Group No:

Experiment-06

Study of I-V Characteristics of BJT and Implementation of BJT CE Amplifier

CSE251 - Electronic Devices and Circuits Lab

Objective

1. To observe and understand the IV characteristics of a BJT.
2. To design a common emitter amplifier using BJT and observe the amplified signal.

Equipments

1. BJT (C828)
2. Resistance ($1k\Omega, 2.2k\Omega, 4.7k\Omega, 10k\Omega, 33k\Omega, 100k\Omega$)
3. Capacitor ($10\mu F, 47\mu F$)
4. DC power supply
5. Trainer Board
6. Digital Multimeter
7. Breadboard
8. Chords and Wire

Background Theory

Introduction

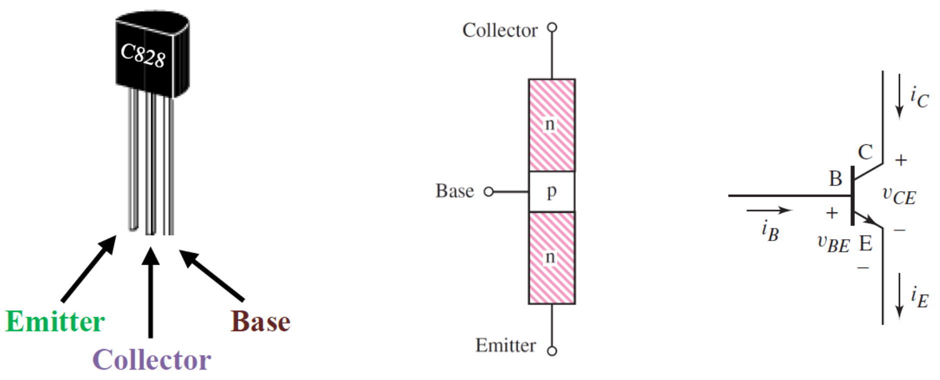


Figure 1: IC, Simple Geometry and Circuit Symbol of an npn BJT

The bipolar junction transistor (BJT) is a type of transistor that is used for electrical amplification and in very-high frequency applications such as radio frequency (RF) circuits for wireless systems and high-speed switching emitter-coupled logic (ECL) gates. BJT is primarily a three terminal device consisting of the following terminals: Base (B), Emitter (E), Collector (C). There are two types of BJTs: (i) npn BJT and (ii) pnp BJT. Our discussion and experiment will be confined to npn BJT. Figure 1 shows the IC, circuit symbol and simple geometry of an npn BJT. The arrowhead in the circuit symbol is always placed on the emitter terminal, and it indicates the direction of the emitter current. For an npn BJT, this direction is out of the emitter. The npn BJT contains a thin p-region between two n-regions. So the transistor consists of two pn junctions, the emitter–base junction

(EBJ) and the collector–base junction (CBJ). Depending on the bias condition (forward or reverse) of each of these junctions, different modes of operation of the BJT are obtained. The operating modes are: Cut-off, Active and Saturation. Table 1 summarizes the modes of operation. The active mode is the one used if the transistor is to operate as an amplifier. Switching applications (e.g. logic circuits) utilize both the cutoff mode and the saturation mode. There can be a fourth mode of a BJT called the reverse-active mode which occurs when the EBJ is reversed biased and the CBJ junction is forward biased (not shown in the table).

Table 1: BJT Modes of Operation		
Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

Of the three modes of operation of BJT, the active mode is the most important one because BJT can be used as an amplifier only in this mode. BJT will be in active mode when EBJ is in Forward Bias and CBJ is in Reverse Bias. BJT operates in saturation mode when its collector current is not dependent on the base current and has reached a maximum. This happens when both the EBJ and the CBJ are in Forward Bias. In saturation mode, huge amount of current flows through BJT and it acts like a closed switch. Cut-off mode is the opposite of saturation mode. In cut-off mode, both junctions of BJT remain reverse biased. That is why no current flows through the device (actually, very negligible amount of current flows) and the BJT acts like an open switch.

