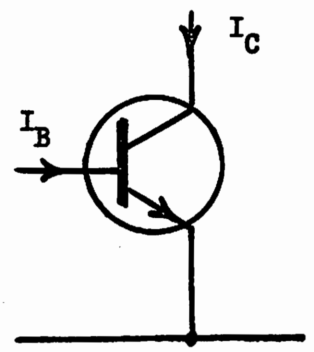
TRANSISTOR PARAMETERS AND EQUIVALENT CIRCUIT C PART 1

1. SMALL SIGNAL CURRENT GAIN (h_{fe})



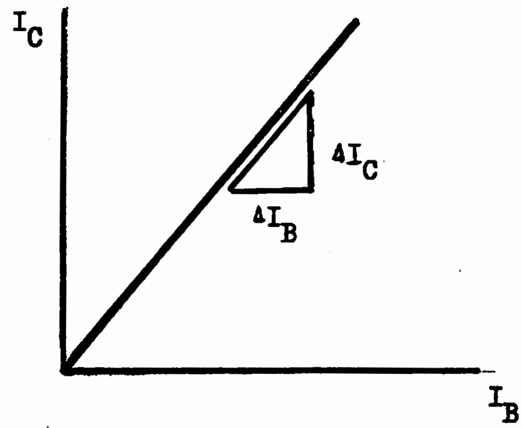


Fig. 1 Current Gain

1.1 The small signal current gain

$$h_{fe} = \frac{\Delta I_c}{\Delta I_B} = \frac{i_c}{i_b}$$

Note lower case letters indicate ac currents.

1.2 Over the normal range of collector current the transfer characteristic approximates to a straight line. It follows that the ac current gain

$h_{fe} = h_{FE}$ (The DC current gain)

