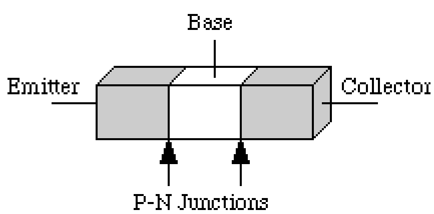
Experiment 11
Bipolar Junction Transistor

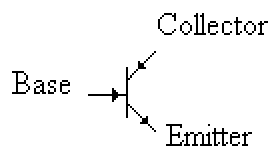
Objectives:

In this experiment you will investigate the characteristics of the bipolar junction transistor (BJT) and study its applications as:

- logic inverter and switch
- amplifier
- current source



Schematic repsentation of the NPN BJT



Circuit rpesentation of The NPN BJT

❶ *BJT* Characteristics:

- **We first start by connecting the circuit of figure 1 which will be used to determine the characteristics of the 2N222 BJT, and its different regions of operations.**
- **We start with V_{BB} = 1 V, and we increase V_{BB} to 8 V in steps of 0.2V. While measuring the collector current IC, the Base current IB, the collector-to- emitter voltage VCE, and the base-to-emitter-voltage V_{BE}.**

In the active or the saturation region:
$0.7 < V_{BE} < 0.8$
In the saturation region: V_{CE}= 0.2 V
In the saturation region: V_{CE}> 0.2 V

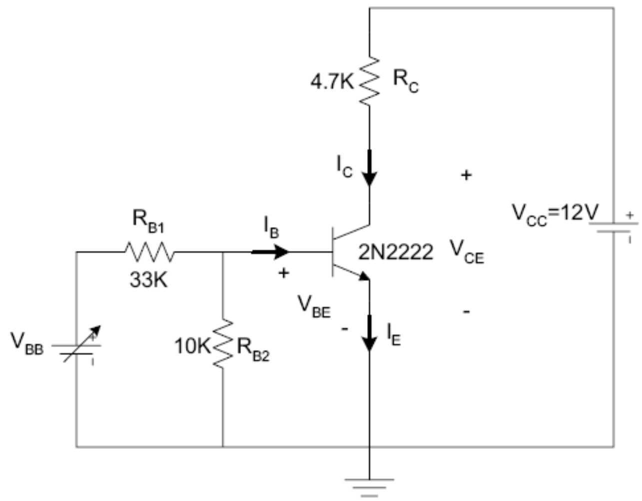


Fig. 1

❷ How do we find β?

- **Vary I_B with a certain range and measure V_{CE}, IC and V_{BE}**
- **Divide V_{CE} by V_{BE}**
- **Find $\beta = I_C / I_B$**

❸ BJT as a Switch:

- **We first start by determining the values of R_B and R of figure 2 so to meet the following specifications: When VIN = 5V, the transistor is fully saturated with IC/IB = β/10 and with a LED current of 10 mA (LED drop voltage is 2V).**

- **Then we start varying V_{IN} from 0 to 2 V in steps of 0.2 V and we measure V_{out} Then we increase VIN from 2 to 5 V in steps of 0.5V and we measure V_{out}. WE also note if the LED is glowing and for what values of V_{IN}.**

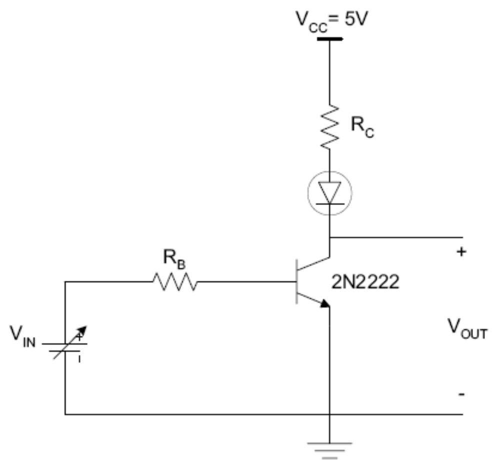


Fig. 2

Switch:

- **ON → SATURATION**
- **OFF→ CUTOFF**

The drop across the BJT is very small. if it increases then there would be too much heat and thus the transistor would burn out.
The drop across the transistor could be calculated using the formula: (V_{CC}- o.2). If we divide this value by the current I we calculate the resistor's value R_c.

❹ General Remarks:

- **A transistor is a current controlled device.**
- **In a transistor the base current defines which region we would be working in.**
- **A MOSFET is a voltage controlled device.**
- **We usually take a constant value of β throughout the experiment.**

❺ How do we measure I_B?

At the edge of saturation or in the active region only $I_C = \beta I_B$
If we use a value of β equal to 100 we might burn the transistor.
Thus we have to increase β by a factor of 10 for example (usually) and thus we would have $\beta' = \beta/10$

The β force is the factor that forces the transistor to go to saturation by β ' = β /10. Thus the current I_B would increase and IC would remain fixed with I_C= (β /10) I_B the R_B could be calculated by R_B= (V_{CC} - 0.7)/ $I_{B\ calculated}$.