Input and Output I-V Characteristics of BJT

The I-V characteristics of a BJT depends on the circuit configuration. There are three basic configurations for connecting the BJT: the common base (CB) configuration, the common emitter (CE) configuration, and the common collector (CC) configuration. Though each configuration has their own applications, the CE is the most widely used configuration and by far the most popular for amplifiers.
In CE configuration, the emitter is the common terminal. Hence, the input is between the base and the emitter while the output is between the collector and the emitter. So, the input I-V characteristics is the variation of the base current I_B with the base-emitter voltage V_{BE}, and the output I-V characteristics is the variation of the collector current I_C with the collector-emitter voltage V_{CE}.
The following figure shows the input I-V characteristics of an npn BJT for the CE circuit configuration which illustrates the variation in I_B with respect to V_{BE} when V_{CE} is kept constant. In the graph, I_B changes exponentially as V_{BE} changes. This is obvious since the BJT's base-emitter junction is similar to a pn junction diode. So it's current voltage relationship should also be like a pn junction diode.

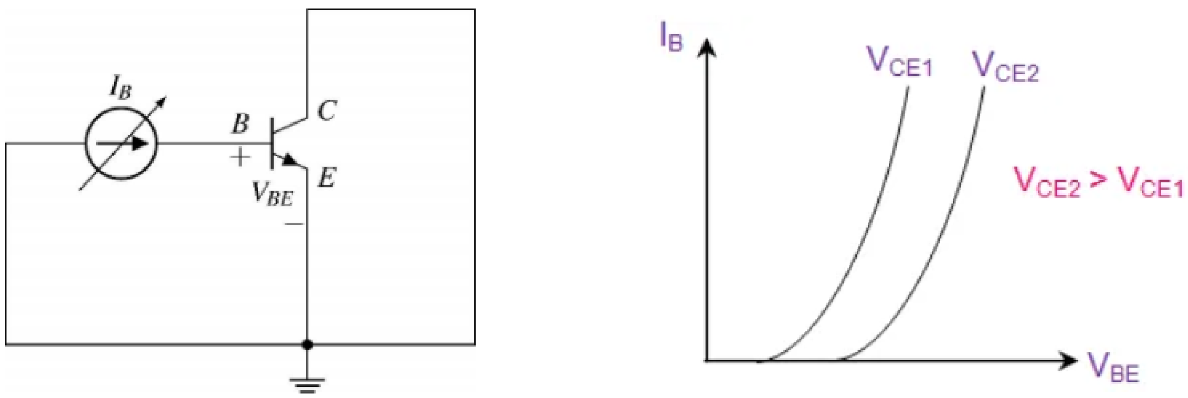


Figure 2: BJT input IV characteristics Circuit and Graph in CE configuration

The output I-V characteristic of a BJT in CE configuration is also referred to as the collector characteristic. We are mainly interested in this one. The following circuit and graph shows the output I-V characteristics of a BJT in CE configuration. The I-V characteristics shows the variation in I_C with the changes in V_{CE} when I_B is held constant. In the graph we can see a rapid increase in collector current at the beginning. Then the collector current becomes almost constant. This graph can be divided into 3 regions:

1. Active Region (where output current becomes almost constant)
2. Saturation Region (where I_C increases rapidly)
3. Cut-off Region (where the current is zero/almost zero)

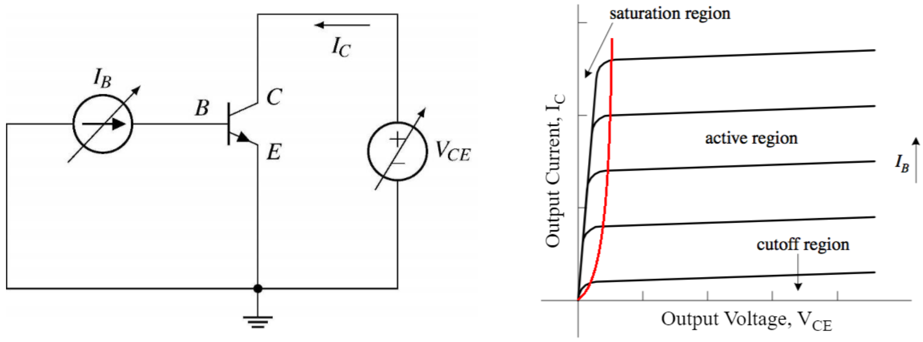


Figure 3: BJT output IV characteristics Circuit and Graph in CE configuration

From the output I-V characteristics we see that, in the active region, if we keep V_{CE} constant, I_C increases with the increase of I_B. This relationship between I_C and I_B in active mode is actually linear in nature which can be represented by the following equation: $I_C = \beta I_B$, where β is a constant. Typically, $\beta = 50$ to 200.

