

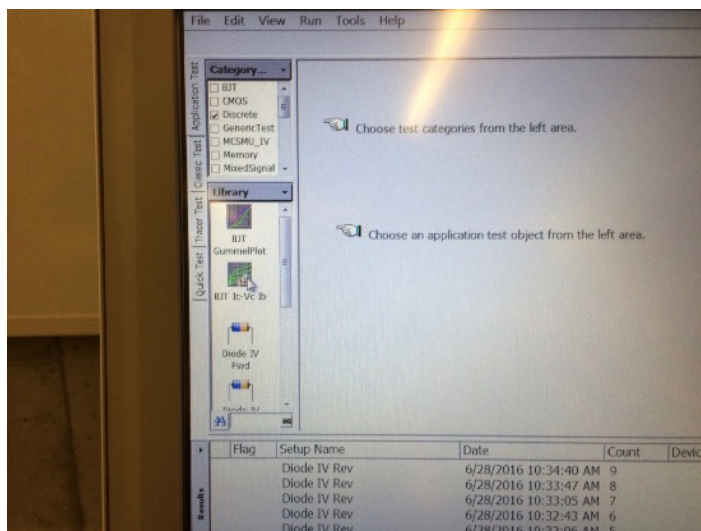
## BJT measurements with B1500A semiconductor analyzer

The following tutorial will take you through the basic steps of measuring the current-voltage characteristics of bipolar junction transistors.

1. If the analyzer is completely off, start by turning on the power. The power button is in the lower right corner of the front panel. Since it is a Windows machine, it will take a while for it to boot up.
2. Once booted, launch the EasyEXPERT program, which controls the set up and operations of the SMUs of the analyzer.



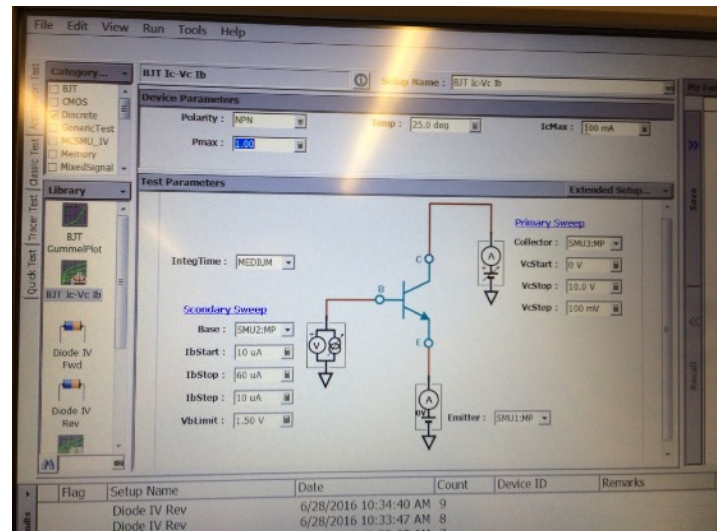
3. Once EasyEXPERT is running, begin the setup by choosing the “Discrete” category (meaning discrete component measurements) and then the specific BJT Ic-Vc Ib measurement from the Discrete library.



- The default settings for the BJT measurement appear on the next screen.

You can use the default settings if you choose, but the configuration shown at right is a good place to start for a basic *npn* BJT measurement. Specifically,

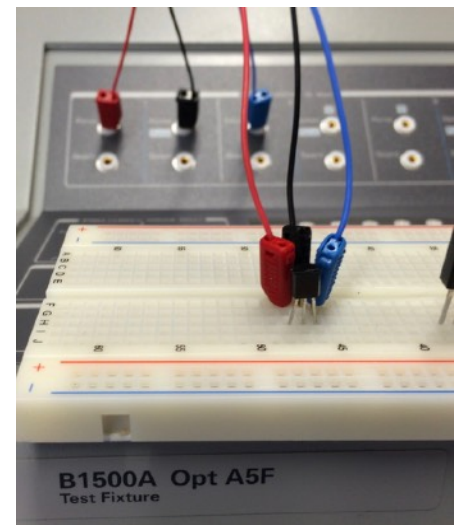
- use SMU 1 for the emitter
- use SMU 2 for the base
- use SMU for the collector



- have the primary collector voltage sweep range from 0 to 10 V in 0.1-V increments
- have the secondary base current sweep range from 10  $\mu$ A to 60  $\mu$ A in 10- $\mu$ A increments,
- set the maximum collector current limit to 100 mA.

