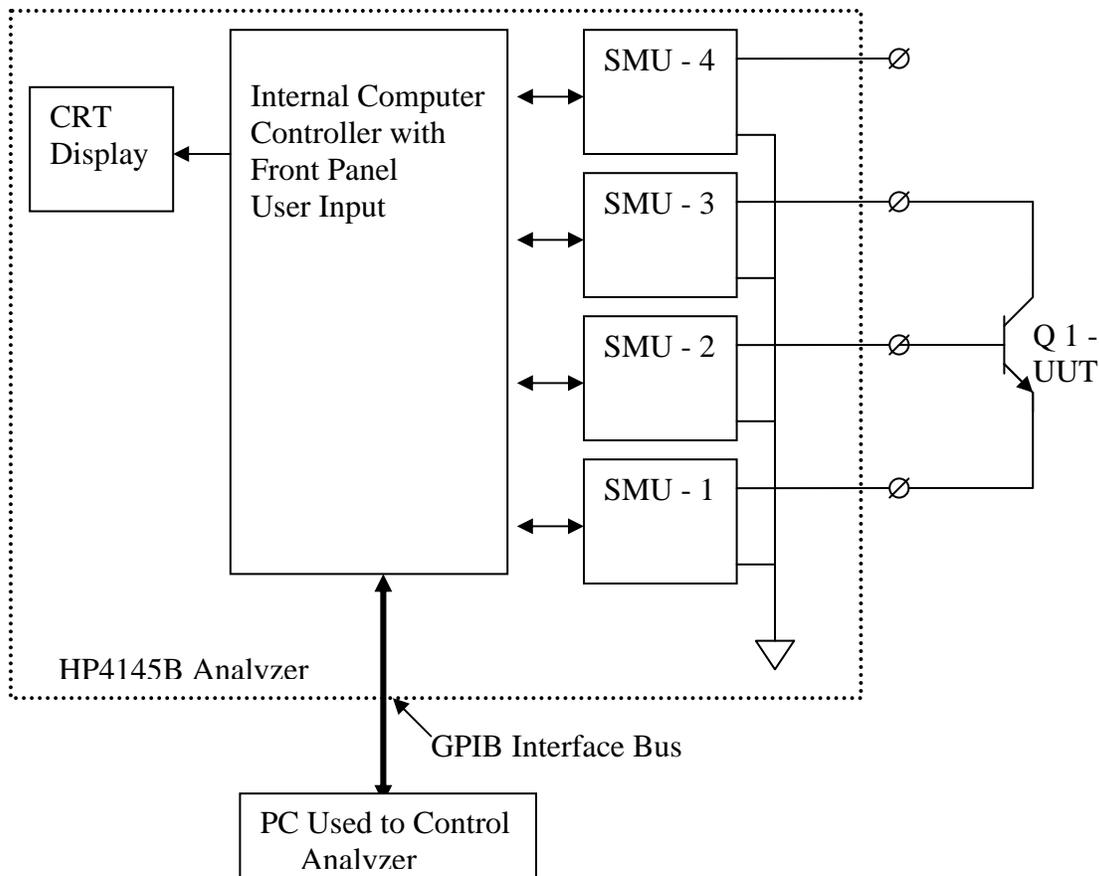


## Engineering 1620

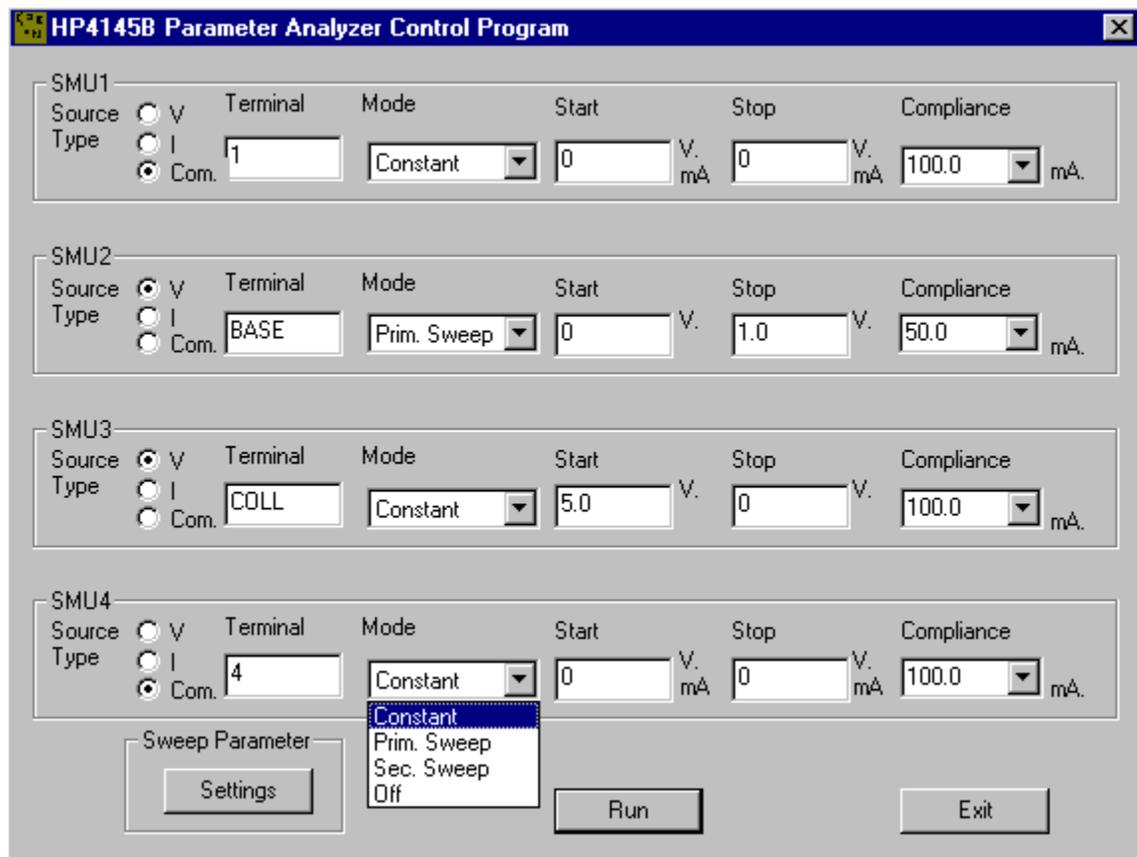
### Using the Hewlett-Packard 4145B Semiconductor Parameter Analyzer

**The Instrument:** You will do most of the measurements for Lab 2 with a semiconductor parameter analyzer that was purchased from Hewlett Packard with a gift from AT&T some years ago. Its user interface is formidable and its data is easier to manipulate in electronic form, so I have written software to make the experience pleasanter. However, first you need to understand a little about the instrument. The analyzer is really just four Source and Measurement Units or SMU's that can be controlled either through a computer port or from the front panel. Each SMU has one output terminal relative to a common ground and can be programmed separately to be either a voltage source or a current source. Both source types can have a constant output or can be stepped through a range of values. You can read the current of a voltage source or the voltage of a current source, but only make measurements from two SMUs for each measurement condition. Results can be displayed on a built-in CRT or may be read back through the control port. The figure below is a block diagram of the machine connected to a bipolar transistor and to a PC for control.



