Low Cost PC Based BJT Curve Tracer cum Binning Machine
Arvind Kumar Gupta*, Anil Kumar Pandey**, Mohit Tyagi*, Mayank Rajput***
*Rahul Multidisciplinary Research Centre, B-3, CEL Apartments, Plot- B14, Vasundhara Enclave, Delhi-110096, India
**Department of Electronics and Communication Engineering, Greater Noida Institute of Technology, Plot -7, Knowledge Park-II, Greater Noida- 201306, India,
***Electronic Systems and Computer Science Laboratory, H-210, Beta-2, Greater Noida-201310, India

Abstract: Determination of the characteristics of semiconductor component and its segregation is very important before circuit assembly. Though a number of equipments are commercially available to determine the characteristics of the semiconductor devices, but they are costly, bulky and take considerable workspace. A need was felt to develop low-cost equipment which can be operated anywhere. This paper presents the design and experimental results of a low cost PC based BJT Curve Tracer cum Binning Machine. The machine consists of hardware part which is implemented using 89c51 microcontrollers and software part which is developed in Microsoft Visual Basic 6.0. This system plots the input characteristic curves, h-parameters, C-E resistance and early voltage of the given transistor. Binning machine is used to find the working mode of BJT and to find whether the BJT is working or not. All the data can also be stored in a user defined output file in the computer for further analysis. This paper also describes the principle of operation and block diagram of the machine. This machine can be used by hobbyists, professionals and students alike.

Keywords: BJT, Curve tracer, Tests, Binning, Transistor, PC, Microcontroller

I. Introduction
In product development it is extremely important to know the characteristics of BJT accurately. It is possible to obtain a V-I plot by hand with an ammeter, voltmeter and an adjustable power source. But it is more convenient to display the complete curve in an automated measurement by using an instrument called curve tracer. Curve tracers are available in the market from various manufacturers. Since these instruments include power supplies, switches and X-Y display, they are expensive and take significant benchspace. It is possible to make a curve tracer utilizing plotting and other provisions of the personal computer. Transistor binning is a process of identifying different types of transistors into categories so that they could be easily used for required purposes. This paper presents theory, description, functioning and result of the low-cost PC-Based BJT Curve Tracer cum Binning Machine. The summary of the work along with conclusions is also presented. Section-2 describes the theory of the curve tracer. Section-3 gives the block diagram along with the description of each block and its functioning. Section-4 gives the process description. The results and conclusions are given in section-5. Summary of the work is given in section-6.

II. Theory
The transistor is a three terminal device. It has three regions, namely Emitter, Base and Collector. The bipolar junction transistor is a current controlled device. BJT’s are used in three different configurations: (1) Common Base (2) Common Collector (3) Common Emitter
The summary of these configurations is given in table-1.

<table>
<thead>
<tr>
<th>BJT Configuration</th>
<th>Common Base</th>
<th>Common Collector</th>
<th>Common Emitter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Gain</td>
<td>High</td>
<td>Nearly unity</td>
<td>High</td>
</tr>
<tr>
<td>Current Gain</td>
<td>Unity</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Power Gain</td>
<td>= Voltage gain</td>
<td>Medium</td>
<td>Very high</td>
</tr>
<tr>
<td>Input output phase relationship</td>
<td>0°</td>
<td>0°</td>
<td>180°</td>
</tr>
<tr>
<td>Input Resistance</td>
<td>Low</td>
<td>Quite high</td>
<td>Relatively low</td>
</tr>
<tr>
<td>Output Resistance</td>
<td>Relatively high</td>
<td>Quite low</td>
<td>Relatively high</td>
</tr>
</tbody>
</table>
The selection of transistor configuration which is most suited for a particular application depends upon the characteristics like input impedance, output impedance, gain and input/output phase relations, etc. The common emitter configuration is widely used because in this mode input impedance and output impedance are medium as compared to the common base and common collector configuration and power gain is high in common emitter configuration. Therefore, it was decided to design a curve tracer based on common emitter configuration. The present work deals with the input characteristics and determination of $h$-parameters of the transistor. Based on the calculation of $h$-parameter and according to value of $\beta$, conditions of ‘GO’ and ‘NO GO’ are obtained which help in the process of binning of the transistor to acceptable or not acceptable categories respectively.

To draw the input characteristics we have taken transistor in a common emitter configuration. The input characteristics are the plot between the base current ($I_B$) and base emitter voltage ($V_{BE}$). Voltages $V_{BE}$ and $V_{CE}$ are applied to the base terminal $B$ and collector terminal $C$ with respect to the common emitter terminal $E$. The Base-Emitter junction is in the forward bias while the Collector-Base junction is in the reverse biased.

### A. Input characteristics

The Emitter-Base junction of the common-emitter configuration can be considered as a forward biased diode; the current-voltage characteristics are similar to that of a diode:

$$I_B = f \left( V_{BE}, V_{CE} \right) \approx f \left( V_{BE} \right) = I_0 \left( e^{V_{BE} / V_T} - 1 \right)$$

$V_{CE}$ has a small effect on $I_B$.

### B. Output characteristics

$$I_C = f \left( I_B, V_{CE} \right) \approx f \left( I_B \right) = \beta I_B \text{ in linear region}$$

When $I_B$ is increased, $I_C$ is correspondingly increased by $\beta$ (D.C. gain) fold.

