HEWLETT PACKARD

4145A Semiconductor Parameter Analyzer

HP-IB SYSTEMS

TECHNICAL DATA MAY 1982

Computer age curve tracer combines precision dc measurements with latest computer and display technologies.

HP 4145A SEMICONDUCTOR PARAMETER ANALYZER

The 4145A stimulates voltage and current sensitive devices and measures resulting current and voltage responses. The 4145A also performs mathematical operations on measurement data. This adds up to fast, accurate analysis of semiconductor devices leading to increased productivity and improved quality.

Stimulus Measurement Units (SMUs) are the heart of 4145A. Each of four built-in SMUs can alternately act as 1) a voltage source/current monitor or 2) a current source/voltage monitor. One advantage of the SMU concept is that a four-terminal device can be completely characterized by the 4145A without changing connections – only changing SMU operating modes is required.

Two additional voltage sources and two voltage monitors are also built in for applications which require more than the four SMUs.

Control of the 4145A can be accomplished from the front panel keyboard, external HP-IB* (IEEE 488), or from floppy discs used for program and data storage.

Finally, output information can be displayed on the built-in CRT, dumped to external digital printer/plotters, or sent over HP-IB lines to a computer for further data manipulation.

* HP-IB: Not just IEEE-488, but the hardware, documentation and support that delivers the shortest path to a measurement system.

Applications

The 4145A is at home connected to a wafer prober for testing devices in the wafer stage. And after a device is packaged, the supplied 16058A test fixture can be used. The 16058A includes seven plug-in test modules for testing many kinds of packages. Shown below are the 16058A Test Fixture plus supplied connector plate used for adapting to prober shield boxes.

Features

1. High Resolution (2048 x 2048) CRT combines graphic and alphanumerics. Display formats include 1) graphics, 2) list (tabular), 3) matrix, 4) schmoo and 5) time domain. CRT size is 152.4 mm (6 inch) diagonal.
2. Soft keys simplify required operations into single keystrokes. These keys provide help to the operator 1) during measurement set up, 2) during graphic analysis and 3) during I/O operation.
3. Page control keys enable flexible, interactive control of all operations.
4. Execute single and repetitive measurements. Use APPEND key to retain up to 570 measurements in buffer memory for comparison.
5. Execute sequence programs containing up to 24 separate measurement and output operations.
6. Trade-off measurement speed and noise reduction using three selectable integration times: SHORT (3.6 ms per measurement), MED (1 power line period) and LONG (16 power line periods).
7. 4145A can dump its graphics display to digital printer/plotters without the aid of an HP-IB controller. Recommended peripherals include 2631B/G Printers, 2671A/G Printers, 7225B Graphics Plotter, 7245B Plotter/Printer, 7470A Plotter, 7580A Drafting Plotter and 9872C Graphics Plotter.
8. Flexible positioning of markers and cursors during graphic analysis.
9. Compensate for internal analog offsets to insure best measurement accuracy.
10. Built-in floppy disc drive accepts 5" discs. Each of five supplied discs has 34K byte user storage space for program and data storage.
11. Edit programs and data entry.
12. Alphanumeric entry keys are used for programming and mathematical operations. Physical constants include dielectric constant of vacuum (e), electron charge (q) and Boltzmann's constant (k). Algebraic operators like +, •, exponential and Δ (differential) are also included.

