Aim

To observe (i) various modes of operation in a common-emitter BJT circuit, (ii) quiescent point or bias point for a voltage-divider biasing circuit (for a voltage amplifier), and (iii) to study the application of BJT as a switch to design an automatic street light.

Introduction

BJTs are extensively used in all types of electronic circuits. The aim of this part of the experiment is to familiarize you with the basic modes of operation and features of a BJT through the study of simple BJT circuits. The BJT that you will be using in this experiment is BC547 (the pin diagram is shown in Fig. 1), which has a typical current rating of 100 mA (maximum).

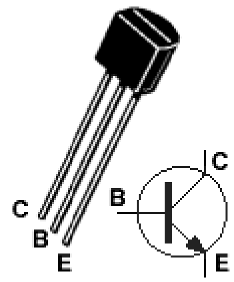

Figure 1: NPN BC547

Make sure to connect the transistor correctly in the circuits. Also, while changing any component in the circuit, please turn the power supply off, and turn it on again only after all the required changes have been made and the circuit is complete.

BJT Inverter Circuit

BJT inverter circuit is commonly used to implement the NOT function (i.e., the output is an inverted form of the input) using discrete BJTs. The circuit also illustrates the basic modes of operation of a BJT. Set the β of the BJT element in the simulator as 200 to represent BC547.

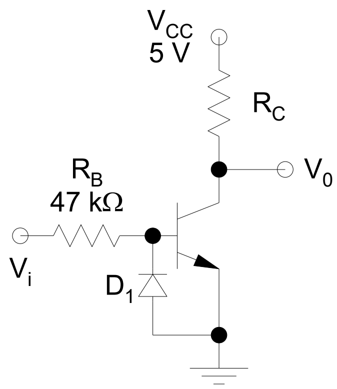

Figure 2

Experiment (i): Observing VTC and modes of operation for an inverter circuit

(i) Wire the BJT inverter circuit of Fig. 2. Use R_C = 1 kΩ.

(ii) Adjust the FG to obtain a 200 Hz triangular wave (minimum value 0V maximum value +5 V) and connect the same as the input (V_i) to the circuit.

(iii) Note that you already know that when input is above a certain threshold such that base current is large enough to drive the BJT into Saturation, the output voltage (v_{CE}) is nearly zero (v_{CE} ~0.1 V).

You also know that when the input is below certain voltage, such that the EBJ is not forward biased, the BJT is in Cut-off mode, and output voltage ($v_{CE} = V_{CC}$)

Further, in between, the values of input voltage that correspond to base current such that the operation point lies in active region, would result in amplification of the input waveform. This is where the BJT acts as an inverting amplifier.

Based on your knowledge about the modes of operation of the BJT, observe the output and input waveforms carefully to identify the points (input voltage values) where the BJT is in (i) cut-off (ii) active, and (iii) cut-off modes. Fill these values of input voltages in the Observation Table 01.

(iv) Use the X-Y mode and sketch the voltage transfer characteristic (VTC – V_0 versus V_i) of the inverter as seen on the DSO (it should be somewhat similar to the one shown in Fig. 3). Save this waveform.

(v) Now use R_C = 15 kΩ, and observe the change in gain of the linear region.

Note: The transistor has a low base-emitter junction reverse breakdown voltage. To ensure that this junction does not break down due to wrong polarity of the applied voltage, the diode D_1 is used – it clamps the maximum reverse bias across the junction to approximately −0.7 V.

Observation Table 1

Mode of Operation	Input values	Circuit acts as
Cut-off	______< V_{in} < _____	
Active	______< V_{in} < _____	
Saturation	______< V_{in} < _____	

Voltage divider bias for Common Emitter Amplifier

BJT amplifiers most commonly employ the common emitter (CE) configuration. You will check the biasing conditions of the given circuit.

Experiment (ii): Measuring the DC Bias point for a Common-Emitter Amplifier Circuit

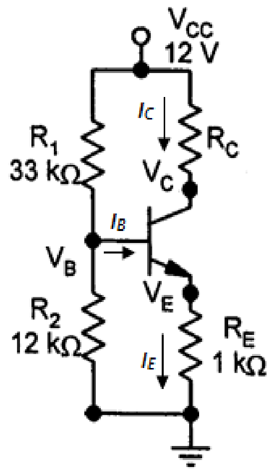

Figure 4

Step 1: Wire the circuit as shown in Fig. 4 in Falstad Circuit Simulator. Set the β of the BJT element in the simulator as 200.

Step 2: Measure the values of node voltages V_B, V_C, and V_E, and branch currents I_B, I_C, and I_E (using the Ammeter and Voltmeter probes in the simulator), and report in Observation Table 2. What is the current mode of operation?

Step 3: Using the measured value of base current, calculate the value of β using:

$$I_B = \frac{V_{Th} - V_{BE(on)}}{R_{Th} + (\beta + 1)R_E}$$

where $V_{Th} = V_{CC}\, R_2/(R_1 + R_2)$ and $R_{Th} = R_1 || R_2$. As per the datasheet of BC547, β should be in the range of 200 to 450. Consider $V_{BE(on)}$ = 0.7 V.

Step 4: From the calculated value of β and measured value of I_B, obtain the theoretically calculated values of V_B, V_C, and V_E, an I_B branch currents I_C, and I_E using the following equations:

$I_C = \beta I_B$ and $I_E = (\beta + 1)\, I_B$

$V_{CE} = V_{CC} - I_C R_C - I_E R_E$

Step 5: For R_C, measure the node voltages and branch currents again, and comment on the mode of operation.

Observation Table 2

R_C		I_B	I_C	I_E	V_B	V_C	V_E	I_C/I_B	Mode of Operation
3.3 kΩ	Measured								
	Calculated								
15 kΩ	Measured								

Application of BJT as a Switch: Automatic Street Light

(To be done on Autodesk Tinkercad)

A resistance of a light-dependent resistor (LDR) reduces significantly when illumination falls on it, and LDRs therefore find application in light-sensing circuits.

Experiment (iii)

Design a circuit using a 10-kΩ resistor, two 1-kΩ resistors, an LDR, BJT BC547, and an LED, such that the LED glows when LDR is placed in the absence of illumination, and remains off when the LDR is well-illuminated.