

BME/ISE 3512 Bioelectronics

Laboratory Four - Bipolar Junction Transistor (BJT)

Learning Objectives:

Know how to differentiate between PNP & NPN BJT transistors using a multimeter.
Be familiar with the operation of a common emitter amplifier.
Be familiar with the use of a BJT transistor as a switching device.

Laboratory Equipment:

NI myDAQ
Multimeter

Supplies and Components:

Breadboard
100 Ω Resistor
1 K Ω Resistor
10 K Ω Resistor
100 K Ω Resistor
33 K Ω Resistor
.1 μ F Capacitor
Transistors (2N3904 and 2N3906 one each)
LED

Pre-Lab Questions

1. Name the three terminal leads of a BJT transistor.
2. List the difference between PNP and NPN BJTs.
3. What is meant by the B (h_{fe}) of a BJT transistor?
4. What is meant by the term *saturation*; by the term *cut-off*?

Post-Lab Questions

1. Briefly explain the concept of a bipolar junction transistor.
2. Briefly explain the operation of a common emitter amplifier.
3. Explain advantages and disadvantages of using a transistor switch compared to a mechanical switch.

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Laboratory Procedures

There are basically two types of BJT: NPN and PNP. 2N3904 is a popular NPN transistor and 2N3906 is a popular PNP. The maximum V_{CE} and I_C of these two kinds of transistor are 40V and 100 mA, respectively (another popular NPN transistor, 2N2222, can provide an I_C up to 500 mA)

- 1) Use a multimeter to identify the type of transistor (NPN or PNP) and the three terminals: B (base), E (emitter), and C (collector).

Sometimes, the letters E, B, C are shown on the transistor. For many transistors however, E, B, and C are not shown. The following procedure lets you identify the three terminals as well as determine the type of transistor.

For an NPN transistor, from B to C is a forward-biased diode and from B to E is another forward-biased diode, as shown in Figure 1. For a PNP transistor, from C to B and from E to B are two forward-biased diodes, as shown in the figure. Based on this principle, we can find β as well as to determine the type (NPN or PNP).

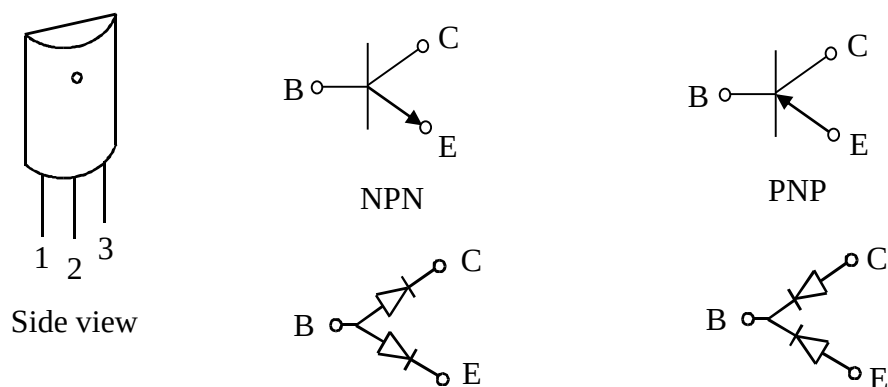


Figure 1. Transistors of type NPN and type PNP

- a) Step 1. Name the three terminals of each transistor as 1, 2, and 3 as shown in figure 1. (Usually the middle terminal (2) is the B, but you have to verify it). Set the multimeter selector to **<diode>** (a symbol $\rightarrow|$). Place the meter leads on the transistor terminals as shown in Table 1 and record the reading of the meter.

Table 1

Multimeter leads to Transistor Terminals		Meter Reading
Positive (red)	Negative (black)	
2	1	
2	3	
1	2	
3	2	
1	3	
3	1	

Using the myDAQ multimeter: A reading indicates a forward-biased diode. Therefore, if the first two rows show a reading, terminal 2 is B (base) and the transistor is type NPN. If rows 3 and 4 show a reading, 2 is B and the transistor is type PNP.

Using the multimeter at lab station: A low reading (< 1.00) indicates a forward-biased diode. Therefore, if the first two rows show low reading, terminal 2 is B (base) and the transistor is type NPN. If rows 3 and 4 show low reading, 2 is B and the transistor is type PNP.