4145A Advantages and Benefits

Measurement

20 built-in test instruments

- ☐ Each SMU = 4 instruments: voltage source/current monitor and current source/voltage monitor
- ☐ Plus two extra voltage sources and two voltage monitors

Makes most semiconductor dc parameter measurements

- ☐ Test wafers or packaged devices
- ☐ Measure dcI from ±50 fA to ±100 mA, dcV from ±100 μV to ±100 V
- ☐ Source dcI from ±1 pA to ±105 mA, dcV from ±1 mV to ±100 V
- ☐ Time domain testing

Repeatable testing/reduced operator errors

- ☐ Record test setups on floppy discs
- ☐ Make all tests without changing DUT connections

Reliable and non-destructive

- ☐ Auto-cal for accuracy
- ☐ Noise averaging
- ☐ Set maximum current and voltage limits to protect DUT

Fast

- ☐ Recall complex test setups from floppy discs
- ☐ Run sequential tests automatically without changing DUT connections
- ☐ Up to 150 measurements per second
- ☐ Sweep log or linear

Display

Time-saving CRT display interacts with operator

- ☐ Display formats include list, schmoo, matrix, graphic and time domain

Analysis

Automatic computation of dc parameters like h_{FE} and g_m

- ☐ User defined functions can operate on measurement data
- ☐ Keyboard includes Boltzman's constant, electron charge, dielectric constant of vacuum, plus algebraic operators

Improve productivity with computer aided graphic analysis

- ☐ Marker function provides 4 digit numeric readouts of displayed parameters
- ☐ Zero-in fast with "auto scale", "zoom" and "move window" commands
- ☐ Numeric readout of dc parameters like early voltage and threshold voltage are obtained using "line" and "cursor"

Data Output and Systemization

Hard copy as easy as a single keystroke

- ☐ Display can be dumped to HP-GL printers and plotters. External controller not needed.

Systemize to achieve automation

- ☐ HP-IB makes the 4145A semiconductor parameter analyzer a good choice for systemization

4145A Key Features

Stimulus Measurement Unit (SMU)

Four SMUs are built into the 4145A. Each SMU can be used as 1) a voltage source and current monitor or 2) a current source and voltage monitor.

SMU Range:
V: ±1 mVdc to ±100.00 Vdc
I: ±1 pAdc to ±100.0 mAdc

Accuracy:
V: ±0.15% to ±(0.15% + 40 mV)
I: ±0.4% to ±1.8%

Measurement Speed

Make up to 150 measurements per second

Voltage Source (V_S)

Two additional voltage sources are built into the 4145A.

Output Range: ±20.000 Vdc
Accuracy: ±0.5%

Voltage Monitor (V_M)

Two additional voltage monitors are built into the 4145A.

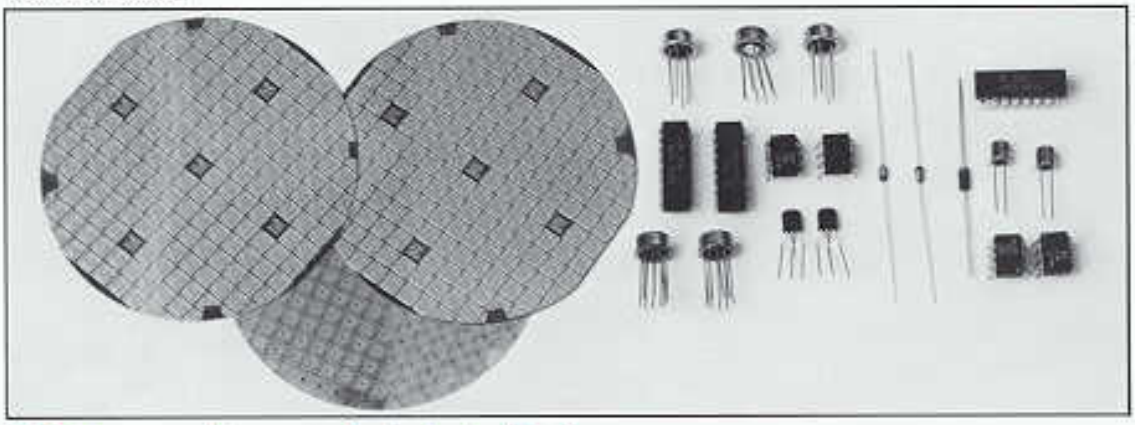
Measuring Ranges: ±20.000 Vdc and ±2.0000 Vdc
Accuracy: ±0.5% (20 V range) and ±0.2% (2 V range)

Complete Evaluation of Semiconductor Devices

SMU range is ± 100 mA and ± 100 V—sufficient to cover most semiconductor evaluation parameters. The 4145A thus functions well in TEG (Test Element Group) measurements performed on semiconductor wafers as well as in parameter extraction of simulation models in computer aided design applications. The 4145A can also be used for characterization of packaged devices using the supplied 16058A Test Fixture.