The ratio of the output current $I_C$ and the input current $I_B$ is defined as the Common Emitter current gain or current transfer ratio ($\beta$).

$$\beta = \frac{I_C}{I_B} = \left( \frac{I_E - I_B}{I_B} \right) = \frac{I_E}{I_B} = 1 / (1 - \alpha) - 1 = \alpha / (1 - \alpha)$$

### III. Block diagram of curve tracer

Figure-1 shows the block diagram of the Curve Tracer and Binning Machine. Starting from the top we can see that the output of the Curve Tracer is communicated through a serial port RS-232 to the PC through a USB connection with the help of RS-232 to USB cable. The BJT under test is inserted in the socket provided in the machine on the front panel. A value of $V_{CE}$ is selected and the process is started by pressing ‘START BUTTON’ provided in the visual basic program on the PC. This starts the machine. The microcontroller 1 instructs the microcontroller 2 to fix the value of $V_{CE}$ and start the counter of microcontroller 2 to set the value of $V_B$. The counter value passes through the ADC to switch and then to transistor under test. This $V_B$ value is also given to MUX. This analog signal is converted to a digital signal by ADC and it is then given to the microcontroller 1 and from there to a PC through RS-232. Also the value of $V_{BE}$ is given to the MUX and this voltage is sent to the PC through ADC and microcontroller 1. In the visual basic program the value of $I_B$ is calculated.

![Figure-1: Curve Tracer and Binning Machine](image1)

![Figure-2: Flow chart of the process](image2)
IV. Process description

There are two microcontroller in the system in which one is ‘Master’ and other is ‘Slave’. The microcontrollers are initialized as soon as the system is switched on. It then checks whether character is provided (by pressing the ‘START BUTTON’ on the PC screen) as the input or not. If not, then it waits till the character is given as an input. If a character is present, then it is fetched. It then checks which variable is given as an input. Figure 2 shows the flow chart of the process.

When the Microcontroller 1 receives the input as ‘D’ from the computer, it calls ADC (Analog to Digital Converter) activates the ADC. If the ADC is busy then it checks until the ADC is free and if it is free then it continues as such. It then clears the R/H of ADC and then checks for the polarity. If the value is over range, then it returns ‘+999999’ if it lies within the range it performs conversion and returns the digital value to the microcontroller. When the microcontroller receives the input as ‘A’ then it calls DAC1 (Digital to analog converter). It converts it into hexadecimal from ASCII value, and then the value is moved to port 1 of microcontroller 2. The value of $V_{CE}$ is obtained and it is common for both input and output characteristics of the transistor. When the microcontroller receives the input as ‘B’ then it calls DAC2 (Digital to analog converter). It converts it into hexadecimal from inputted ASCII value, and then the value is moved to port 2 of microcontroller 2. The values of $I_B$ and $V_{BE}$ are obtained.

V. Result and conclusion

C. Curve Tracer

When the program of the curve tracer machine, developed in Visual Basic 6.0, is run on a PC, a window appears on the PC screen. The window provides two options, namely ‘Curve Tracing’ and ‘Binning’.

After properly inserting the BJT in the ‘Device under Test’ Port as we click on the button “Curve Tracing” the following screen shown in figure-3 appears. The curves obtained and shown in figure-3 are the characteristic curves of the BJT under test. It contains all the information regarding the parameter of the transistor. Now this information can be used for the transistor binning.

D. Binning of transistors

After properly inserting the BJT in we click on the button “Binning”. A window as shown in figure-4 appears on the PC. If the transistor parameters do not match from the given set of parameters, the screen shown in figure-4 results. However, if the transistor parameters are matched with the given set of parameters instead of ‘NO GO’ shown in figure-4 ‘GO’ appears indicating the transistor is OK.

In the forward active mode, the base is higher than the emitter and the collector is higher than the base (In this mode, $I_c = \beta I_b$). In the reverse active mode, the base is lower than the emitter and the collector is lower than the base. Table 2 and Table 3 shows the modes of operation of the npn and pnp BJT respectively.

In this part we have checked three different transistors i.e. BC547, CK100, SL100 which were inserted in the port given in the circuit. All the transistors were checked whether working or not. After that, their parameters were automatically calculated for forward active mode and reverse active mode by click on the start button. All parameters were automatically calculated and saved in a specific file.
Table-2: Mode of operation of a npn transistor

<table>
<thead>
<tr>
<th>Mode of Operation</th>
<th>B-E Junction</th>
<th>B-C Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward</td>
<td>Reverse</td>
<td>Forward-active</td>
</tr>
<tr>
<td>Reverse</td>
<td>Forward</td>
<td>Saturation</td>
</tr>
<tr>
<td>Reverse</td>
<td>Reverse</td>
<td>Cutoff</td>
</tr>
</tbody>
</table>

Table-3: Mode of operation of a pnp transistor

<table>
<thead>
<tr>
<th>Mode of Operation</th>
<th>B-E Junction</th>
<th>B-C Junction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse</td>
<td>Forward</td>
<td>Reverse-active</td>
</tr>
<tr>
<td>Reverse</td>
<td>Reverse</td>
<td>Cutoff</td>
</tr>
<tr>
<td>Forward</td>
<td>Forward</td>
<td>Saturation</td>
</tr>
</tbody>
</table>

Figure-5: Transistor Forward active mode and Reverse active mode testing

VI. Summary

The input characteristic curves of the BJT can be drawn and binning of Bipolar Junction Transistors (BJTs) can be done by this simple machine. It is very light weight and involves a negligible cost for any institute laboratory or industry to afford. This curve tracer circuit was designed for low power BJT curve tracing and binning. It can be extended for high power transistors and diodes characteristic curve tracing and binning.

VII. References

[7]. Curve Tracer, Catalogue, Radiant Technologies, Inc.

VIII. Acknowledgment

The authors gratefully acknowledge the infrastructural support provided by the GNIOT, Greater Noida. The first author gratefully acknowledges the useful discussions he had with Prof. S. K. Mahajan, IIMT Greater Noida, Dr. T. K. Saxena, Chief Scientist NPL New Delhi. The first author also acknowledges the financial and logistic support provided by RMRC, Delhi.