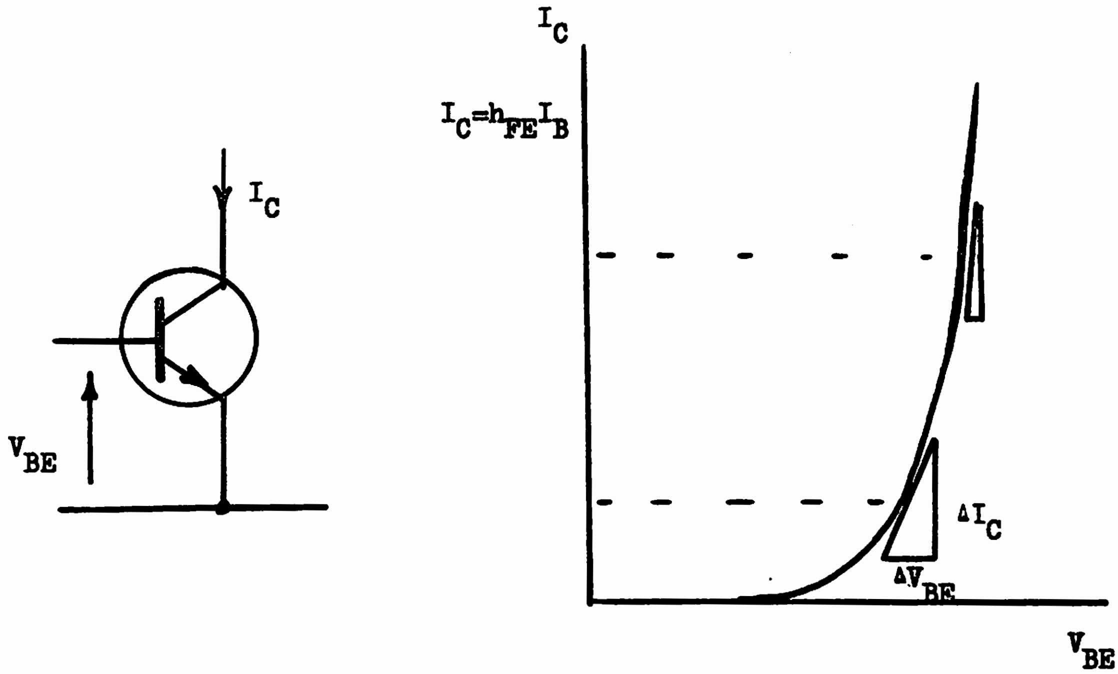


Fig. 2 Transconductance

2. TRANSCONDUCTANCE (g_m)

2.1 Transconductance

$$g_m = \frac{\Delta I_c}{\Delta V_{BE}} = \frac{i_c}{V_{be}} \quad \text{mA/V}$$

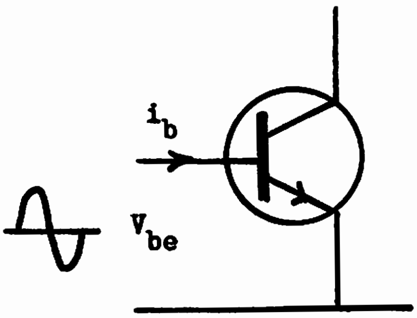
Fig 2 shows that the value of g_m will depend on the point at which the slope is measured. The fact that the curve approximates to an exponential enables the value of g_m at any point on the curve to be calculated from the equation

$$\boxed{g_m = 35 I_c}$$

This equation is also true for collector currents up to approximately 5mA.

TRANSISTOR PARAMETERS AND EQUIVALENT CIRCUIT

3. INPUT RESISTANCE (h_{ie})



Note The current and voltage shown in the diagram are ac values not dc.

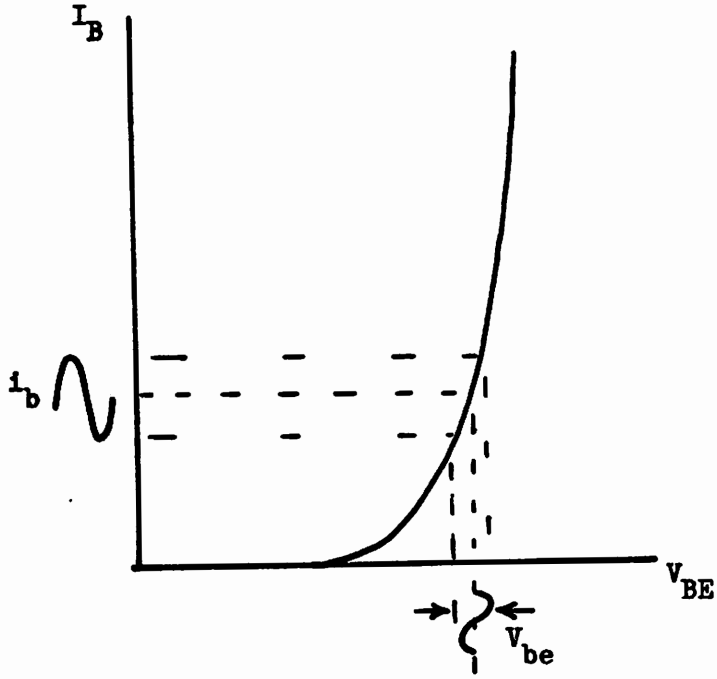


Fig. 3 Input resistance

3.1 The ac input resistance of the transistor

$$h_{ie} = \frac{V_{be}}{i_b}$$

now $$h_{ie} = \frac{h_{fe}}{g_m} \qquad \left(\frac{i_c}{i_b} \times \frac{V_{be}}{i_c} \right)$$

$$\boxed{h_{ie} = \frac{h_{fe}}{35 I_c}}$$

3.2 This shows that the higher the dc value of the collector current the lower will be the ac input impedance of the transistor.