Notes: The choice of SMUs for each terminal is somewhat irrelevant. If you use a different SMU arrangement, be sure to change the hardware connections to the transistors. For this particular example, there will one hundred measurements in each  $V_{CE}$  sweep and six sweeps for the different base currents, so there will be a total of 600 data points. Change these parameters as needed to get more or fewer points. Most discrete transistors can probably handle 100 mA, so set that as the upper limit in order to see the fullest possible range of currents.

- Make connections to the transistor. The particular *npn* BJT being measured here is a 2N3904, which is a garden-variety low-power transistor. This is similar to the PN2222 in the 230 lab kit and has the same pin arrangement.

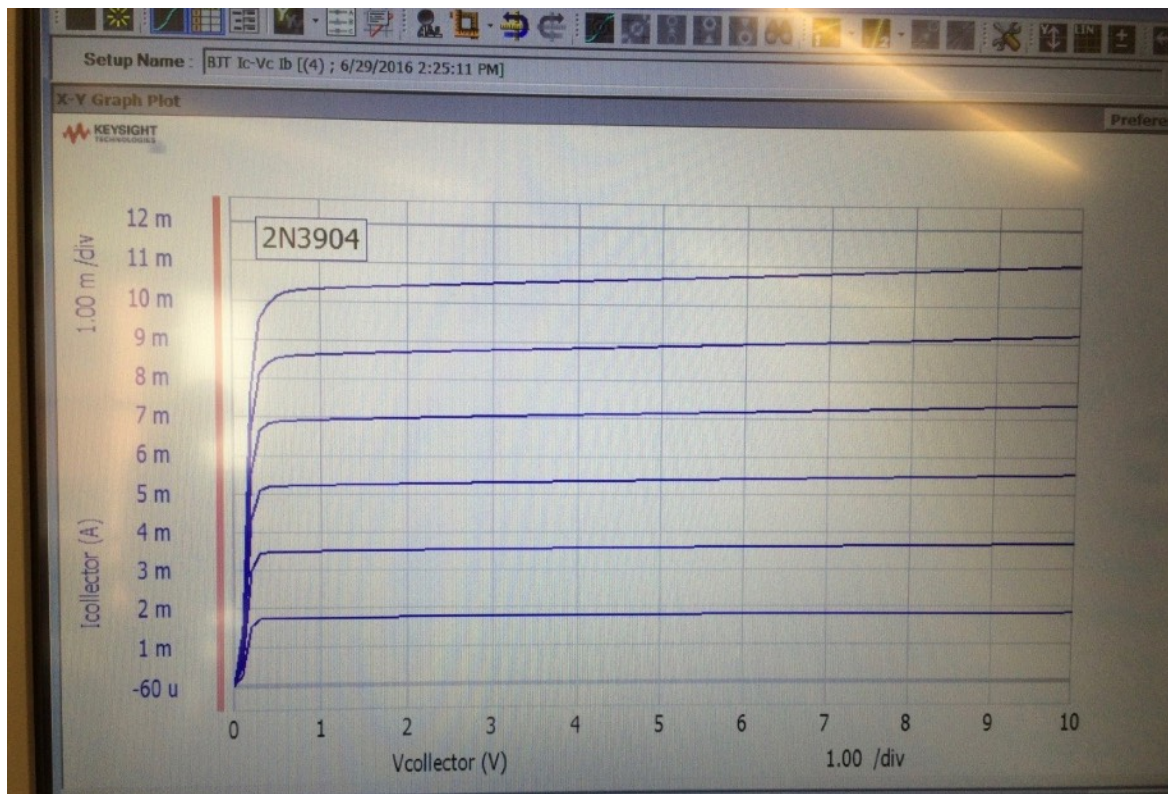


6. Click the run button to start the measurement. (Or select run from the menu.)

Note: Depending on what the previous users were up to, the run control icons may not be visible. To get them back, use the “Tools → user preferences” menu item to make them re-appear.

