Z_i

$$Z_i = \frac{V_b}{I_b}$$

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

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

$$= h_{ie} - \frac{h_{re} I_c Z_L}{I_b}$$

$$\therefore Z_i = h_{ie} + h_{re} A_I Z_L$$

$$= h_{ie} - \frac{h_{re} h_{fe} Z_L}{1 + h_{oe} Z_L}$$

$$\therefore Z_i = h_{ie} - \frac{h_{re} h_{fe}}{Y_L + h_{oe}} \qquad (\text{since } Y_L = \frac{1}{Z_L})$$

Voltage gain:

The ratio of output voltage to input voltage gives the gain of the transistors.

$$A_v = \frac{V_C}{V_b} = - \frac{I_C Z_L}{V_b}$$

$$\therefore A_v = \frac{I_B A_i Z_L}{V_b} = \frac{A_i Z_L}{Z_i}$$

Output Admittance:

It is defined as

$$Y_0 = \left.\frac{I_c}{V_c}\right|_{V_s} = 0$$

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

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

$$\text{when } V_s = 0, \quad R_s \cdot I_b + h_{ie} \cdot I_b + h_{re} V_c = 0.$$

$$\frac{I_b}{V_c} = - \frac{h_{re}}{R_s + h_{ie}}$$

$$\therefore Y_0 = h_{oe} - \frac{h_{re} \, h_{fe}}{R_s + h_{ie}}$$

Voltage amplification taking into account source impedance (R_S) is given by

$$A_{VS} = \frac{V_c}{V_s} = \frac{V_c}{V_b} * \frac{V_b}{V_S} \qquad \left(V_b = \frac{V_s}{R_s + Z_i} * Z_i \right)$$

$$= A_V \cdot \frac{Z_i}{Z_i + R_s}$$

$$= \frac{A_i \, Z_L}{Z_i + R_s}$$

A_v is the voltage gain for an ideal voltage source ($R_v = 0$).

Consider input source to be a current source I_S in parallel with a resistance R_S as shown in **fig. 3**.

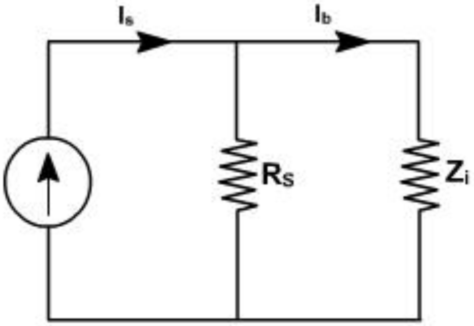


Fig. 3

In this case, overall current gain A_{IS} is defined as

$$A_{I_s} = \frac{I_L}{I_s}$$

$$= -\frac{I_c}{I_s}$$

$$= -\frac{I_c}{I_b} * \frac{I_b}{I_s} \qquad \left(I_b = \frac{I_s * R_s}{R_s + Z_i} \right)$$

$$= A_I \cdot \frac{R_s}{R_s + Z_i}$$

$$\text{If } R_s \rightarrow \infty, \quad A_{I_s} \rightarrow A_I$$

To analyze multistage amplifier the h-parameters of the transistor used are obtained from manufacture data sheet. The manufacture data sheet usually provides h-parameter in CE configuration. These parameters may be converted into CC and CB values. For example **fig. 4** h_{rc} in terms of CE parameter can be obtained as follows.

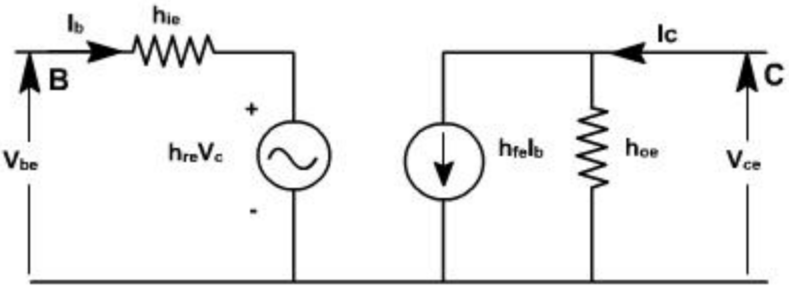


Fig. 4

For CE transistor configuaration

$V_{be} = h_{ie} I_b + h_{re} V_{ce}$

$I_c = h_{fe} I_b + h_{oe} V_{ce}$

The circuit can be redrawn like CC transistor configuration as shown in **fig. 5**.