Applications include dc characterization of these semiconductors:

- ☐ Bipolar Transistors
- ☐ MOS structures, Junction FETs, GaAs FETs
- ☐ Semiconductor Diodes
- ☐ Photoelectric conversion devices (Photodiodes, Phototransistors)
- ☐ Light Emitting Devices (LEDs, GaAs Infrared Emitting Diodes)
- ☐ Operational Amplifiers
- ☐ Gated Diodes
- ☐ Static Electricity Induced Transistors (SITs)



MOS Structure Parameter Analysis Application

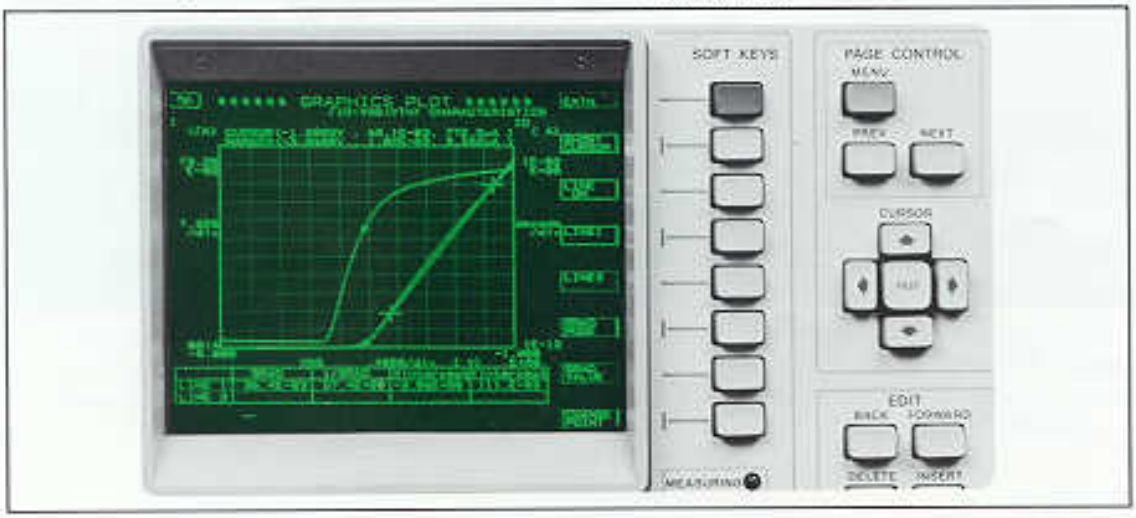
Theoretical threshold voltage is a dc parameter of great significance. 4145A can reduce time required to obtain this parameter. The example CRT display shows FET $\sqrt{I_D} - V_{GS}$ and $\log I_D - V_{GS}$ on a plot with double Y axes.

Using the $\sqrt{I_D} - V_{GS}$ plot and LINE function, theoretical $V_{GS(th)}$ can be read directly (under X-Intercept) as −3.06 volts. $I_{D(th)}$ is also read directly (marker readout) as 3.322 μA. This complete measurement and graphic analysis was done in less than two minutes.

The $\log I_D - V_{GS}$ plot is commonly used to obtain V_{GS} values at specific values of I_D. Such V_{GS} values can easily be obtained in numeric form using 4145A's marker and interpolation functions.