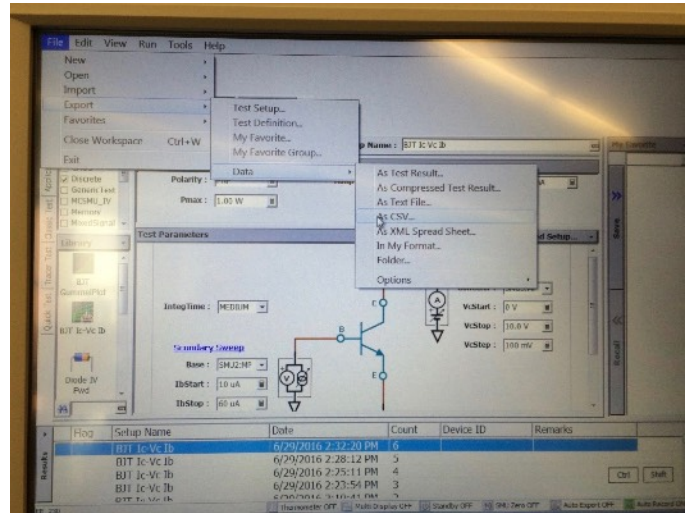
A plot window will open and data will begin to be plotted. It will take a few seconds to run through the entire 600 measurements.

7. Most likely, the data will not fill much of the plot. Click the “Auto-scale” icon to have the axes automatically re-scaled to so that the curves fill most of the graph. Also, if you want, you can add a text label telling what transistor has been measured. (Click the “text” icon, type in the desired text, and then drag it to whatever position you would like.)

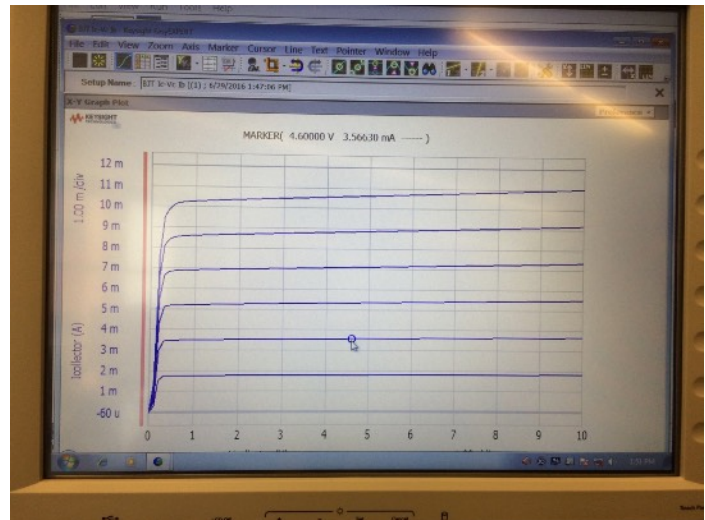


8. And there you have it. To save an image of the graph, plug in a flash drive and use the “Save Image...” menu item on the plot window. Be sure to choose your flash drive as the destination for the image file before clicking “Save”. The resulting bitmap image (.bmp file) can be printed directly or inserted into a word processor document if needed.

9. Alternatively, you can save the data as a common-separated-variable (.csv) file that can be read into Excel or Matlab for further data analysis or to create your own plots. To save the data in .csv format, go back to the measurement setup window and select the measurement from the list of recent measurement shown at the bottom of the window. (You may need to adjust the window partitions to see the list. The measurement that you want to save is probably the most recent one, which is the top one in the list.) Then select the “File → Export → Data → As CSV...” menu item, choose your flash as the file destination, provide a name for the file, and save it. Note that when you go to open the CSV file in Excel, there will be a lot of header information — you will need to sort through all of that extra material to get to the data that you would like to plot.



10. You might want to determine the  $\beta_F$  for the transistor. You can do that right from the plot on the machine. Start by returning to the plot window. Turn on the data marker using the “Marker” icon at the top of the window. Use the cursor to move the marker to one of the curves near the center of the plot. The voltage and current at the maker location are displayed just above the plot.

