EXPERIMENT #4
RC COUPLED TRANSISTOR AMPLIFIER

Small signal transistor stages can be coupled by use of resistive-capacitive (RC) type networks. The use of coupling and bypass capacitors cause the transfer gain of the amplifier to fall-off at low frequencies. Amplifiers not employing coupling and bypass capacitors such as DC amplifiers are capable of amplifying very low frequency signals. The capacitor C1 in Figure 4-1 couples the AC signal source to the active device and blocks the DC components.

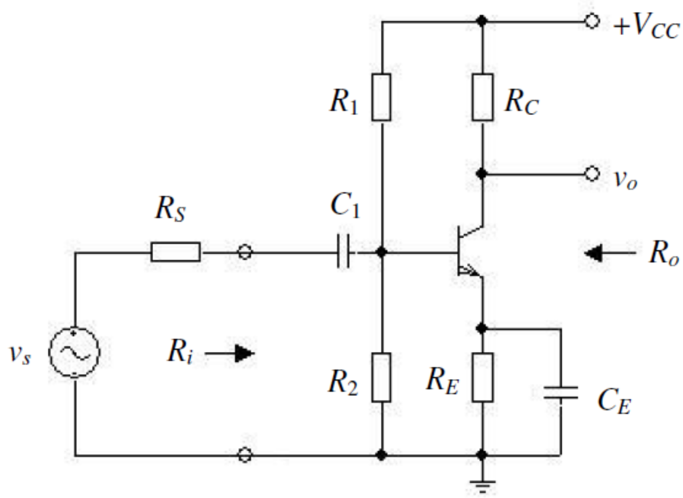


Figure 4-1: Single Stage RC-Coupled, Common Emitter Transistor Amplifier

The voltage gain for the transistor circuit with input coupling is:

$$A_v(s) = \frac{-h_{fe} R_B R_C}{\left[R_S\left(R_B + h_{ie}\right) + R_b h_{ie}\right]} \cdot \frac{s}{s + \dfrac{1}{C_1\left[R_S + \left(R_B // h_{ie}\right)\right]}}$$

which can be written as:

$$A_v(s) = -\frac{R_C}{r_e} \cdot \frac{R_i}{R_S + R_i} \cdot \frac{s}{s + \dfrac{1}{C_1\left(R_S + R_i\right)}}$$

where

$$r_e = \frac{h_{ie}}{h_{fe}} = \frac{0.026}{I_E}, \quad R_i = R_B // h_{ie} \quad \text{and} \quad R_B = R_1 // R_2$$

The pole frequency of this transfer function is:

$$f_p = \frac{1}{2\pi C_1\left(R_S + R_i\right)}$$

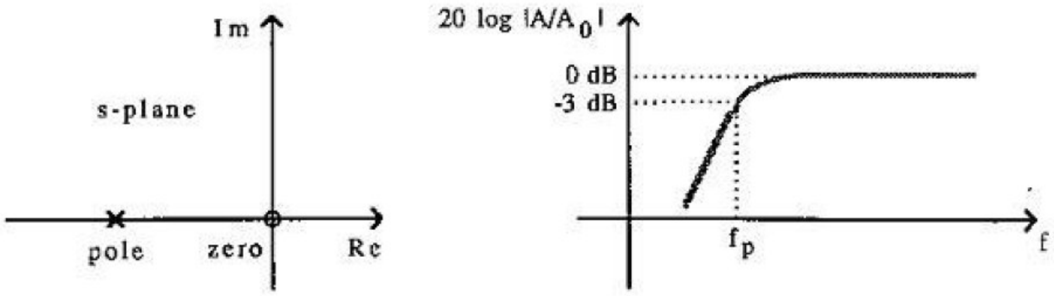


Figure 4-2: The pole-zero diagram and Bode plot of gain (the effect of coupling capacitor)

In the midband range, $C1$ can be assumed short circuit, hence

$$A_o = A_v(midband) = -\frac{R_C}{r_e} \cdot \frac{R_i}{R_S + R_i}$$

$$A_o \approx -\frac{R_C}{r_e} \qquad \text{if} \quad R_S << R_i$$

The pole-zero diagram and asymptotic Bode plot of gain are shown in *Figure 4-2*. The effect of adding an emitter resistor R_E with bypass capacitor C_E produces essentially the same effect as the input and output coupling capacitors. The voltage gain can be written as:

$$A_v(s) = \frac{-h_{fe} R_B R_C}{[R_B R_S + h_{ie} R_B + h_{ie} R_S]} \cdot \frac{s + \frac{1}{R_E C_E}}{s + \frac{1}{R_E C_E} + \frac{1 + h_{fe}}{C_E [h_{ie} + (R_B // R_S)]}}$$

this can be rearranged for h_{fe} >>1:

$$A_v(s) = -\frac{R_C}{r_e} \cdot \frac{R_i}{R_S + R_i} \cdot \frac{s + \frac{1}{R_E C_E}}{s + \frac{1}{R_E // [r_e + (R_S // R_B)/h_{fe}] C_E}}$$