Parameters which can be analyzed include:

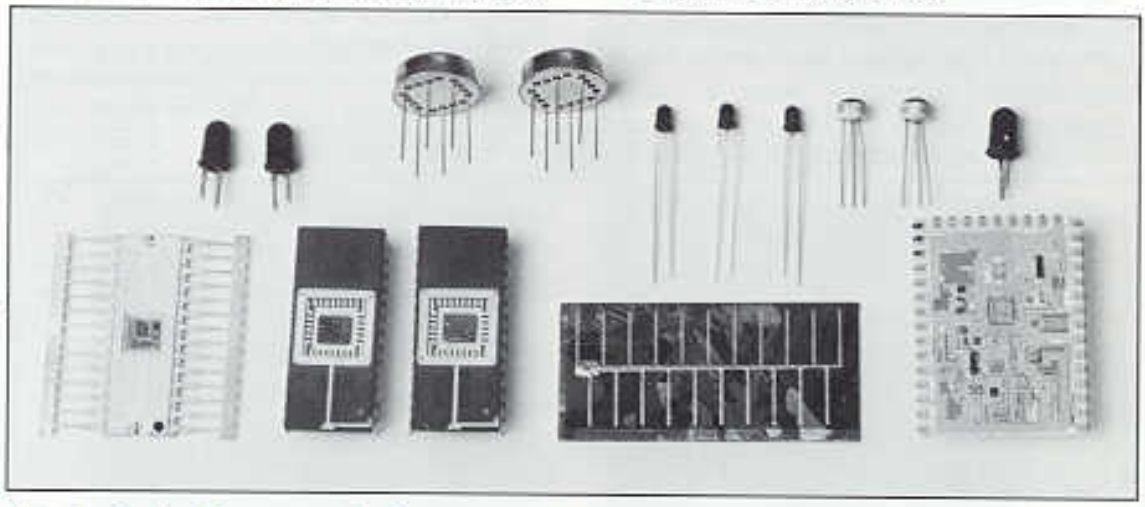
- ☐ Threshold Voltage Bulk Potential Dependency
- ☐ Extrapolated Threshold Voltage
- ☐ Gain Factor (K) in Saturated/Non-Saturated Regions
- ☐ Mutual Conductance Drain and Gate Voltage Dependency
- ☐ Body Factor Effect Multiplication Factor (M)
- ☐ Punch-Through Voltage
- ☐ PN Junction Break-Down Voltage
- ☐ Channel Conductance-Gate Voltage Characteristic



Research and Development of New Materials

Eight different analysis methods are featured on the 4145A. Readings are made using contactline, gradient, comparison, zoom, or marker methods. The calculation function has 11 arithmetic functions including LOG, EXP and Δ (differential calculation). Two user defined functions can also be used. 4145A thus provides the research lab with capability that will meet dc characterization requirements for present devices, and also provides functions needed for development of new materials.

- ☐ Solar Cell Elements
- ☐ Solar Cell Arrays
- ☐ Amorphous Silicon Devices
- ☐ Liquid Crystal Structures
- ☐ Ceramic Semiconductors



Bipolar Device Parameter Analysis

The 4145A can simultaneously measure $I_C - V_{BE}$ and $I_B - V_{BE}$. After each measurement, h_{FE} vs. I_C can automatically be computed and plotted on a log-log scale.

In addition, the 4145A can display a straight line positioned as a tangent at any point along the $h_{FE} - I_C$ curve. Once the line is positioned, slope and X intercept values can be read directly on CRT. Next, a parallel shift can be performed on the tangent line. This allows numeric values of knee current (I_K) and maximum value of h_{FE} (β_{FM}) to be read directly on CRT. These are parameters of the Gummel-Poon Model. Such capabilities make 4145A a valuable tool in bipolar integrated circuit design.

