Lab 6: Transistors I

Goal

The goal is to understand the most important bipolar transistor circuits.

Objectives

1. Identify transistor terminals using the multimeter
2. Construct an Emitter follower and estimate input/output impedance
3. Estimate the transistor current gain (β or h_{FE})
4. Construct a current source and estimate the output compliance

Expectations

1. You are expected to take detailed notes during each step outlined in the procedure that can be used during the lab report write-up.
2. You are expected to provide a neat table of the data that you measured where you clearly label what each data set is and include units for all measured quantities.
3. You are expected to clearly record the measured values of any components that you use.
4. You are expected to clearly record the detail related to images captured by the oscilloscope.
5. You are expected to make your final plots in a program such as Excel. Make sure that your data points appear clearly on the plots, that all axes are clearly labeled and have units.
6. If it is possible to compare your measurements with an expectation or a prediction, you are expected to do so in your lab report
7. You are expected to answer the questions encountered in this manual as well as discuss exercises given during the lectures in your lab write up.

Introduction to Concepts

The transistor is a device that can amplify, producing an output signal with more power in it than the input signal. The additional power comes from an external source of power.

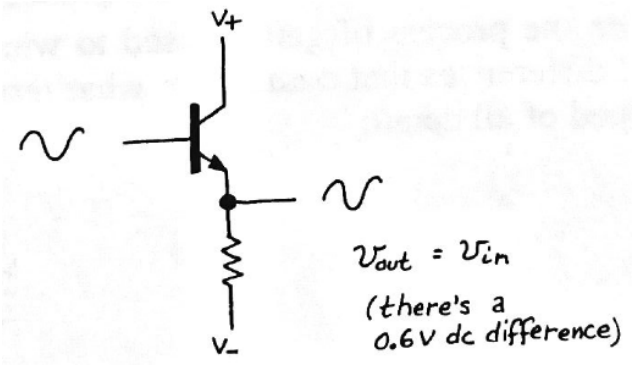

Figure 1: An emitter follower changes the impedance of its input signal.

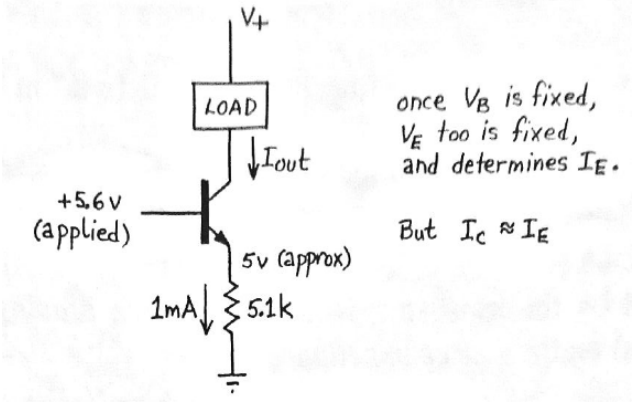

Figure 2: A current source.

The Emitter Follower

The input impedance of an emitter follower is much larger than the output impedance. This means that the circuit requires less power from the signal source to drive a given load than would be the case if the signal source were to drive the load directly. An emitter follower simply changes the impedance of its input signal. A simple view of an emitter follower is shown in Figure 1

The Current Source

An ideal current source provides a constant output current independent of the resistance of the load. A basic current source is shown in Figure 2. A current source can provide constant current to the load only over some finite range of load voltage. The output voltage range over which a current source behaves well is called its **output compliance**.

Preliminary Lab Questions

You will find useful to complete the preliminary lab questions before starting the procedure.

1. Derive an equation for the collector current (I_C) using base current (I_B) and emitter current (I_E) for the circuit shown in Figure 4?

2. Derive an equation for the base current (I_B) using R and 3.6 kΩ in the circuit shown in Figure 4?
3. Combine above two equations to obtain an equation for the collector current (I_C) using R, 3.6 kΩ, and voltage drop across the Base to emitter (V_{BE})?
4. Derive an equation for the collector current (I_C) using base current (I_B) and emitter current (I_E) for the circuit shown in Figure 5?
5. Derive an equation for the collector current (I_C) using V_{BE}, 470 Ω at the base and 820 Ω at the emitter for the circuit shown in Figure 5?
6. Calculate the collector current (I_C) using the above two equations?
7. What is the range of resistance for the load of the current source shown in Figure 5 where constant current is expected? This range is called **output compliance** range of a current source.

Equipment and Parts

1. Power supply (EXTEC 18 V DC power supply)
2. Two multimeters
3. RLC meter
4. proto-board (PB 500) with power supply for use as 5V

You will also need the following components in order to carry out this lab.

