Introduction

There are several basic single transistor circuit configurations that serve as the building blocks for larger, more complex circuits. Here you will examine four basic configurations – viz., (i) the universal transistor amplifier, (ii) the common emitter (CE), (iii) the common collector (CC), and (iv) the common base (CB). To DC bias the transistor properly, a basic resistor network will be used to establish a stable DC bias point that is relatively insensitive to the transistor beta. By adding AC bypass capacitors in appropriate locations to create AC small-signal shorts, several small-signal transistor configurations can be realized from the universal transistor amplifier configuration.
Component Familiarization and Identification

It should be instructive to familiarize yourself with your ohmmeter as a means of evaluating properties of junction devices. Use an ohmmeter range whose internal voltage source is high enough (> 0.7 V) to allow a silicon diode junction to conduct. Some ohmmeters intentionally incorporate ranges (often marked with a diode symbol) whose voltages are low enough to allow conventional resistors to be measured even when shunted by diode junctions. Both to verify the ohmmeter polarity and its ability to cause a junction to conduct, check your ohmmeter range(s) using a diode whose banded end is the cathode (from which current flows during conduction). Otherwise, use a second voltmeter to verify the terminal voltage polarity and magnitude. Finally, realize that larger junctions exhibit (slightly) lower resistances, and that the collector-base junction of a typical transistor is much larger than its emitter-base junction. Now take ohmmeter measurements of your transistor(s), thereby checking the transistor type (nnp vs pnp) and the pin connections. Note that the "resistance" between collector and emitter is ∞ for either polarity.

Consider the ease with which you can perform this important piece of detective work. There are even more tricks for using an ohmmeter in evaluating semiconducting devices.
Laboratory Tasks

Task 1 - Establishing a Stable DC Biasing of a Transistor Stage.

Figure 1: $R_1 \approx 20\,k\Omega$, $R_2 = 10k\Omega$, $R_3 \approx 4k\Omega$, $R_4 = 1k\Omega$ and $C_1 = C_2 = C_3 = 20\mu F$

a) Wire the circuit shown in Figure 1 above.

b) Adjust (tweak) $R_2$ so that $V_c = 6V$.

c) Measure the final resistor values, DC voltages and DC currents. Note: the current into the base of the transistor will be quite small so you will need to use a high accuracy multimeter with microamp resolution.

d) Compare the base current to the bias current in $R_2$. If the transistor beta were to double or to half, how would this effect the DC bias point of the transistor? How stable would the DC bias point be if $R_1$ and $R_2$ were made x10 larger?

e) Calculate the small signal $g_m$ and $r_\pi$ of this transistor.
Task 2 - Common Emitter Amplifier - AC Small Signal.

The CE amplifier has high gain, medium input resistance, medium output resistance, but poor high frequency performance. It is a very common gain stage.

a) Wire the circuit shown in Figure 2 above.

b) A 10μF capacitor will appear as an AC short circuit at high enough frequency. What is the magnitude of the impedance of a 10μF capacitor at 10kHz?

c) Draw the AC small-signal model of this circuit. Comment on the effect of R₄. Comment on the effect of R₁ and R₂ compared to rπ.

d) Apply an AC small-signal, sinusoidal input of 10mV peak-to-peak at 10kHz. Measure the resulting AC output signal, peak-peak voltage, frequency, and phase. What is the measured gain?
e) Add a 1k\(\Omega\) resistor in series with the sinusoidal input. Measure the AC output signal. Measure the AC voltage at the base of the transistor. Comment. Estimate the input resistance of the CE amplifier with the R\(_1\)-R\(_2\) bias circuit. The intrinsic input resistance of the CE amplifier is \(r_\pi\). How does the intrinsic input resistance compare to the effect of R\(_1\) and R\(_2\).

f) Add a 1k\(\Omega\) resistor to the output (after the bypass capacitor). Measure the AC output signal. Comment. Estimate the output resistance of the CE amplifier.

g) Increase the input magnitude up to 1V. Measure the output. When does the signal become significantly distorted? \(g_m R_L = \) ? What is happening?

h) Use SPICE to verify your measurements of gain, input resistance, and output resistance using the AC analysis. Use the transient analysis to verify your distortion measurement. (For more advanced SPICE users, there is an additional command for calculating the harmonic distortion.)
Task 3 - Common Collector Amplifier.