Linear Amplifier and Its Circuit Realization

An amplifier is a device that can increase the power of a signal (a time-varying voltage or current) by increasing the amplitude of the signal applied to it. Amplification means increasing the amplitude (voltage or current) of a time-varying signal by a given factor.

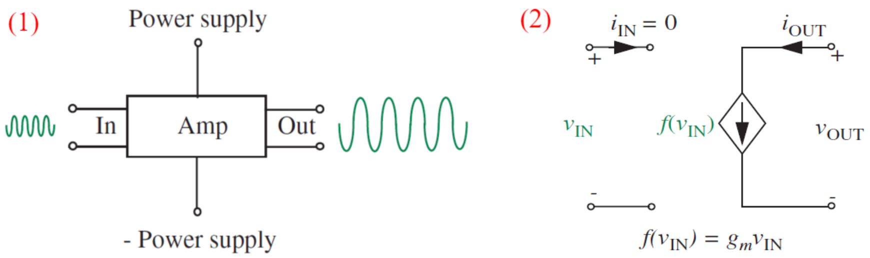


Figure 4: (1) Basic Representation of Amplifier (2) Transconductance Amplifier Realization

A linear amplifier amplifies the signal in the following manner:

Output = k × Input

here, **k = Gain of the Amplifier** [Output/Input can be voltage/current]

Linear amplifier circuits can be realized/made using dependent sources. For example, a transconductance amplifier (Input = Voltage, Output = Current) can be made using a voltage controlled current source which is shown in the figure above.

BJT Common Emitter (CE) Amplifier

In Active mode, BJT acts like a current controlled current source because $I_C = \beta I_B$ and β is constant. So, I_C will change linearly with the change of I_B and we can make linear amplifiers with BJT.

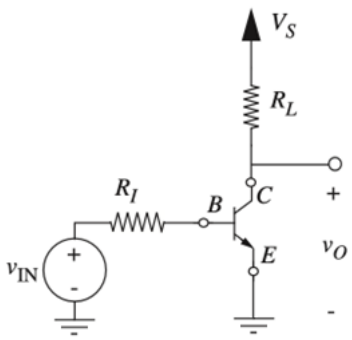


Figure 5: BJT Common Emitter Amplifier Basic Circuit

The figure above shows a basic BJT Common Emitter Amplifier which is by far the most popular BJT amplifier configuration. The CE configuration is the one best suited for realizing the bulk of the gain required in an amplifier. Depending on the magnitude of the gain required, either a single stage or a cascade of two or three stages can be used. The following figure shows a modified implementation of BJT CE Amplifier that takes some practical issues into consideration.

