Başkent University
Department of Electrical and Electronics Engineering
EEM 214 Electronics I
Experiment 7

Bipolar Junction Transistor

Aim:

The aim of this experiment is to investigate the DC behavior of a bipolar junction transistor (BJT) in a common emitter circuit configuration in Fig.1.

Theory:

Like MOSFET, it is another type of transistor with three terminals: *Base* (B), *Collector* (C) and *Emitter* (E). The BJT can either be an *NPN* or a *PNP*. General configuration and the circuit symbol of both of the type of BJTs shown at *table_1*.

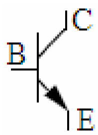
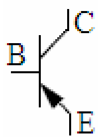
N	***P***	***N***	
emitter	***base***	***collector***	
P	***N***	***P***	

table_1

Unlike MOSFETs, total current in BJTs consist of both Electron and Hole current. BJT is regarded as a current-controlled-current device where the quantity of the base current controls the flow of current from collector to emitter or vice versa.

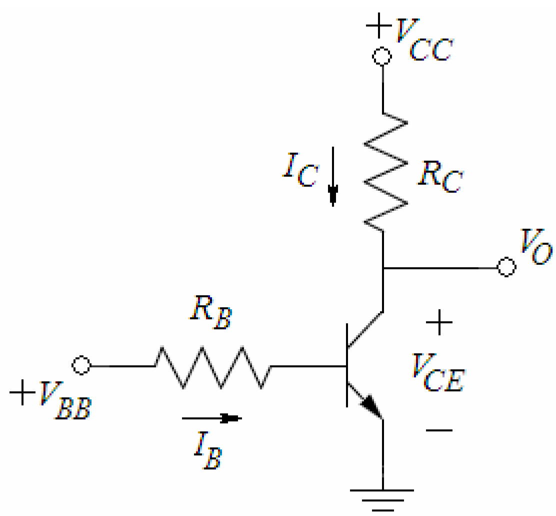


figure_1

At the input side, the base current I_B is determined by V_{BB} and R_B. When $V_{BB} < V_{BE(ON)}$, the transistor is in cut-off (OFF) state, and we have $I_B = 0$. When $V_{BB} > V_{BE(ON)}$, the base current can be found as

$$I_B = \frac{V_{BB} - V_{BE(ON)}}{R_B}$$

from the loop equation at the input side. In this case the transistor might be in forward-active (ACT) or saturated (SAT) state, depending on the values of I_C and V_{CE}.

At the output side, the load line given by the output loop equation

$$V_{CC} = R_C . i_C + v_{CE}$$

determines the behavior of the circuit in Fig.1. For a given base current I_B (calculated at the input side), the intersection of the load line with the transistor i_C-v_{CE} curve determines the operating point (Q-point) and the state of the transistor. If this intersection point is in the "constant current" region of the transistor characteristics, the transistor is in ACT state, $I_C = \beta . I_B$, and $V_{CE} > V_{CE(SAT)}$, Otherwise, the transistor is in SAT state, $V_{CE} \approx V_{CE(SAT)}$ and from the output loop we have

$$I_C = \frac{V_{CC} - V_{CE(SAT)}}{R_C}$$

;where $I_C < \beta . I_B$.

Preliminary Work:

Review Section 5 till section 5.10 in the textbook.

In laboratory you will construct the circuit in Fig.2 using the transistor BC238B.

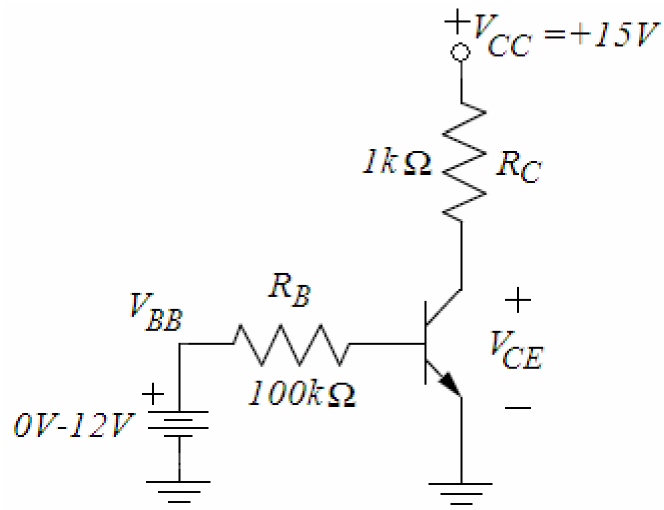


figure_2

The BC238B has a 200< β <320, $V_{CE(SAT)}$ = 0.2V, $V_{BE(ON)}$ = 0.6V and V_A =100 . Use V_T=25mV and emission coefficient as n = 1 even though BC238B transistors may exhibit an emission coefficient in the range ($1 \le n \le 2$). The Pin Diagram of the BC238B is in Fig.3