Figure 3: $R_1 \approx 20k\Omega$, $R_2 \approx 10k\Omega$, $R_3 \approx 4k\Omega$, $R_4 \approx 1k\Omega$ and $C_1 = C_2 = C_3 \approx 20\mu F$

The CC or emitter follower has a gain of about 1, large input resistance, and small output resistance. It has very good high frequency performance. The CC is an excellent buffer circuit.

a) Wire the circuit shown in Figure 3. The $10\mu F$ capacitors act as AC small signal shorts.

b) Draw the AC small-signal model of this circuit. Comment on the effect of $R_1$, $R_2$, and $R_3$.

c) Apply an AC sinusoidal input of 1V peak-to-peak at 10kHz. Measure the resulting AC output signal, peak-peak voltage, frequency, and phase. What is the measured gain? Remove $C_2$, what happened to the output? Explain.

d) Add a $10k\Omega$ resistor in series with the sinusoidal input. Measure the AC output signal. Measure the AC voltage at the base of the transistor. Comment. Estimate the input resistance of the CC amplifier with the $R_1$-$R_2$ bias circuit. The intrinsic input resistance of the CC amplifier is (approximately)
\( (r_n + \beta R_4) \). How does this intrinsic input resistance compare to the effect of \( R_1 \) and \( R_2 \).

e) Add a 100Ω resistor to the output (after the bypass capacitor). Measure the AC output signal. Comment. Estimate the output resistance of the CC amplifier.

f) Increase the input magnitude up to 6V. Measure the output. When does the signal become significantly distorted? What is happening?

g) Use SPICE to verify your measurements of gain, input resistance, and output resistance using the AC analysis. Use the transient analysis to verify your distortion measurement.
Task 4 - Common Base Amplifier.

The CB has a large gain, small input resistance, and medium output resistance. It has good high frequency performance.

a) Wire the circuit shown in Figure 4. The 10μF capacitors act as AC small-signal shorts.

b) Draw the AC small-signal model of this circuit. Comment on the effect of $R_1$, $R_2$, and $R_3$.

c) Apply an AC, small signal sinusoidal input of 10mV peak-to-peak at 10kHz. Measure the resulting AC output signal, peak-peak voltage, frequency, and phase. What is the measured gain?

d) Add a 100Ω resistor in series with the sinusoidal input. Measure the AC output signal. Measure the AC voltage at the emitter of the transistor. Comment. Estimate the input resistance of the CB as an amplifier. (Note that the input resistance of the CB is the same as the intrinsic output resistance of the CC.)
e) Add a 1 kΩ resistor to the output (after the bypass capacitor). Measure the AC output signal. Comment. Estimate the output resistance of the CB amplifier.

f) Increase the input magnitude up to 6V. Measure the output. When does the signal become significantly distorted? What is happening?

g) Use SPICE to verify your measurements of gain, input resistance, and output resistance using the AC analysis. Use the transient analysis to verify your distortion measurement.

Task 5 - Universal Transistor Amplifier.

This circuit is able to provide a precision gain that is relatively independent of the transistor characteristics and is essentially the ratio of $R_3/R_4$. It can also simultaneously act as a buffer.

a) Wire the circuit shown in Figure 5.

b) Draw the AC small signal model of this circuit.

Figure 5: $R_1 \approx 20k\Omega$, $R_2 \approx 10k\Omega$, $R_3 \approx 4k\Omega$, $R_4 \approx 1k\Omega$ and $C_1 = C_2 = C_3 \approx 20\mu F$. 

This circuit is able to provide a precision gain that is relatively independent of the transistor characteristics and is essentially the ratio of $R_3/R_4$. It can also simultaneously act as a buffer.
c) Apply an AC, small-signal sinusoidal input of 10mV peak-to-peak at 10kHz. Measure the resulting AC output signal at $V_{out1}$ and $V_{out2}$, peak-peak voltage, frequency, and phase. What is the measured gain?

d) Add a 1 kΩ resistor in series with the sinusoidal input. Measure the AC output signal. Measure the AC voltage at the base of the transistor. Comment. Estimate the input resistance of the CB with the $R_1$-$R_2$ bias circuit.

e) Add a 1kΩ resistor to the $V_{out1}$ output (after the bypass capacitor). Measure the AC output signal. Comment. Estimate the output resistance.

f) Increase the input magnitude to 2V. Measure $V_{out1}$. When does the signal become significantly distorted? What is happening?

g) Use SPICE to verify your measurements of gain, input resistance, and output resistance using the AC analysis. Use the transient analysis to verify your distortion measurement.