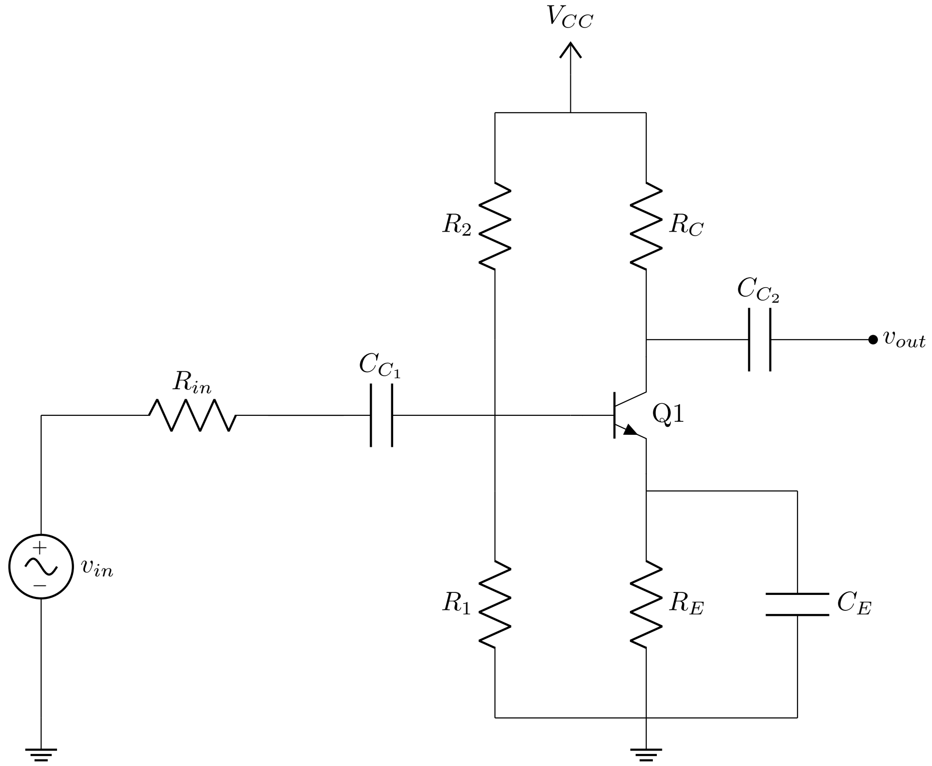


Figure 6: BJT Common Emitter Amplifier

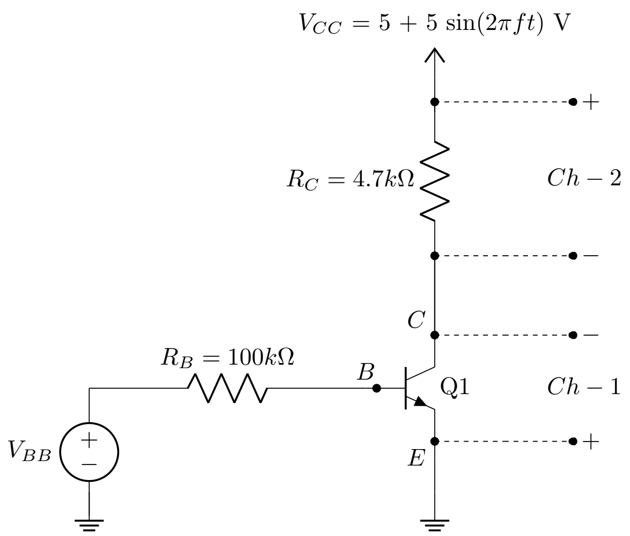
To establish a signal ground (or an ac ground, as it is sometimes called) at the emitter, a large capacitor C_{CE}, usually in the range of micro farads or tens of micro farads is connected between emitter and ground. This capacitor is required to provide a very low impedance to ground (ideally, zero impedance, i.e., in effect, a short circuit) at all signal frequencies of interest. In this way, the emitter signal current passes through C_{CE} to ground and thus bypasses the output resistance of the current source I (and any other circuit component that might be connected to the emitter); hence C_{CE} is called a bypass capacitor. Obviously, the lower the signal frequency, the less effective the bypass capacitor becomes. For our purposes here we shall assume that C_{CE} is acting as a perfect short circuit and thus is establishing a zero-signal voltage at the emitter.

In order not to disturb the dc bias currents and voltages, the signal to be amplified, shown as a voltage source v_{in} with an internal resistance R_{in}, is connected to the base through a large capacitor C_{C1}. Capacitor C_{C1}, known as a coupling capacitor, is required to act as a perfect short circuit at all signal frequencies of interest while blocking dc. Here again we shall assume this to be the case and defer discussion of imperfect signal coupling, arising as a result of the rise of the impedance of C_{C1} at low frequencies. At this juncture, we should point out that in situations where the signal source can provide a dc path for the dc base current I_B without significantly changing the bias point, we may connect the source directly to the base, thus dispensing with C_{C1} as well as R_B. Eliminating R_B has the added beneficial effect of raising the input resistance of the amplifier.

Inclusion of an emitter resistance R_E leads to significant improvements in the amplifier characteristics. R_E increases the input resistance of a BJT substantially. With R_E, the gain of the amplifier is less sensitive to the value of β, which is desirable. Another important consequence of including the resistance in the emitter is that it enables the amplifier to handle larger input signals without incurring nonlinear distortion. This is because only a fraction of the input signal at the base appears between the base and the emitter.