1. 2N3904 transistor
2. Resistor box
3. 1 KΩ, 3.6 KΩ, 470 Ω, and 750 Ω resistors for other circuits
4. Four pairs of crocodile cables
5. Connecting wires (4 - 6)
6. Three BNC to crocodile cables

Procedure

Identify Transistor Terminals

- For testing purpose, transistor junctions can be considered diodes, see Figure 3
- Set the multimeter to **diode test function** and measure voltage drop across two terminals
- Identify BC and BE junctions using the diode test function
- The BC junction voltage drop is the larger of the two junctions.

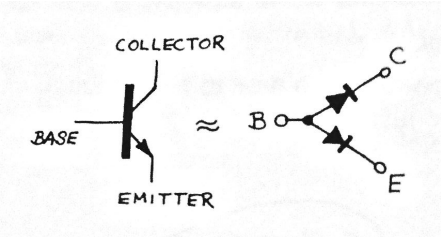

Figure 3: For testing purpose, transistor junctions are diodes.

Transistor Current Gain

- Construct the circuit shown in Figure 4, use one multimeter as an ammeter, set the range to mA
- Use the resistor box as a variable resistor at the transistor base terminal (R).
- Use the 18 V power supply to provide 15 V for the circuit and proto-board (PB 500) to get 5 V. (alternatively one can use another power supply)
- Measure the current (I_C) at different values of resistance at the base. Use 0, 100 Ω, 470 Ω, 1 kΩ, and 10 kΩ
- Measure the V_{BE}
- Using measured values of V_{BE} and total resistance at the base terminal, estimate the base current I_B for different I_C measurements in above step
- Calculate β or h_{FE} for different values of R
- Plot I_C vs I_B
- Plot β vs I_B

Transistor Current Source

- Construct the current source shown in Figure 5, use one multimeter as an ammeter, set the range to mA
- Use the resistor box as a variable resistor at the transistor collector terminal (R which is the load resistance of the current source.
- Use the 18 V power supply to provide 15 V for the circuit and proto-board (PB 500) to get 5 V. (alternatively one can use another power supply)
- Change the resistance from 10 kΩ to 1 kΩ in steps of 1 kΩ and measure the collector current (I_C) and voltage drop across the load resistor (R).
- Change the resistance from 1 kΩ to 300 Ω in steps of 100 Ω and measure the collector current (I_C) and voltage drop across the load resistor (R).

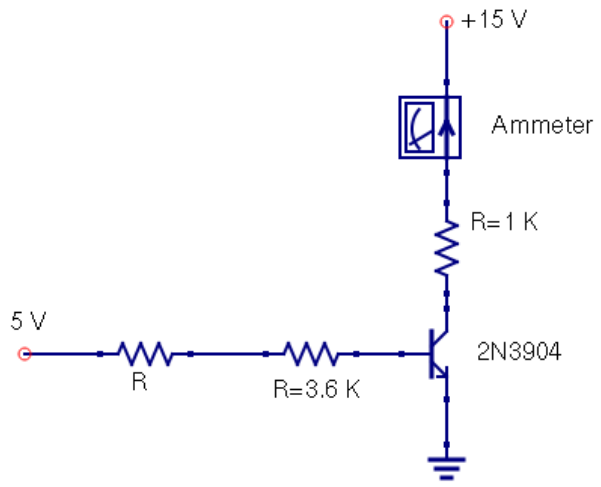

Figure 4: The circuit to measure the β or h_{FE} .

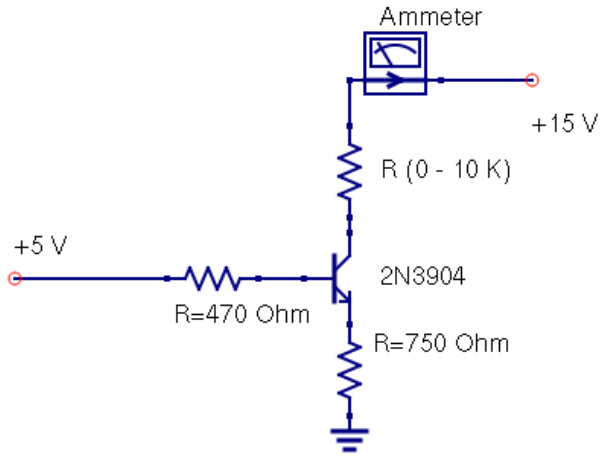

Figure 5: Transistor current source.

- Measure the collector current (I_C) and voltage drop across the load resistor (R) at 100 Ω, 50 Ω, and 10 Ω
- Plot I_C vs R
- Determine the voltage drop across the collector to emitter terminals (V_{CE}) for the data set
- Plot I_C vs V_{CE}
- Determine the compliance range of the current source and discuss the detectable variation in collector current (I_C).

References