Bilkent University

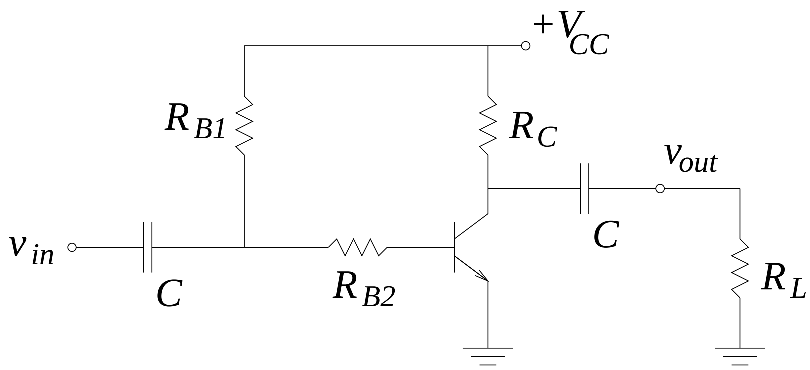
Department of Electrical and Electronics Engineering

EEE 313 Electronic Circuit Design

Experiment 4
Simple BJT Amplifier

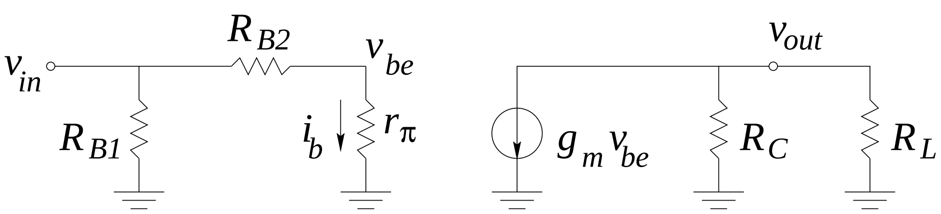
Introduction

The aim of this experiment is to investigate the simple bipolar junction transistor (BJT) amplifier shown in the figure.



The npn transistor is connected in a common emitter configuration. The input and output voltage signals are coupled to and from the amplifier with the use of coupling capacitors. The base resistors R_{B1} and R_{B2} bias the transistor to a Q-point. The collector resistor R_C converts the output current to an output voltage signal. The amplifier output drives a load with resistance R_L. The simple biasing scheme used in this circuit leaves the Q-point sensitive to changes in the value of the transistor β.

The small-signal AC equivalent circuit for this amplifier is shown in the figure.



The value of the small-signal input resistance is determined by the DC base current; $r_\pi = nV_T/I_{BQ}$, where n is the emission coefficient. The small-signal transconductance is given by $g_m = I_{CQ}/nV_T$.

Preliminary work

Review Sections 3.4 and 4.2 in the textbook.

In the laboratory, you will construct the amplifier circuit using the following values:

V_{CC}	R_{B1}	R_{B2}	R_C	R_L	C
15 V	470 kΩ	1.8 kΩ	1 kΩ	100 kΩ	10 μF

The transistor that you will use is BC238B. This transistor has $200 < \beta < 320$. In the preliminary work section, you are asked to base your calculations on three different values of β, namely $\beta_1 = 250$, $\beta_2 = 200$, and $\beta_3 = 320$. Other transistor parameters are $V_{CE(SAT)} = 0.2$ V and $V_{BE(ON)} = 0.6$ V. Assume that the emission coefficient $n = 1$, even though BC238B transistors usually exhibit a higher value. For each β value (250, 200, 320):

1. Analyze the DC circuit to determine the Q-point. Find I_{BQ}, I_{CQ}, and V_{CEQ}.
2. Draw the load line and the transistor i_C–v_{CE} characteristics, and indicate the Q-point. (Separate graph for each β value.)
3. Calculate the peak-to-peak maximum undistorted voltage swing at the output.
4. Draw the AC equivalent model assuming that the capacitors are short circuit at the operating frequency. Calculate r_π, g_m, and the the voltage gain $A_v = v_{out}/v_{in}$.
5. Simulate the amplifier circuit using PSPICE. First do a Bias Point analysis to determine DC voltages and currents. Next, do a Time Domain analysis using an input sine wave of 2 mV peak-to-peak at a frequency of 1 kHz, and determine the voltage gain. Repeat with input amplitudes of 40 mV, 140 mV, and 500 mV; note the changes on the output waveform. Comment on your results.

Experimental work

In this experiment you are going to use the silicon npn transistor BC238B. The spec sheets for this transistor can be found at the course web page. For this transistor, $V_{BE(ON)} \simeq 0.6$ V and $V_{CE(SAT)} \simeq 0.2$ V.

Before constructing the circuit, verify the values of the resistors that you are going to use by measuring their resistances with a multimeter. Make sure that all resistors are within 2% of their marked values. This will assure that your current measurements are accurate.

Construct the amplifier circuit using the values indicated in the preliminary work section.

1. Before connecting the signal generator, measure I_{BQ}, I_{CQ}, and V_{CEQ}, and compare these with your calculations. Draw the load line on a graph and indicate the Q-point.
2. Using your measurements from the previous part, determine the β of the transistor that you are using.
3. In this part you are going to measure the input resistance r_π at the operating point. The resistor R_{B2} and r_π form a voltage divider in the AC circuit. Set the input voltage signal to a sinusoid with 1 kHz frequency and 40 mV peak-to-peak amplitude. Measure v_{be} and determine r_π. Compare this value with your calculations and determine the value of the emission coefficient n.
4. Now you have measured the particular β and n values for the specific transistor that you are using. Calculate the voltage gain of the amplifier using these values.
5. Set the input voltage signal to a sinusoid with 1 kHz frequency and 40 mV peak-to-peak amplitude. Observe the input and output voltage waveforms on the oscilloscope. Measure the voltage gain of the amplifier and compare with your calculations from the previous part.
6. Gradually increase the input signal amplitude and determine the onset of distortion at the output. Measure v_{be} at this point and compare with V_T.
7. Further increase the input signal amplitude and determine the onset of clipping. Measure the peak-to-peak maximum undistorted output voltage swing. (Here “undistorted” really means “unclipped.”) Comment on how this value is related to the location of the Q-point on the load line.
8. Print the output waveform for three different values of peak-to-peak input amplitude: 40 mV, 140 mV, and 500 mV. On each plot, indicate any distortion or clipping that you may see.