$V_{bc} = h_{ie} I_b + h_{rc} V_{ec}$

$I_c = h_{fe} I_b + h_{oe} V_{ec}$

$$h_{rc} = \left.\frac{V_{be}}{V_{ec}}\right|_{I_b=0}$$

$$= \left.\frac{V_{be}+V_{ec}}{V_{ec}}\right|_{I_b=0}$$

$$= \left.\left(\frac{V_{be}}{V_{ec}}+1\right)\right|_{I_b=0}$$

Since $I_b = 0$, $V_{be} = h_{re} V_c = -h_{re} V_{ec}$

$$\therefore h_{rc} = 1 + \left(\frac{h_{re} V_{ec}}{V_{ec}}\right)$$

$$= 1 - h_{re}$$

Similarly

$$h_{fc} = \left.\frac{I_e}{I_b}\right|_{V_{ec}=0} = \left.\frac{-(I_b+I_C)}{I_b}\right|_{V_{ec}=0}$$

$$= -(1+h_{fe})$$

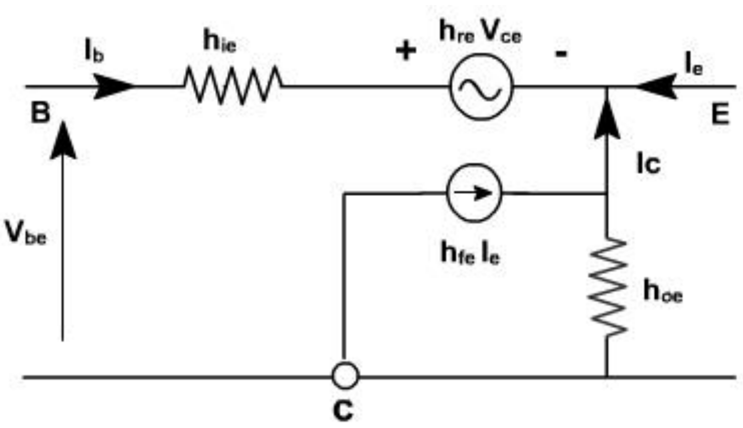


Fig. 5

Example - 1

For the circuits shown in **fig. 1**. (CE?CC configuration) various h-parameters are given

$h_{ie} = 2K$, $h_{fe} = 50$, $h_{re} = 6 * 10^{-4}$, $h_{oc} = 25$ □ A/ V.

$h_{ic} = 2K$, $h_{fe} = -51$, $h_{re} = 1$, $h_{oc} = 25$ □ A/ V.

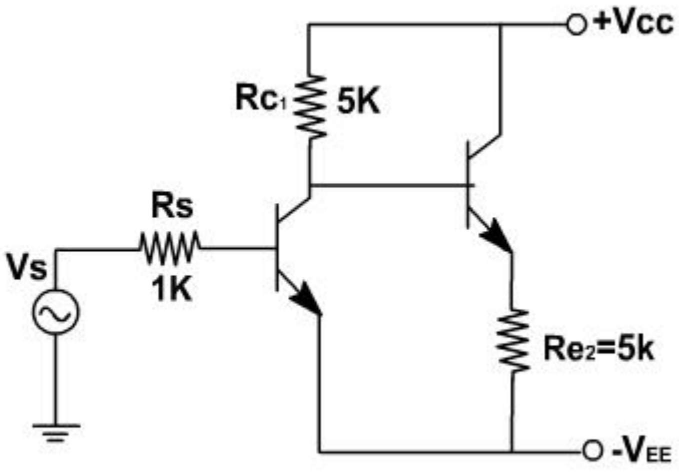


Fig. 1

The small signal model of the transistor amplifier is shown in **fig. 2.**

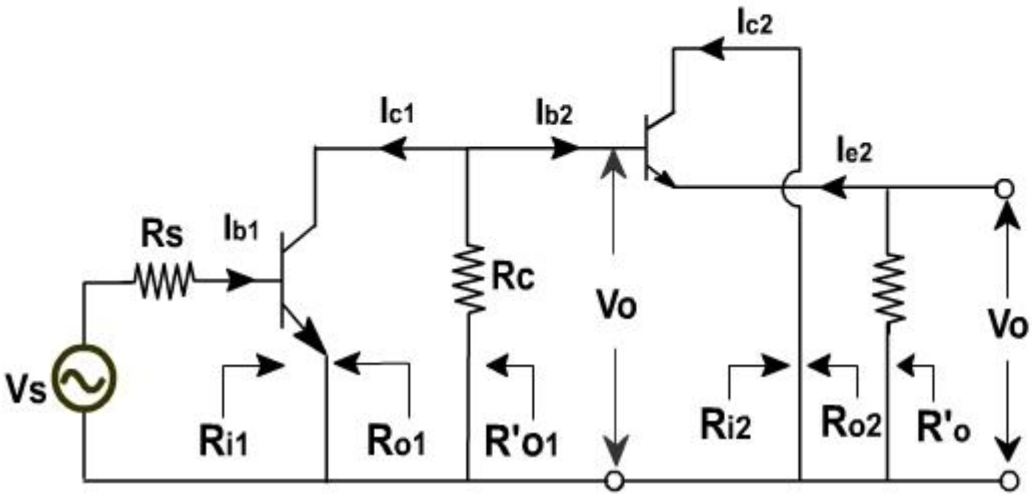


Fig. 2

In the circuit, the collector resistance of first stage is shunted by the input impedence of last stage. Therefore the analysis is started with last stage. It is convenient; to first compute current gain, input impedence and voltage gain. Then output impedence is calculated starting from first stage and moving towards end.