You set the SMUs so that they put the necessary voltages across and currents through the transistor to measure the device I-V properties. For example, to make a Gummel plot of Q1, you would make SMU #1 be a ground connection, make SMU #2 sweep the base voltage from 0 to 1 volt in small increments of 15 to 30 millivolts, and make SMU #3 be a constant voltage source. You would record the values of the currents in SMUs 2 and 3 (IB and IC respectively) as functions of the base voltage (SMU #2) on the CRT and in a computer file for later use. To accommodate the wide range of currents on screen, you would specify logarithmic axes for the display.

**The Software:** To make this experiment really be about transistors and not about the divination of user interfaces, I have written software so the whole process of running the instrument can be done in a Windows™ application program. Guaranteed user friendly GUI, but it is not guaranteed to be entirely reliable.



The main Windows™ user screen is a dialog with four groups of controls, one for each SMU as shown here. The functions of each control within a group are:

- **Source Type** – determines whether that SMU is a voltage source or a current source or is connected to ground. Remember you can only measure the current of a voltage source and the voltage of a current source on this instrument.
- **Terminal** – allows the user to enter up to 4 alphanumeric characters as a terminal name. These names are used to annotate the CRT display and any data file from

the measurement. Names should be mnemonics for the device terminals, e.g., “COL” for collector. **NOTE: Use of this option often runs into a software bug that may really be in the instrument firmware. It may be best not to name the terminals.**