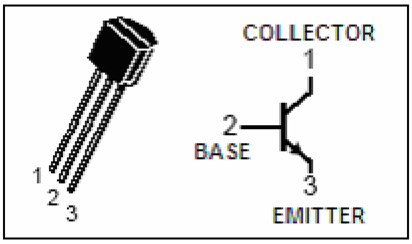


figure_3

At the input side, a variable voltage source is used to set V_{BB} to any desired value between 0 V and 12 V. The base current I_B can be adjusted by changing V_{BB} in this range. (In the experiment, you will measure I_B by measuring the voltage drop across the 100 KΩ resistor, and the particular value of V_{BB} that yields this I_B value will not be that important.)

1) Determine the range of I_B values that can be obtained with $0 \le V_{BB} \le 12$ V. Take $V_{BE(ON)}$ = 0.6 V.

At the output side, the load line $V_{CC} = R_C.i_C + v_{CE}$ together with the transistor i_C–v_{CE} characteristics determine the behavior of the circuit. The transistor characteristics depend on β of the transistor. The β value of a given type of transistor may vary in a large range from transistor to transistor. The transistors that you are going to use in the laboratory will have $200 < \beta < 320$. In this preliminary work section, you will make some calculations with taking β = 260. However, β of the actual transistor that you will use in the laboratory will most likely be different. Therefore, your measurements in the laboratory will not yield the same values as those in the preliminary work. In the following, take β = 260 and $V_{CE(SAT)}$ = 0.2 V.

2) Draw the transistor i_C–v_{CE} characteristics (piecewise linear model) for $I_B = 0\mu$A to $I_B = 100\mu$A in 20μA steps. On the same graph, draw the load lines for $R_C = 1$kΩ and $V_{CC} = 15$V, $V_{CC} = 10$V, $V_{CC} = 5$V, and $V_{CC} = 1$V. Make sure that your graph is to scale and labeled properly.

3) Note that the values of V_{CC}, R_C, and I_B all influence the state of the transistor and the output voltage V_{CE}.

In the laboratory, you will first change I_B and measure I_C, keeping $R_C = 1$kΩ and $V_{CC} =$ 15V fixed. When the transistor is in ACT state, these two currents are related by $I_C = \beta . I_B$. However, increasing I_B beyond a certain value pushes the transistor into saturation.

4) Determine the value of I_B that pushes the transistor into saturation. Take $R_C = 1$ kΩ and $V_{CC} = 15$V.

5) Repeat the previous step for $R_C = 2.2$kΩ.

In the laboratory, you will also trace the transistor i_C–v_{CE} characteristics at a constant value of I_B by changing V_{CC}. You can see how this works by inspecting the graphs of parts 2 and 3. At a fixed value of I_B, changing V_{CC} moves the Q-point along the constant I_B curve. Measuring I_C and V_{CE} as V_{CC} is decreased from 15V to 0V traces the entire transistor characteristics (both ACT and SAT regions) for that particular fixed value of I_B.

6) List and explain all the differences between the piecewise linear model and the actual i_B–v_{BE} and i_C–v_{CE} characteristics of a real transistor, considering all of the possible transistor states in this circuit (OFF, ACT, and SAT).

The PSPICE model for the BC238B transistor has to be included into your PSPICE installation before you can do the next step. Please refer to the WORD Document, that you downloaded, for instructions on how to do this. The β of the transistor in the PSPICE model is approximately 310 – 330.

7) Simulate the BJT circuit using PSPICE with $R_C = 1$kΩ and $V_{CC} = 15$V. Generate a graph of output voltage V_{CE} versus input voltage V_{BB}, where V_{BB} ranges between 0V and 12V. (Use DC Sweep for this purpose.) On the graph, indicate the regions where the transistor is OFF, ACT, and SAT.

8) Zoom in at the SAT region so that small changes in V_{CE} as V_{BB} increases can be clearly seen. Comment on your results.

Experimental Work:

Before constructing the circuit, verify the values of the resistors that you are going to use by measuring their resistances with a multimeter. Make sure that all resistors are within 2% of their marked values. This will assure that your current measurements are accurate.