- b) Step 2. After identifying the type of transistor and terminal B, you need to further identify terminals E and C. This can be done by measuring the β value of the transistor. On the lower-left corner of the lab station multimeter, there is a blue circle with 8 holes. The left 4 holes are for NPN transistors and the right 4 holes are for PNP transistors. Switch the meter selector to **<hfe>** (which has a symbol of transistor) and plug in the transistor. Because you already know the type of transducer and the terminal B, there are only two ways to insert the transducer. For example, if the transducer is NPN and the terminal 2 is B, the terminal 2 should be inserted into the hole named B on the left side. Next, you may first insert terminal 1 into C and terminal 3 into E. If your guess is correct, the meter reading will be high (a normal β value is greater than 100), indicating the terminal 1 is indeed the collector (C) and terminal 3 is indeed the emitter (E). If the meter reading is very low (< 10), then reverse your insertion (put terminal 1 into E and terminal 3 into C). You should get a high reading now.

2) Transistor as an Amplifier

A transistor can be used to amplify an incoming signal. This is accomplished partly because of an additional DC voltage source to drive the amplification. The circuit below is a common emitter amplifier.

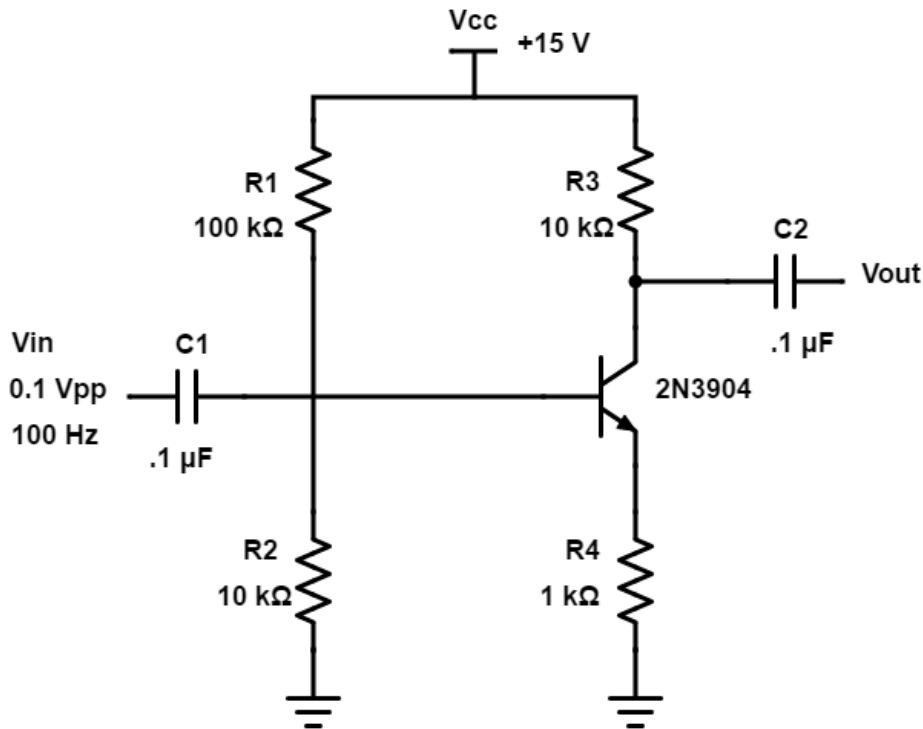


Figure 2. Common Emitter Amplifier

- Measure the value of the resistors and capacitors to be used in the circuit
- Build the Common Emitter Amplifier Circuit
- Increase the sine wave input voltage as follows: 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, and 1.5. At each input voltage, record the peak to peak voltage of the output signal.
- Save a file of the output signal without distortion to be plotted in Matlab or Excel.
- As you increase the voltage, observe the signal and answer the following questions:
 - Does any signal distortion occur and if so when? Any thoughts on why this signal distortion occurs?
 - Is the output signal in phase with the input signal?
 - Is there a DC offset in the output signal?

- 4) Using 2N3904 to build a transistor switch or non-linear driver circuit in digital logic applications

The circuit shown in Figure 2 is called linear amplifiers because one of the most important requirements for the circuit is that the output signal keeps exactly the same waveform of the input signal (no waveform distortion). In digital application, the output of the circuit has only two levels: zero level (logic 0, or logic No) and full-voltage level (logic 1, or logic Yes). For example, depending on the input, the circuit may turn on/off an LED, activate/de-activate a solenoid which opens or closes a valve, energize/de-energize a relay which in turn turns on/off a motor, light, or alarm. In design such a circuit, one mainly needs to consider the current required for driving the output device. For example, if the solenoid needs 150 mA to be activated, one has to use 2N2222 instead of 2N3904. Build the circuit shown in Figure 4. The LED normally is off. When the switch S is closed, it should be turned on.