- **Mode** – has the choice list shown open for SMU4. The value for a constant output is set in the Start box. Primary Sweep steps that output from the Start to the Stop value in small increments. If a second supply has to be swept, then the “Secondary Sweep “ SMU will do the step action, but a primary sweep runs at each secondary step value. For example, to take the usual IC(VCE, IB) curve set, you might make the collector voltage from SMU #3 the primary sweep over several volts and make SMU # 2 supply the secondary sweep of base current in steps to generate the parametric curves. You **must specify a primary sweep** source and cannot specify more than one secondary source.
- **Start and Stop** – set values for the range of swept supply outputs. The value in the Start box also sets the value for a constant supply. Values for any one SMU must all be either positive or negative, and the magnitude of the Stop value must be larger than the Start magnitude.
- **Compliance** – sets the limits on the voltage from a current supply or the current from a voltage supply. (The units’ labels change automatically with the supply type.) You protect your device from excessive heat or voltage with these selections. The compliance is **also used to set the scale ranges** for dependent values on the CRT display so it is important to choose a compliance that will give data taken from the screen the best possible accuracy. For example, if you leave the collector compliance at its default value of 100 ma and only supply enough base current to reach a collector current of 1 ma, then the curves will all be squashed at the bottom of the screen. (The computer data would still be okay because it is returned in floating point notation.)
- **Sweep Parameters “Settings” Button** – opens a dialog for setting the number of primary and secondary steps. There are two considerations in changing these settings from their default values of 26 and 11. First, the total number of steps (the product of primary and secondary steps) that can be displayed on the CRT is limited to about 280 by the amount of storage memory in the analyzer. (This machine is a 1985 design!) Moreover, if you want the data to be stored on the control PC, then the number of points has to be less than 78. (This is why the software limits number of primary steps to 77.)

Second, the count includes a step for the Start value, so to divide the range into N equal steps, you have to set the number of steps to  $N + 1$ . If you exceed the total number of steps but not the number per primary sweep, then the software will offer you the chance to take data in individual primary sweeps with secondary steps in between. The display will only show one trace at a time and you have to plot the data on the PC to see the full curve set.

**Data Files:** The program uses the usual Windows file dialog to let you name your data. Please do not leave your data on the desktop. The PC is a standard Engineering machine that is on the engineering network. You can log on and store your data in your own file

area or you can use web-email to send it to yourself. (Remember to get an electronic TA signature for this data.) The data files should be largely self-explanatory. There is a header with the instrument setup parameters and then the data is in comma-delimited columns suitable for pasting into a spreadsheet.

Two features do require explanation. One is that every data column has a column to its left containing an alphabetic code. The code indicates whether the data is valid and if it is not valid, then why it is not. The letter codes are:

Letter	Condition
N	Normal valid data – best to use only this data
C	Compliance limit reached on this channel – the driving voltage or current is probably incorrect
T	Compliance error on another channel affects this data
X	Measurements are oscillating
V	ADC is saturated
L	Inadequate time averaging.
U	Computed swept value, rather than measured. Correct if the other data is valid.

The second data file feature is a pair of options for formatting parametric curve data. One option is columnar data in the native format of the parameter analyzer. This is certainly adequate for many purposes including any diode or Gummel plot data. However, that format is a little awkward to work with when trying to use Excel or MATLAB for plotting large sets of data from parametric curve sets. The software will give you a choice of a “Matix” format that puts the data into a multicolumnar arrangement. For example, if you take data for a bipolar transistor with IC vs VCE at several values of base current, the software in this mode will form a matrix in which the collector voltage is in one column and the current for each successive base current is in an adjoining column. This is probably what you want for such data.

**Matters Mechanical:** You attach your device to the SMUs with a small protoboard that sits inside a box next to the analyzer. **The cover on this box must be closed** for the computer to be able to control the analyzer – this is a safety measure enforced by the designers of the analyzer. You need to pay attention to your connections so you assign SMU functions correctly. Also, the instrument is old enough that we cannot get plugs for the SMU terminals. Two channels are wired with wires tack-soldered inside the box. The connections are only tenuously reliable. If a measurement result looks peculiar, re-check that the connections are really working. They are easy to fix if we know about problems. Remember to record the temperature if you are trying to recover a temperature dependent parameter.

**What works and what doesn't:** The software has had more debug this year so it should be more reliable and flexible than last year. I have only tried a few common setups and may not have caught all the problems. I have seen one situation in which the analyzer fails to accept a valid command – problem with the analyzer firmware as best I can tell. Turning the analyzer off and restarting both it and the driving software fixes the problem.

If you enter an illegal parameter combination or one of my program bugs turns up, the software will usually just show an error box and quit. Please let me know of persistent bugs and what combination of conditions produces the error. (The only known bug right now is with terminal labels. See above.)

If the software locks up, it may also be necessary to reboot the PC. The GPIB port can lose contact with the analyzer and only restarting the computer rectifies the problem. (“If the problem persists, contact the software vendor.”)

**Additional Hints:** Please remember that I try to keep up-to-date hints about problems or common misperceptions on the class web site under “Laboratory Hints and Corrections.”