Construct the circuit given in the preliminary work section using R_C = 1kΩ. Set V_{CC} = 15V. Make sure that V_{BB} can be adjusted in the 0 V to 12 V range.

During the entire experiment, to measure I_B first measure the voltage drop across the 100kΩ base resistor with a multimeter, and then divide this value by 100kΩ. Similarly, measure I_C by first measuring the voltage drop over R_C and then dividing this by R_C.

1) Set $I_B = 0\mu$A. Measure I_C and V_{CE}. What is the state of the transistor?

$I_C =$
$V_{CE} =$

2) You will first measure the β of this transistor at various values of I_B. Set $I_B = 5\mu$A to $I_B = 40\mu$A in 5μA steps. For each value of I_B, measure I_C and V_{CE}, make sure that the transistor is not SAT by comparing V_{CE} with $V_{CE(SAT)}$, and calculate β. Transistor β measured like this may depend on I_B to some extent (a difference between the actual device and its model). Find the average β value using the eight β values that you measured. In the rest of the experiment, use this average β value.

I_B	I_B	I_C	V_{CE}	β
5μ				
10μ				
15μ				
20μ				
25μ				
30μ				
35μ				
40μ				

3) Using the data that you took in the previous part, plot I_C versus V_{CE}. Fit a straight line to your data and determine the axis crossings. Make sure that your graph is to scale and labeled properly. What does the resulting straight line represent?

4) You will now see how increasing I_B pushes the transistor into saturation. Set $I_B = 50\mu$A to $I_B = 100\mu$A to in 10μA steps. For each value of I_B, measure I_C and V_{CE}, and determine the state of the transistor by comparing $\beta.I_B$ with I_C. How does V_{CE} compare with $V_{CE(SAT)}$ before and after saturation? Note the differences between the model and the actual behavior of the transistor.

I_B	I_C	V_{CE}	β
50µ			
60µ			
70µ			
80µ			
90µ			
100µ			

5) Include the data points that you took in the previous part to the I_C versus V_{CE} plot of part 3. Has the straight line behavior changed in any way?

6) You will now trace the transistor i_C–v_{CE} characteristics at a constant base current of $I_B = 20\mu$A. This can be done by changing V_{CC} to sweep the load line as you measure I_C. and V_{CE}. Starting from V_{CC}=15V, decrease V_{CC} in steps that are not larger than 1 V, and measure I_C. and V_{CE} at each point. Take closer data points once in the SAT region. Plot your data on a graph paper.

V_{CC}	I_C	V_{CE}
15V		
14V		
13V		
12V		
11V		
10V		
9V		
8V		
7V		
6V		
5V		
4V		
3V		
2V		
1V		

7) Using the data of the previous part, determine the Early voltage V_A. To do this, you will have to calculate the slope of the i_C–v_{CE} curve in the ACT region, and determine where this line crosses the horizontal (v_{CE}) axis.

8) You will now investigate how changing the slope of the load line by changing R_C affects the circuit. Replace R_C with a 2.2kΩ resistor. Set I_B=5µ to I_B=70µ in 5µA steps. For each value of I_B, measure I_C and V_{CE}. Plot this data on the graph of parts 3 and 5. How does changing R_C influence the I_B value that pushes the transistor into SAT?

I_B	I_B	I_C	V_{CE}	β
5µ				
10µ				
15µ				
20µ				
25µ				
30µ				
35µ				
40µ				
50µ				
60µ				
70µ				
80µ				

Lab Instruments:	**Components:**
Breadboard Multimeter DC Power Supply	BC238B *npn* transistor 100 kΩ 1 kΩ 2.2 kΩ

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Experiment Results

I_B	I_B	I_C	V_{CE}	β
5μ				
10μ				
15μ				
20μ				
25μ				
30μ				
35μ				
40μ				

I_B	I_C	V_{CE}	β
50μ			
60μ			
70μ			
80μ			
90μ			
100μ			

V_{CC}	I_C	V_{CE}
15V		
14V		
13V		
12V		
11V		
10V		
9V		
8V		
7V		
6V		
5V		
4V		
3V		
2V		
1V		

I_B	I_B	I_C	V_{CE}	β
5μ				
10μ				
15μ				
20μ				
25μ				
30μ				
35μ				
40μ				
50μ				
60μ				
70μ				
80μ				

Student Name :

Number :

Signature……………….……….