The zero and pole frequencies are respectively:

$$f_0 = \frac{1}{2\pi \; R_E C_E}$$

$$f_p = \frac{1}{2\pi \left\{ R_E // \left[r_e + \frac{R_S // R_B}{h_{fe}} \right] \right\} C_E}$$

In most cases:

$$(R_S // R_B)/h_{fe} << r_e << R_E$$

and

$$f_p \approx \frac{1}{2\pi \ r_e C_E}$$

In the midband frequency range, the emitter capacitor can be assumed short circuit and the gain can be found as:

$$A_o \approx -\frac{R_C}{r_e} \qquad \text{if} \quad R_S << R_i$$

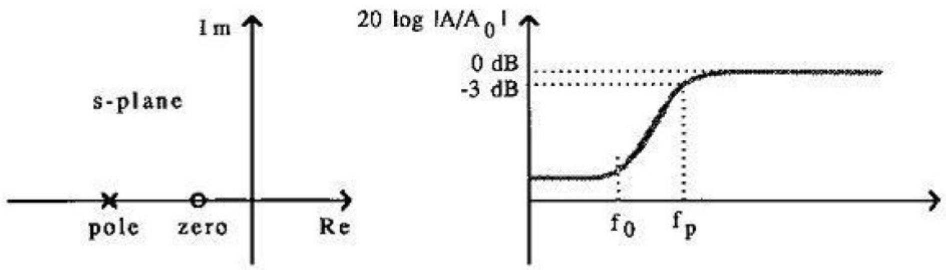


Figure 4-3: The pole-zero diagram and Bode plot of gain (the effect of Emitter bypass capacitor)

In most applications, both C_E and C_1 are present and the analysis is very complicated. However, the emitter bypass capacitor usually determines the low-frequency response, and this requires that the pole frequency due to C_1 be far below the pole frequency due to C_E. This implies that:

$$\frac{1}{C_1(R_S + R_i)} << \frac{1}{C_E r_e}$$

For most cases $r_e < (R_S+R_i)$, but this situation may change when one choses $C_E >> C_1$. The amplifier input and output impedances are also frequency dependent. However, these are normally specified for the midband frequency range. For the common emitter amplifier:

$$R_i = R_B // h_{ie} \approx h_{ie} = h_{fe} r_e$$

$$R_o = R_C // (1/h_{oe}) \approx R_C$$

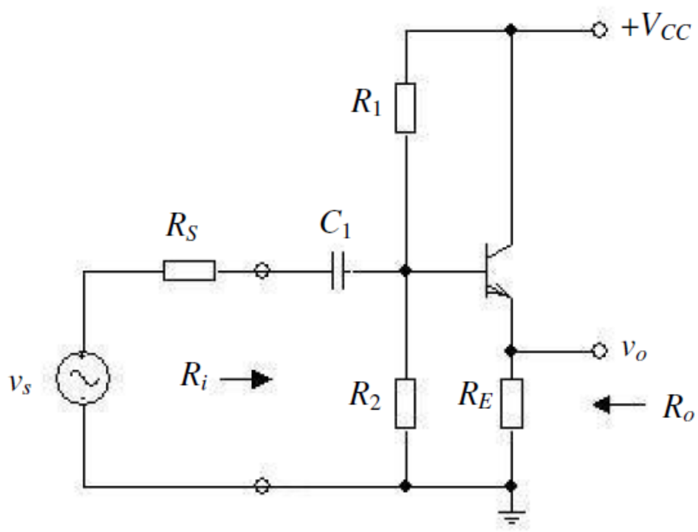


Figure 4-4: Emitter Follower Circuit

and for the emitter follower circuit:

$$R_i = R_B // \left[h_{fe}\left(r_e + R_E\right)\right] \approx R_B // \left(h_{fe} R_E\right)$$

$$R_o = R_E // \left[r_e + \frac{R_S // R_B}{h_{fe}}\right] \approx r_e$$

EQUIPMENT

1. CRT oscilloscope
2. Audio signal generator
3. Electronic A.C. voltmeter
4. Decade resistor box
5. Bread-board

COMPONENTS

1. Transistor: BC238B or equivalent
2. Capacitors: 100 nF, 1µF, 10µF and 100µF
3. Resistors: 270k, 82k, 2k7, 1k

PROCEDURE

1. Set-up the circuit shown in *Figure 4-5*. Calculate the D.C. operating point and *Av*, *Ri*, *Ro* for both emitter follower and common emitter configuration.