❻ Connect the circuit in figure 2. Vary V_{IN} from 0 V to 2 V in steps of 0.2 V and measure V_{OUT} (by the oscilloscope). Increase V_{IN} from 2 V to 5 V in steps of 0.5 V and measure V_{OUT}. We also note the value of V_{IN} at which the LED starts glowing.

❼ *BJT* as an Amplifier:

Why is the DC analysis important?

- **Point of operation Q (we need to get Q)**
- **Place in small signal model and analyze**

DC measurements: g_m is needed to place the transistor in the active region that is to check if the transistor is in the active region.

V_{CE}>0.3 V_{CC} = 1/3 V_{CC}

❽ Connect the circuit of figure 3- c

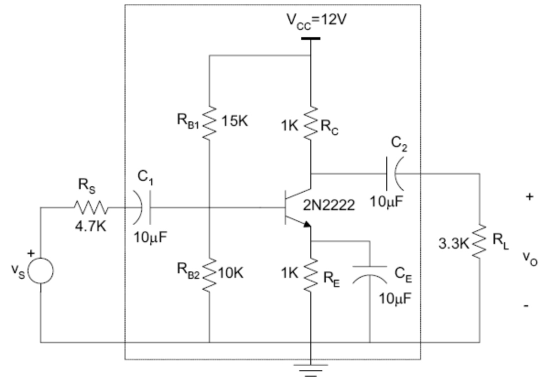


Fig. 3-c

The voltage source is a 100 mV peak-to-peak, 10 KHz sine *signal* (by the function generator)

Measure *off-circuit* the values of the resistors RS and RL.

1. Measure the output voltage across the load resistor RL. Calculate the voltage gain v_O/v_S.

Note: ***Even thought the ratio v_O/v_S is less than 1, we still refer to it as* gain*. When we connect the BJT amplifier block, the ratio will become much larger than 1.***

V_o is $(V_s - V_i)/V_{CC}$ - 0.3

And $V_i = V_o/R_L$

Find $A_v = V_o / V_i$

❾ As we can see in the first 2 steps the gain does not change though Vin is much bigger in step 2 then in 1 . This is because the gain does don't depend here on the amplitude of Vin . In fact we have that Vout = $(R_L / (Rs + RL))$ Vin, so the ratio Vout / Vin is equal to RL / (Rs + RL) which is a constant (here it is equal to 0.41). As we can also see for low frequencies the gain is approximately equal to RL/(Rs + RL) and for very high frequencies the gain is much more less then RL / (Rs + RL). This is due to coupling capacitance in the circuit.

❶⓿ *BJT* as a Current Source:

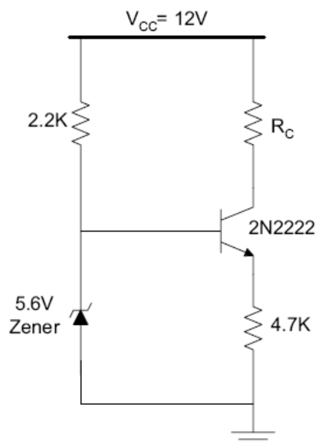


Fig. 4-a

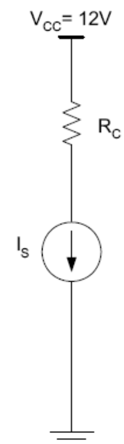
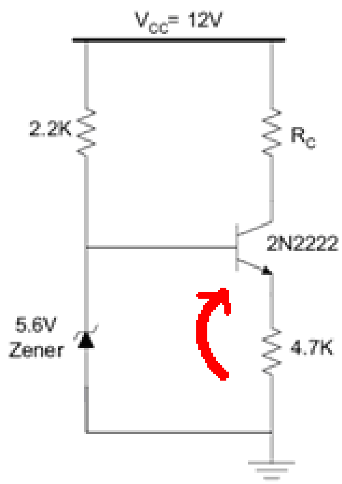


Fig. 4-b

Why do we use a Zener diode?

We use a Zener diode to maintain V_{BE} (VB- ground) at a certain voltage. That is to hold a constant voltage between the base and the ground. We could use a Zener diode or a battery.

IB should be constant then



should be constant as well

❶❶ Connect the circuit shown in Fig. 4-a. Start with RC = 0 (short circuit). We measure the base voltage and the emitter voltage. Also *measure off-circuit* the value of the 4.7 KΩ emitter resistor.
Increase the value of RC from 0 to 12 KΩ using 1 KΩ, 1.5 KΩ, 2.2 KΩ, 2.7 KΩ, 3.3 KΩ, 4.7 KΩ, 5.6 KΩ, 6.8 KΩ, 8.2 KΩ, 10 KΩ, and 12 KΩ resistors, and measure the collector current of the transistor and the collector-to-emitter voltage.

Note: **R_C should be measured *off-circuit*.**

General Shape of the BJT