4. VOLTAGE GAIN (A_V)

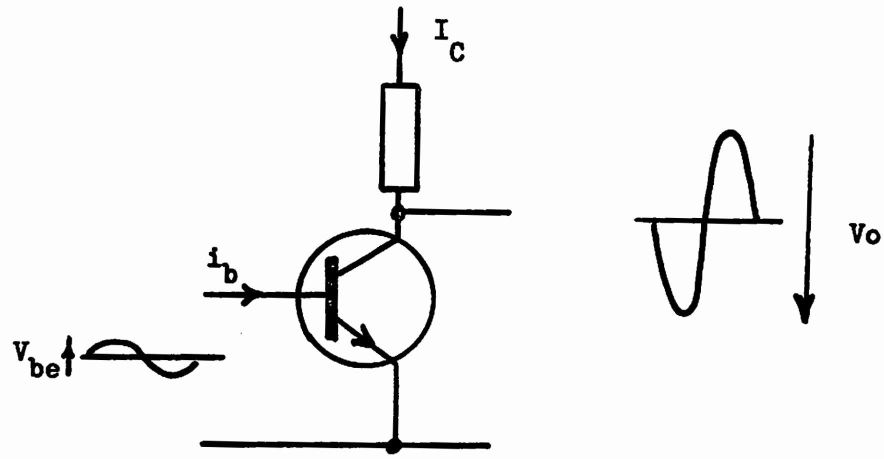


Fig. 4 Voltage gain

TRANSISTORS PARAMETERS AND EQUIVALENT CIRCUIT

4.1 The ac output voltage is due to the variation in I_c through R_L

$$V_o = -i_c R_L$$

where $i_c = g_m \times V_{be}$ $\qquad \left(g_m = \frac{i_c}{V_{be}} \right)$

hence $V_o = -g_m V_{be} R_L$

and the voltage gain

$$A_V = \frac{V_o}{Vin} = \frac{-g_m V_{be} R_L}{V_{be}} = \boxed{-g_m R_L}$$

$$\boxed{A_V = -35 I_c R_L}$$

The larger the collector current of the transistor the greater is its voltage gain.

5. INPUT AND OUTPUT IMPEDANCE OF THE COMMON EMITTER AMPLIFIER

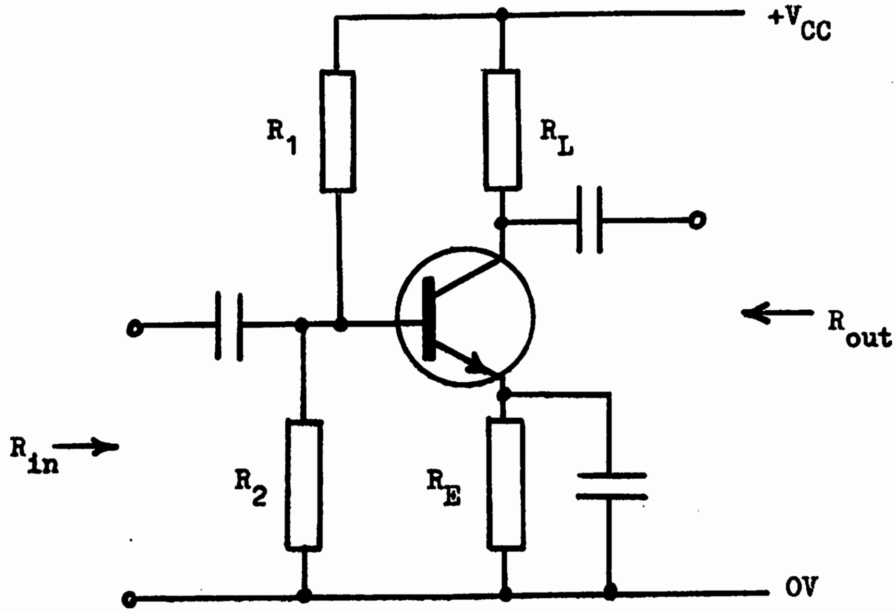


Fig. 5 Input and output impedance

5.1 The $+V_{cc}$ supply line is normally well decoupled to earth, hence as far as ac signals are concerned it can be considered to be at zero ac potential. The resistance 'seen' looking in at the input terminals, assuming all the capacitors have negligible reactance, will be