The voltage signal resulting at the collector, v_c, is coupled to the load resistance R_L via another coupling capacitor C_{C2}. We shall assume that C_{C2} also acts as a perfect short circuit at all signal frequencies of interest; thus, the output voltage $v_o = v_c$. Note that R_L can be an actual load resistor to which the amplifier is required to provide its output voltage signal, or it can be the input resistance of a subsequent amplifier stage in cases where more than one stage of amplification is needed.

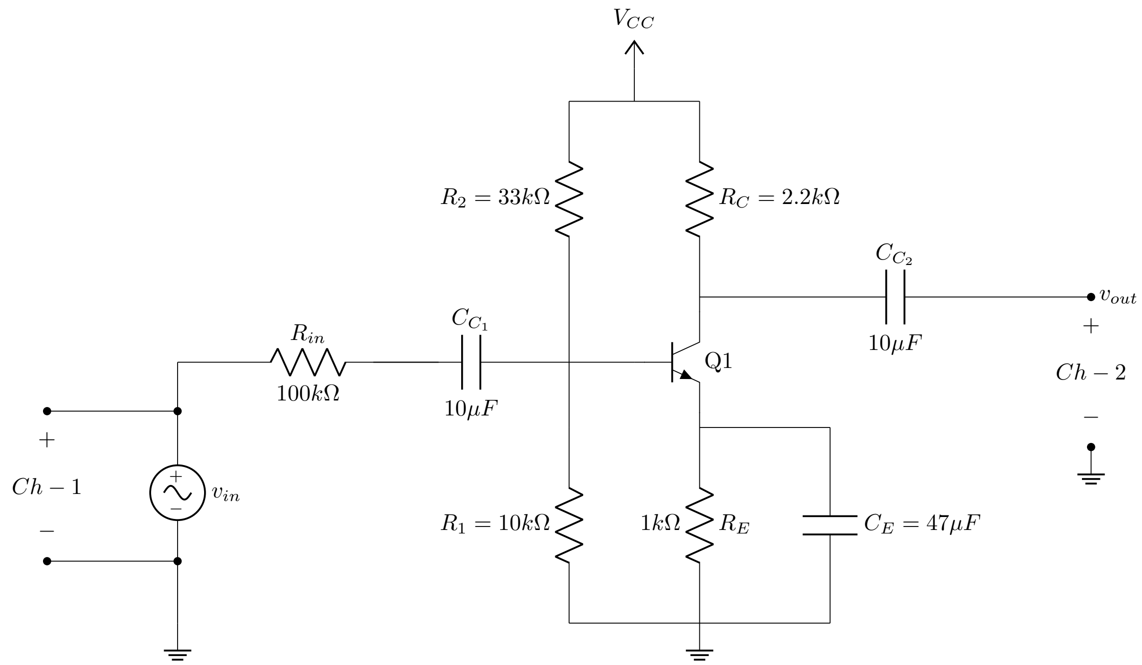
Task-01: I-V Characteristics of a BJT



Procedure

1. Construct the circuit shown above. Use the dc power supply for V_{BB} and the function generator for V_{CC}. Set $f = 5$ Hz.
2. Invert the Channel-1. Set the oscilloscope in X-Y mode.
3. Now, rotate the voltage knob of the dc power supply slowly from 0V to 5V. You should observe the change in the IV characteristics. Capture the plots for different V_{BB} using your mobile camera.

Task-02: BJT Common Emitter (CE) Amplifier



Procedure

1. Construct the circuit given above. Use $v_{in} = 150$ mV (p-p) with f = 1 kHz.
2. Observe Ch-1 and Ch-2 and capture image using your mobile camera.
3. Measure the peak-to-peak value of both v_{in} and v_{out} and fill up the data table.

Data Table: BJT Common Emitter (CE) Amplifier

Amplitude of the input signal, v_{in} (from oscilloscope) (mV)	**Amplitude of the output signal, v_{out} (from oscilloscope) (V)**	**Gain $= \frac{\lvert v_{out} \rvert}{\lvert v_{in} \rvert}$**

Task-03: Report

1. Cover page [include course code, course title, name, student ID, group, semester, date of performance, date of submission]
2. Attach the Signed data sheet
3. Attach the captured photos and describe them properly.
4. Add a brief Discussion regarding the experiment.