Calculated : V_{CEQ} = ... I_{CQ} = ...

Measured : V_{CEQ} = ... I_{CQ} = ...

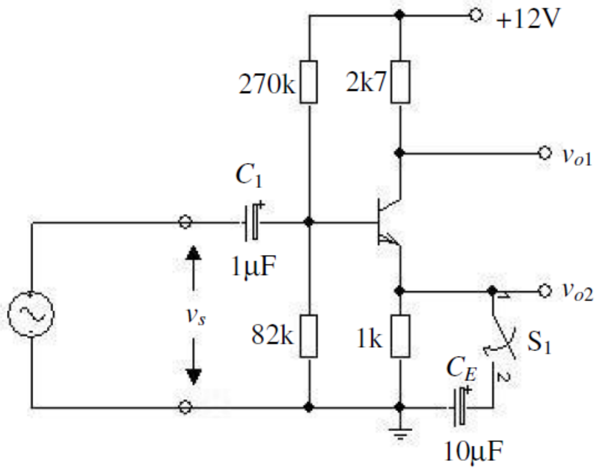


Figure 4-5: Experimental Single Stage Amplifier

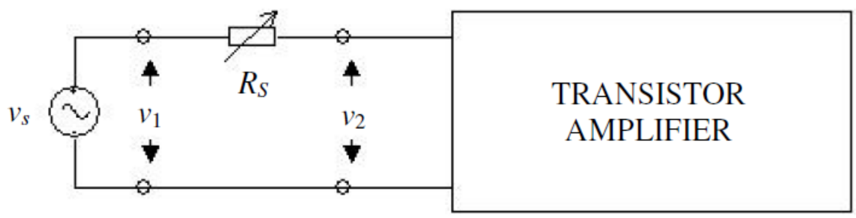
2. Apply a 20mVpp-10kHz sine wave to the input and measure *vo*1 (when S1 is closed) and *vo*2 (when S1 is opened). Calculate the voltage and the current gains of common emitter amplifier and emitter follower circuits respectively.

v_{o1} = ... v_{o2} = ...

A_{v1} = ... A_{v2} = ... A_{i1} = ... A_{i2} = ...

3. Insert a resistor decade box between the source and the input. Adjust R_S to obtain $v2=v1/\ 2$. The input impedance is then equal to R_S.

R_i (common emitter)= ....



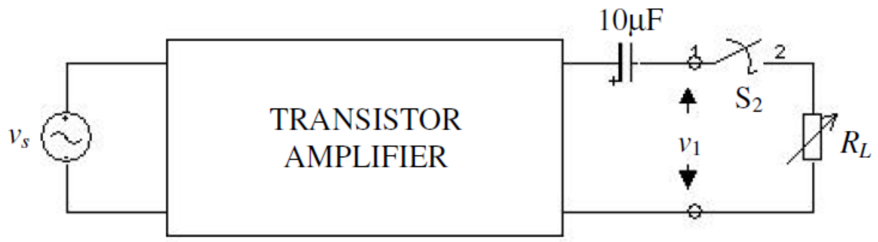
4. Open the switch S1 and repeat step 3 for the emitter follower circuit.

Ri (emitter follower)= ....

5. Apply the following procedure to measure the collector and the emitter output impedances:

Measure the amplitude of the A.C. signal *v*1 with the switch S_2 open. Now close the switch and adjust R_L until *v*1 is halved. The output impedance *Ro* is then equal to R_L.

Ro (collector)= ....



6. Repeat step 5 for the emitter follower circuit.

Ro (emitter)= ....

7. Using the set-up in *Figure 4-5* apply a 10kHz sine wave to the amplifier and adjust *vin* until you see a distortionless output waveform. Take the peak value of this signal as your reference voltage *vr*. Then keeping the input voltage constant, change the frequency and read the output voltage *vo*. Take enough data to make a rough plot of the voltage gain as the input frequency is varied. Measure the lower 3dB frequency and compare with your calculated value.

f (Hz)	100	200	500	1000	2000	5000	10000
20 log (v_o / v_r) (dB)							0

f(-3dB) = ...

8. Sketch and dimension the Bode magnitude plots of the voltage gains on semi-log paper.