$$R_{in} = R_1 /\!/ R_2 /\!/ h_{ie}$$

5.2 At low frequencies when the reactance of the coupling capacitor becomes appreciable the gain of the circuit will fall. The 3dB point will occur when

$$X_c = R_{in}$$

5.3 The value of C must be large for a good low frequency response. C is normally 4 μF or greater

5.4 The output resistance of the amplifier is

$$R_L /\!/ \text{transistor output resistance}$$

As the transistor output resistance h_{oe}^{-1} is $\gg R_L$ the amplifier output impedance can be taken to be

$$R_o = R_L$$

6. THE EQUIVALENT CIRCUIT FOR A TRANSISTOR

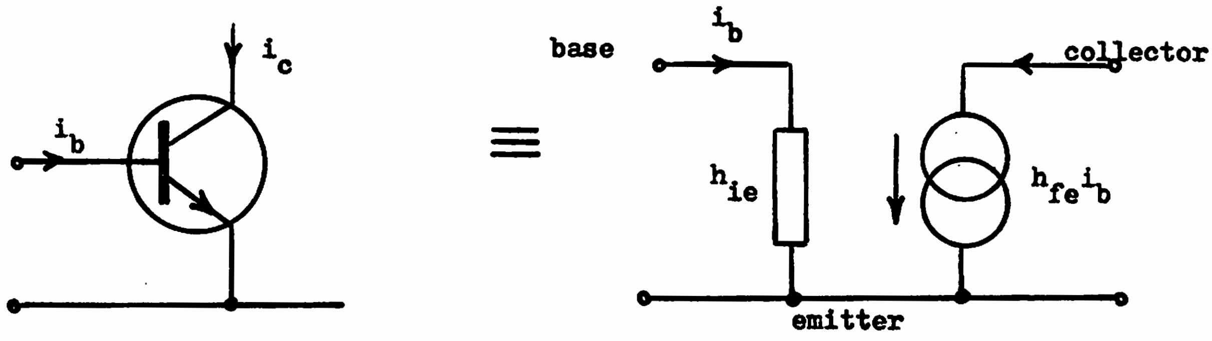


Fig. 6 Simplified ac equivalent circuit

6.1 Representing the transistor by an equivalent ac circuit simplifies analysis of more complex amplifier circuits.

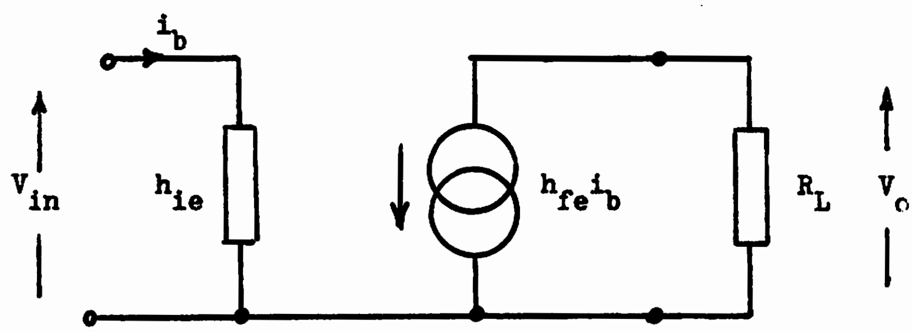


Fig. 6 Equivalent circuit for a common emitter amplifier

6.2 With reference to Fig 6.

$$V_{in} = i_b \times h_{ie}$$

$$V_o = - h_{fe}\, i_b\, R_L$$

hence voltage gain $A_v = \dfrac{V_o}{V_{in}} = \dfrac{-h_{fe}\, i_b\, R_L}{i_b\, h_{ie}}$