$$A_{i2} = \frac{-h_{fe}}{1+h_{oc}Z_L} = \frac{51}{1+25*10^{-6}*5*10^{3}}$$
$$= 45.3$$

$$R_{i2} = h_{ic} + h_{rc}A_{i2}Z_L$$
$$= 2*10^{3} + 1*45.3*5*10^{3}$$
$$= 228.5K \text{ (high input impedence)}$$

$$A_{V2} = \frac{V_0}{V_2} = \frac{A_i Z_L}{Z_{i2}}$$
$$= \frac{45.3*5}{228.5} = 0.99 \approx 1$$

$$R_{L1} = R_{C1} \| R_{i2}$$
$$= \frac{5*228.5}{5+228.5} = 4.9K$$

$$A_{i1} = -\frac{h_{fe}}{1+h_{oe}R_L} = \frac{-50}{1+25*10^{-6}*4.9*10^{3}}$$
$$= 44.5$$

$$R_{i1} = h_{ie} + h_{re}A_{i1}R_{L1}$$
$$= 2 - 6*10^{-4}*44.5*4.9$$
$$= 1.87K$$

Voltage gain of first stage is

$$A_{V1} = \frac{A_{i1}R_{L1}}{R_{i1}} = \frac{-44.5*4.9}{1.87}$$
$$= -116.6$$

$$Y_{o1} = h_{oe} - \frac{h_{fe}\ h_{re}}{h_{ie}+R_s}$$
$$= 25*10^{-6} - \frac{50*6*10^{-4}}{2*10^{3}+1*10^{3}}$$
$$= 15*10^{-6}\,\text{mho}$$

$$R_{o1} = \frac{1}{Y_{o1}} = 66.7K$$

$$R'_{o1} = R_{o1} \| R_{c1}$$
$$= 66.7 \| 5$$
$$= 4.65K$$

The effective source resistance R'_{S2} for the second stage is $R_{01} \| R_{C1}$. Thus $R_{S2} = R'_{01} = 4.65K$

$$Y_{O2} = h_{oe} - \frac{h_{fe}\ h_{rc}}{h_{ic} + R_{S2}}$$

$$= 25 * 10^{-6} - \frac{(-51)(1)}{2 * 10^{3} + 4.65 * 10^{3}}$$

$$= 7.70 * 10^{-3}\ {}^{A}\!/_{V}$$

$$R_{O2} = \frac{1}{Y_{O2}} = 130\Omega$$

$$R'_{O2} = R_{O2} \,||\, R_{c2}$$

$$= 0.13 \,||\, 5K$$

$$= 127\Omega$$

Overall current gain of the amplifier is A_i and is given by

$$A_i = -\frac{I_{e2}}{I_{b1}}$$

$$= -\frac{I_{e2}}{I_{b2}} * \frac{I_{b2}}{I_{c1}} * \frac{I_{c1}}{I_{b1}}$$

$$= -A_{i2} \cdot \frac{I_{b2}}{I_{c1}} * A_{i1}$$

The equivalent circuit of the amplifier is shown in **fig. 3**. From the circuit it is clear that the current i_{c1} is divided into two parts.

Therefore,

$$\frac{I_{b2}}{I_{c1}} = \frac{-R_{c1}}{R_{c1} + R_{i2}}$$

and

$$\therefore A_I = A_{i2} \cdot A_{i1} \cdot \frac{R_{c1}}{R_{c1} + R_{i2}}$$

$$= 45.3 * (-44.5) * \frac{5}{228.5 + 5} = -43.2$$

$$A_V = \frac{V_0}{V_I} = \frac{V_0}{V_2} \bullet \frac{V_2}{V_1}$$

$$= A_{V2} \cdot A_{V1}$$

$$= 0.99 * (-11.6)$$

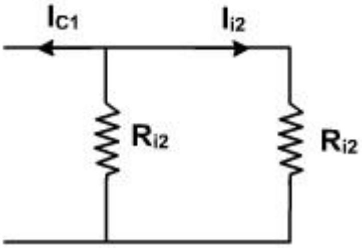
$$= 115$$

Overall voltage gain of the amplifier is given by

$$A_{VS} = \frac{V_0}{V_S} = A_V \cdot \frac{R_{i1}}{R_{i1} + R_S}$$

$$= -115 * \frac{1.87}{1.87 + 1}$$

$$= -75.3$$



Simplified common emitter hybrid model:

In most practical cases it is appropriate to obtain approximate values of A_V , A_i etc rather than calculating exact values. How the circuit can be modified without greatly reducing the accuracy. **Fig. 4** shows the CE amplifier equivalent circuit in terms of h-parameters Since 1 / h_{oe} in parallel with R_L is approximately equal to R_L if 1 / h_{oe} >> R_L then h_{oe} may be neglected. Under these conditions.

$I_c = h_{fe} I_B$.

$h_{re} v_c = h_{re} I_c R_L = h_{re} h_{fe} I_b R_L$.

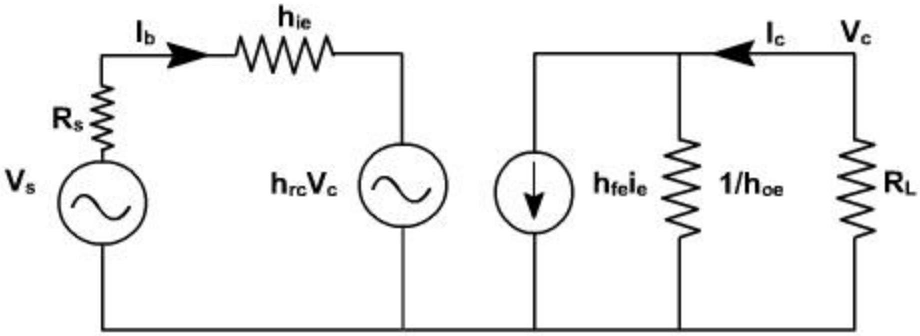


Fig. 4

Since $h_{fe}.h_{re}$ □ 0.01, this voltage may be neglected in comparison with h_{ic} I_b drop across h_{ie} provided R_L is not very large. If load resistance R_L is small than hoe and h_{re} can be neglected.

$$A_I = -\frac{h_{fe}}{1+h_{oe}R_L} \approx -h_{fe}$$

$$R_i = h_{ie}$$

$$A_V = \frac{A_I R_L}{R_i} = -\frac{h_{fe} R_L}{h_{ie}}$$

Output impedence seems to be infinite. When $V_s = 0$, and an external voltage is applied at the output we fined $I_b = 0$, $I_C = 0$. True value depends upon R_S and lies between 40 K and 80K.

On the same lines, the calculations for CC and CB can be done.

CE amplifier with an emitter resistor:

The voltage gain of a CE stage depends upon h_{fe}. This transistor parameter depends upon temperature, aging and the operating point. Moreover, h_{fe} may vary widely from device to device, even for same type of transistor. To stabilize voltage gain A_V of each stage, it should be independent of h_{fe}. A simple and effective way is to connect an emitter resistor R_e as shown in **fig. 5**. The resistor provides negative feedback and provide stabilization.

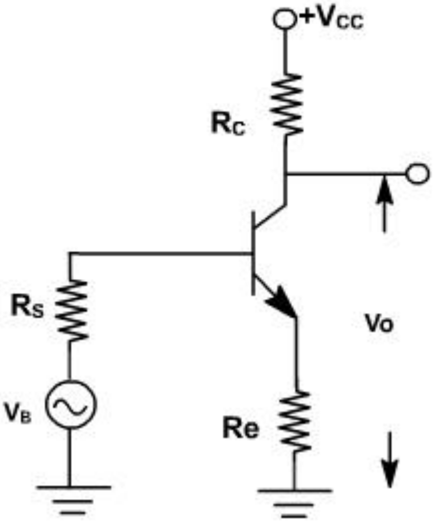


Fig. 5

An approximate analysis of the circuit can be made using the simplified model.

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

$$= -h_{fe}$$

It is unaffected by the addition of R_C.

Input resistance is given by

$$R_i = \frac{V_i}{I_b}$$

$$= \frac{h_{ie}\ I_b + (1+h_{fe})\ I_b\ R_e}{I_b}$$

$$= h_{ie} = (1+h_{fe})\ R_e$$

The input resistance increases by $(1+h_{fe})\,R_e$

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

Clearly, the addition of R_e reduces the voltage gain.

If $(1+h_{fe})R_e >> h_{ie}$ and $h_{fe} >> 1$

then

$$A_v = \frac{-h_{fe}\ R_L}{(1+h_{fe})R_e} \approx -\frac{R_L}{R_e}$$

Subject to above approximation A_V is completely stable. The output resistance is infinite for the approximate model.