Laboratory Manual

EE-153L – Introduction to Electrical Engineering

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Experiment 11

Implementation of BJT as a Switch

11.1 Objective

This experiment aims to implement a Bipolar Junction Transistor (BJT) as an electronic switch. Students will learn how a BJT transitions between cutoff (OFF) and saturation (ON) states and observe the resulting waveforms across the load resistor and across the collector–emitter terminals (V_{CE}). The role of base current and load resistance will also be analyzed to evaluate switching performance.

11.2 Theory Overview

A Bipolar Junction Transistor (BJT) can operate in different regions depending on its base current and the applied voltages. When used as a switch, the BJT is driven between the **cutoff region** (no base current, transistor OFF) and the **saturation region** (sufficient base current, transistor fully ON).

- **Cut-off Region (Switch OFF)**
  Base-emitter junction is not forward biased ($I_B \approx 0$), so no collector current flows.
  The transistor behaves like an open switch.
  $V_{CE} \approx V_{CC}$ (maximum).
- **Saturation Region (Switch ON)**
  Base current is large enough to drive the transistor fully ON.
  Transistor behaves like a closed switch.
  V_{CE} drops to a small value (typically 0.1 – 0.3 V).
  The effective ON-state resistance is:

$$R_{CE(ON)} = V_{CE(ON)} / I_C$$

Where, $I_C = (V_{CC} - V_{CE}) / R_L$

When a **square wave** is applied to the base, the transistor repeatedly shifts between cutoff and saturation, allowing the output voltage across the load to switch between high and low levels. This forms the basis of using the BJT in digital circuits, motor drivers, relay drivers, and many switching power applications.

11.2.1 Pre-Lab Task

Before performing the experiment in the laboratory, complete the following tasks in LTspice (using a 5 V square wave at the base) to demonstrate your understanding of the theoretical concepts. These preparatory tasks will help you predict circuit behavior and verify your results during the lab session.

11.3 Equipment

- DC Power Supply (12 V)
- Signal Generator (5 V square wave)
- NPN BJT (2N2222 or similar)
- Load Resistor: 1 kΩ
- Base Resistor: 1 kΩ
- Digital Multimeter
- Oscilloscope (Channels 1 & 2)
- Breadboard and wires

11.4 Schematics

A simple NPN transistor switch circuit including:

- R_B = 1 kΩ from square-wave source to base
- R_L = 1 kΩ from V_{CC} = 12 V to collector
- Emitter to ground
- Measure output V_{CE} and voltage across R_L