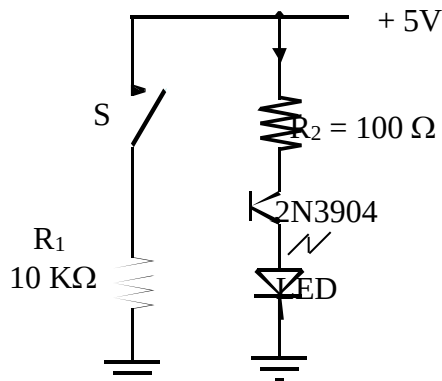


Figure 3. A circuit for drive an LED

- Measure the value of the resistors to be used in the circuit
- Build the circuit in figure 3
- Measure the values of V_{CE} , V_{BE} , V_{BC} , I_B , I_C , I_E when LED is OFF
- Measure the values of V_{CE} , V_{BE} , V_{BC} , I_B , I_C , I_E when LED is ON

Grading Rubric: Bipolar Junction Transistor (Lab 4)

Name: _____

	Points
Cover Page	___ / 3
I) Introduction	
Discuss the following principles of a Bipolar Junction Transistor (BJT): • Discuss a Bipolar Junction Transistor • What are the three terminals of a BJT • Discuss NPN and PNP transistors	___ / 6
I) Circuit Diagrams (Circuit Maker Only)	
1) Experiment 2 –Common-Emitter Amplifier	___ / 4
A. Label measured resistor and capacitor values. Label the transistor with the part number (2N3904). Label input voltage. Label Vout	
2) Experiment 3- Transistor Switch or Non-Linear Driver	___ / 4
A. Label the resistors with measured values. Label the transistor with the part number (2N3904). Label the voltage input.	
II) Data and Results	
1) Experiment 1- Identifying E, B and C for NPN/PNP Transistors	
a. Table 1 (See Lab Manual) for NPN Transistor (2N3904)	___ / 3
b. Measured Value of β (hfe) for NPN Transistor	___ / 2
c. Based on your analysis of the NPN transistor, identify the Base (B), Emitter (E) and Collector (C) using the pin notation (1, 2 and 3) shown in Figure 1 of the lab manual.	___ / 3
d. Table 1 (See Lab Manual) for PNP Transistor (2N3906)	___ / 3
e. Measured Value of β (hfe) for PNP Transistor	___ / 2
f. Based on your analysis of the PNP transistor, identify the Base (B), Emitter (E) and Collector (C) using the pin notation (1, 2 and 3) shown in Figure 1 of the lab manual.	___ / 3
2) Experiment 2- Simple Common-Emitter Amplifier	
a. Table of Measured Values for Resistors and Capacitor	___ / 3
b. Equation for Gain, G (Based on Vin and Vout)	___ / 3
c. Vin when Vout Starts to Show Distortion	___ / 2
d. Graph of V _{IN} and V _{OUT} (Without Signal Distortion)	___ / 5
e. Table of each Input Voltage, Output Voltage, and Gain of Common Emitter Amplifier. Make sure to include Units	___ / 5
3) Experiment 3- Transistor Switch or Non-Linear Driver	
a. Table of Measured Values for all Components	___ / 5
b. Table of Measured values of V _{CE} , V _{BE} , V _{BC} , I _B , I _C , I _E when LED is ON	___ / 8
c. Table of Measured values of V _{CE} , V _{BE} , V _{BC} , I _B , I _C , I _E when LED is OFF	___ / 8
III) Discussion	
1) Experiment 2	
a. Discuss observations made of the output signal a. Does any signal distortion occur and if so when? Any thoughts on why this signal distortion occurs? b. Is the output signal in phase with the input signal? c. Is there a DC offset in the output signal?	___ / 5
2) Experiment 3	
a. Discuss how the measured results explain how the transistor functions and how the transistor switch works	___ / 5
IV) Post-Lab Questions	
a. Post Lab Question #1	___ / 5
b. Post Lab Question #2	___ / 5
c. Post Lab Question #3	___ / 5
V) References	___ / 3