$$\underline{A_v = -g_m R_L}$$

input impedance $= h_{ie}$

output impedance $= R_L$

7. COMMON EMITTER AMPLIFIER WITH UNDECOUPLED EMITTER RESISTOR

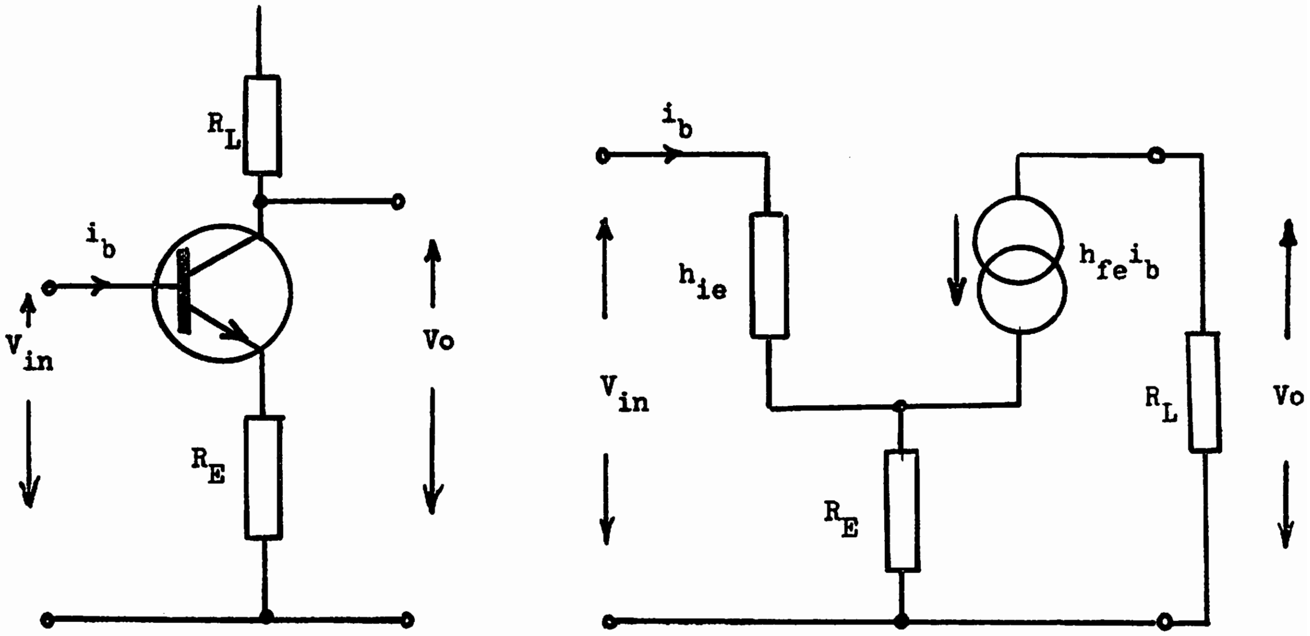


Fig 7 Undecoupled emitter circuit

7.1 With reference to Fig 7

$$V_{in} = i_b h_{ie} + (h_{fe} + 1) i_b R_E$$

$$V_o = -h_{fe} i_b R_L$$

The voltage gain will be

$$A_v = \frac{V_o}{V_{in}} = \frac{-h_{fe} i_b R_L}{i_b h_{ie} + (h_{fe} + 1) i_b R_E}$$

$$\boxed{A_v = \frac{-g_m R_L}{1 + g_m R_E}}$$ (assuming $h_{fe}+1 \approx h_{fe}$)

Now if $g_m R_E \gg 1$ then $A_v = \dfrac{-g_m R_L}{g_m R_E}$ $\boxed{= \dfrac{-R_L}{R_E}}$