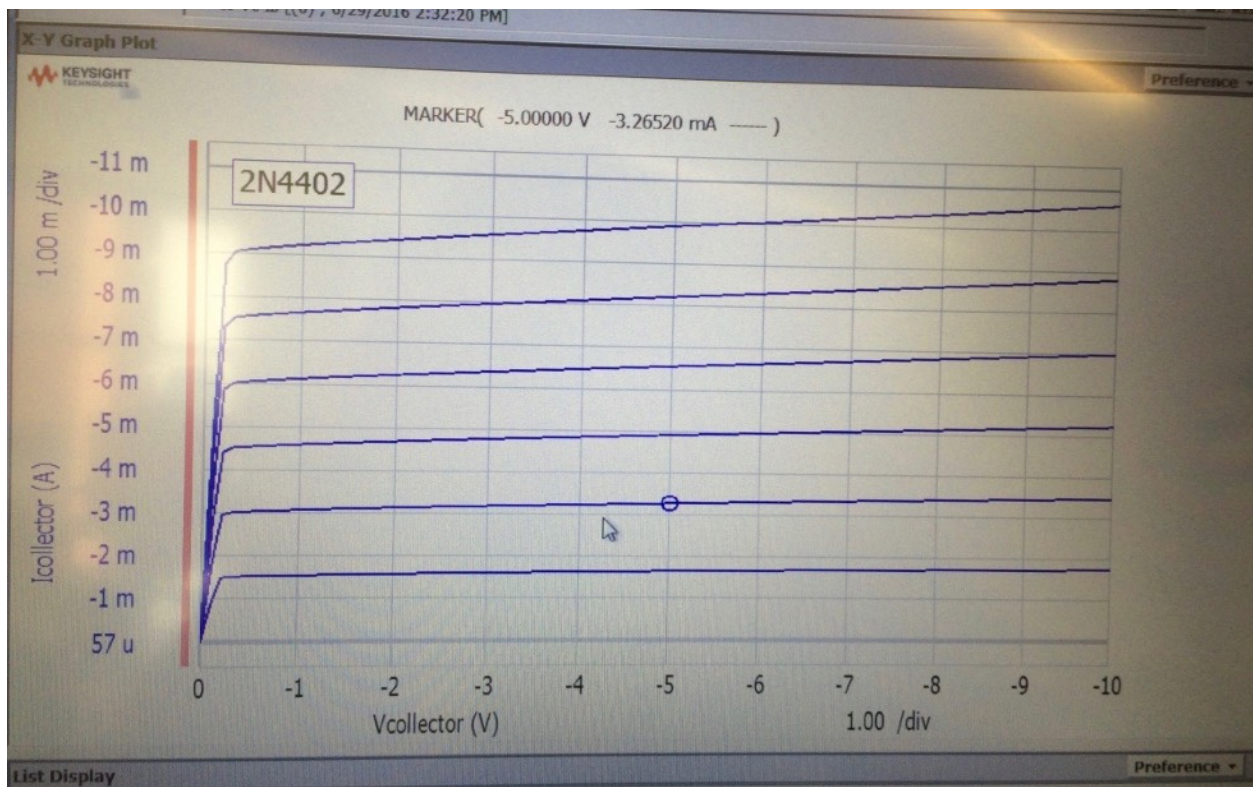


The marker is on the second of the family of curves, which in this case corresponds to a base current of  $20 \mu\text{A}$ . The collector current at the marker is  $3.566 \text{ mA}$ .

Then  $\beta_F = (3.556 \text{ mA}) / (20 \mu\text{A}) = 177.8$ . Easy.

## PNP BJT measurements

Measuring *pnp* transistors is just as easy and requires only one change in the measurement set up. Specifically, go back to the measurement set up page and change the polarity (located near the top of the window) from NPN to PNP. You don't need to change the SMUs or even the collector voltage or base current settings. Although we know that the voltages and currents for *pnp* transistors should all be negative, the analyzer automatically converts the positive values used for the *nnp* measurement to negative values for the *pnp* measurement. Then it is simply a matter of plugging in the *pnp* transistor (double-check the connections) and running the measurement.



The above plot was obtained for a 2N4402 *pnp* transistor (similar to the 2N2907 that is in your lab kit.) Note the negative values on the voltage and current axes. The curves correspond to base currents ranging from  $-10 \mu\text{A}$  to  $-60 \mu\text{A}$ . From the marker coordinates, we can determine the current gain for the transistor to be  $\beta_F = (-3.265 \text{ mA}) / (-20 \mu\text{A}) = 163.3$ .

As always, when done with the analyzer, unplug your components and quit the EasyEXPERT software. If you will be the last person using the analyzer, you can also power it down. Otherwise, leave it powered on for the next user.