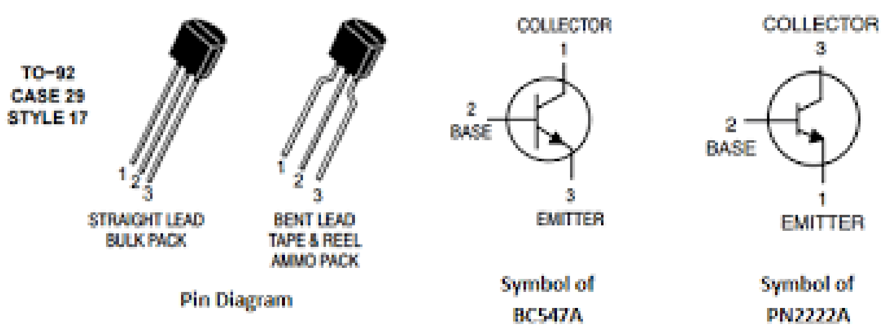

Fig 11.1

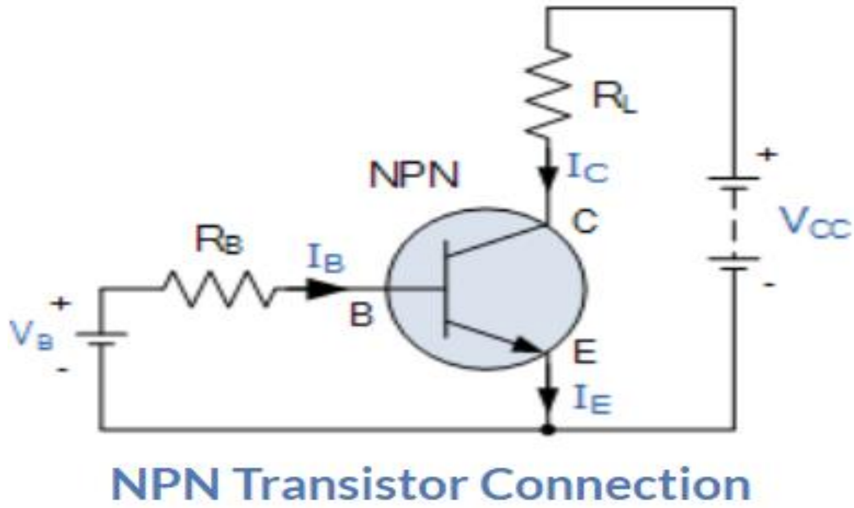

Fig 11.2

11.5 Procedure

1) Identify the transistor terminals (Emitter, Base, Collector) using the provided pinout diagram or the device datasheet.
2) Connect the circuit on the breadboard by placing the NPN BJT and wiring the emitter directly to ground.
3) Connect the load resistor (1 kΩ) between the collector and the +12 V DC supply (V_{CC}).
4) Insert the base resistor (1 kΩ) between the function generator output and the base terminal of the transistor.
5) Configure the function generator to output a 5 V square wave at a frequency of your choice (e.g., 1 kHz).
6) Verify all wiring and ensure correct polarity before powering the circuit.
7) Connect Oscilloscope Channel 1 to the base of the transistor to observe the input square wave.
8) Connect Oscilloscope Channel 2 across the collector–emitter terminals (V_{CE}) or across the load resistor (V_L), depending on the measurement being taken.
9) Turn ON the power supply and function generator and observe the switching action on the oscilloscope.
10) Record the waveform shape and voltage levels for both the ON state and the OFF state of the transistor.
11) Measure V_{CE} in the ON state, then calculate collector current using $I_C = V_L / R_L$.
12) Compute the ON-state resistance of the transistor using;

$$R_{CE(ON)} = V_{CE} / I_C$$

13) Compare theoretical and measured values, and note any deviations due to transistor characteristics or circuit losses.

11.6 Data Tables

Parameter	**Theory**	**Measured**
V_{CE} (ON) (V)	0.1~0.3 V (typical)	
Load Voltage (ON) (V_L)	$V_{CC} – V_{CE}$	
Collector Current ($I_C = V_L / R_L$)		
ON-State Resistance ($R_{CE} = V_{CE} / I_C$)		
V_{CE} (OFF)	$\approx V_{CC}$	

Table 11.1

11.7 Questions

1. Why does the transistor act like an open switch when the base current is zero?

2. What condition must be satisfied to drive a BJT into saturation?

3. How does the value of the base resistor R_B affect switching performance?

4. Calculate I_C and R_{CE} if $V_{CE} = 0.18$ V with $R_L = 1$ kΩ.

5. Explain why V_{CE} is high in the OFF state and very low in the ON state.

11.8 Conclusion

Assessment

Sr. No.	Specific Course Learning Outcomes	Knowledge Domains	Performance indicator
	Upon completion of this course, the students will be able to		
1	**USE** electronic lab instruments including the digital multi-meter, function generator, oscilloscope and electronic circuit trainer.	P1	• Proper wiring of the circuit • Correct use of instruments (signal generator, oscilloscope) • Data recorded in table
2	**CONSTRUCT** and **ANALYZE** basic circuits.	P2	• Relate experiment with theoretical concept discussed in class. • Describe relevant mathematical equations • Discuss discrepancies between theoretical, simulation and experimental results • Possible sources of discrepancies and ways to improve
3	**COMMUNICATE** clearly and effectively through presentation and/or report	A2	• Report is structured properly • Figures and Graphs annotated • Language is clear
4	**DEMONSTRATE** teamwork and show commitment to the group in achieving the objectives of laboratory	A2	• Does his/her part in the group • Listen to other's ideas • Does not argue
5	**DEMONSTRATE** punctuality, dress appropriately and comply with the standard safety procedures of the lab	A2	• Wear proper dress to perform the tasks and Follow lab timing • Follow safety instructions for handling the instruments.