TRANSISTOR PARAMENTERS AND EQUIVALENT CIRCUIT

Note The loss of gain from $g_m R_L$ is due to NFB. The approximation

$$A_v = \frac{R_L}{R_E} \text{ is acceptable where } \frac{R_L}{R_E} \text{ is less than } 10$$

7.2 The transistor input impedance

$$R_{in} = \frac{V_{in}}{i_b}$$

now $V_{in} = i_b h_{ie} + (h_{fe} + 1) i_b R_E$

hence $R_{in} = \frac{V_{in}}{i_b} = h_{ie} + (h_{fe} + 1) R_E$

$$\boxed{R_{in} = h_{ie} + h_{fe} R_E}$$ assuming $h_{fe} + 1 \simeq h_{fe}$

7.3 An undecoupled emitter resistor increases the input impedance of the amplifier by $h_{fe} R_E$. If the circuit uses a high h_{fe} transistor and R_E is 1K or greater than the effective input impedance of the transistor will be hundreds of kilohms

8 THE FIELD EFFECT TRANSISTOR

8.1 There is no simple relationship that can be used to determine mathematically the equivalent parameters for a FET. The use of load lines is a more acceptable method of analysing FET amplifiers.

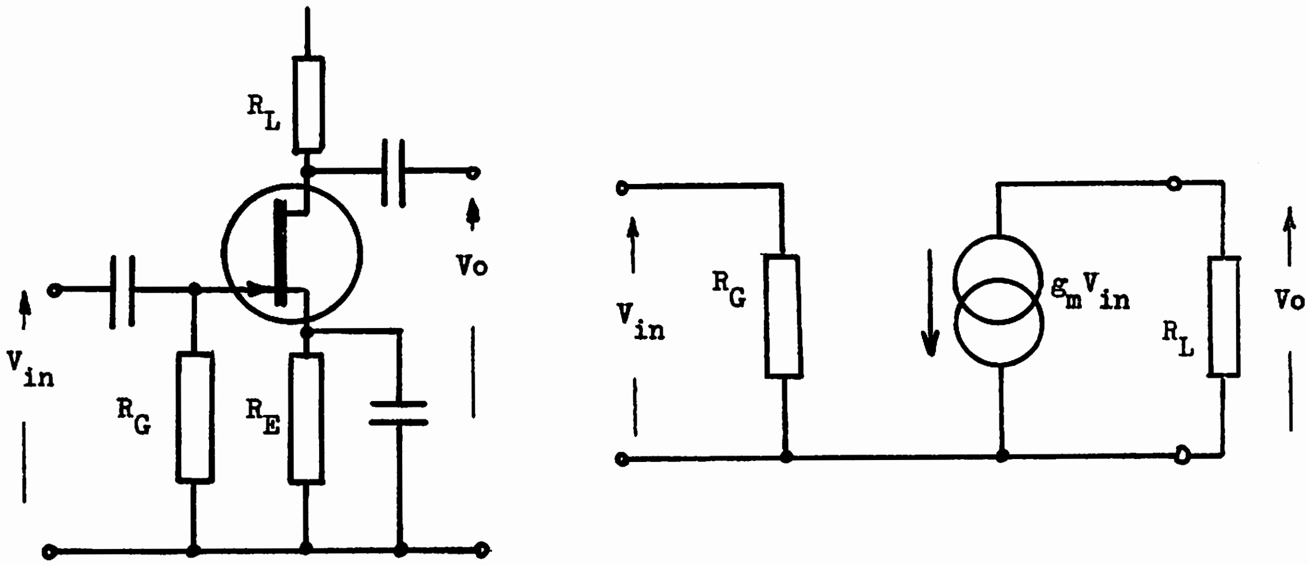


Fig. 8 Equivalent circuit for a FET common source amplifier.

8.2 Fig 8 shows the equivalent circuit for FET common source amplifier The value of g_m would have to be obtained from manufacturers data or by reference to the drain characteristic.

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20th November, 1980