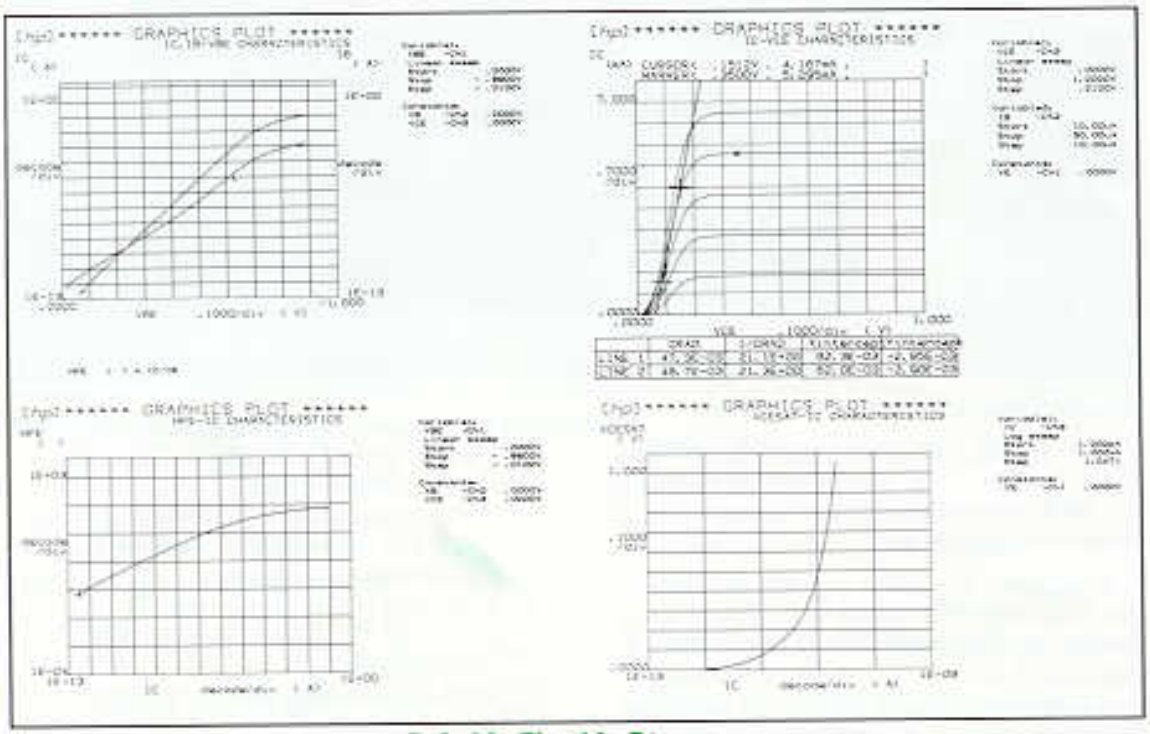
- ☐ DC Current Gain (h_{FE}, h_{FB})—Collector Current Characteristics
- ☐ Evaluation of Surface Recombination Current as Related to PN Junction Forward Bias Characteristics
- ☐ Evaluation of Current Generation as Related to PN Junction Reverse Bias Characteristics
- ☐ Breakdown Voltage (BV_{EBO}, BV_{CBO}, BV_{CEO}, BV_{CSO})
- ☐ Sheet Resistance
- ☐ Resistivity
- ☐ Collector—Emitter and Emitter—Base Saturation Voltage
- ☐ Collector Cut-Off Current (I_{CBO}, I_{EBO})

Auto Sequence Programs Can Automate Your Evaluation Procedures

The 4145A can be programmed to perform sequential measurements and output the results. The AUTO SEQUENCE SETUP (shown at the right) is an automated procedure for characterization of I_C, $I_B - V_{BE}$, $h_{FE} - I_C$, collector current – voltage and $V_{CE(SAT)}$ of a bipolar transistor.

The auto sequence program initiates a measurement sequence, activates the plotter/printer for hard copy results and then stores measurement data in disc memory. Hard copy output is shown below.

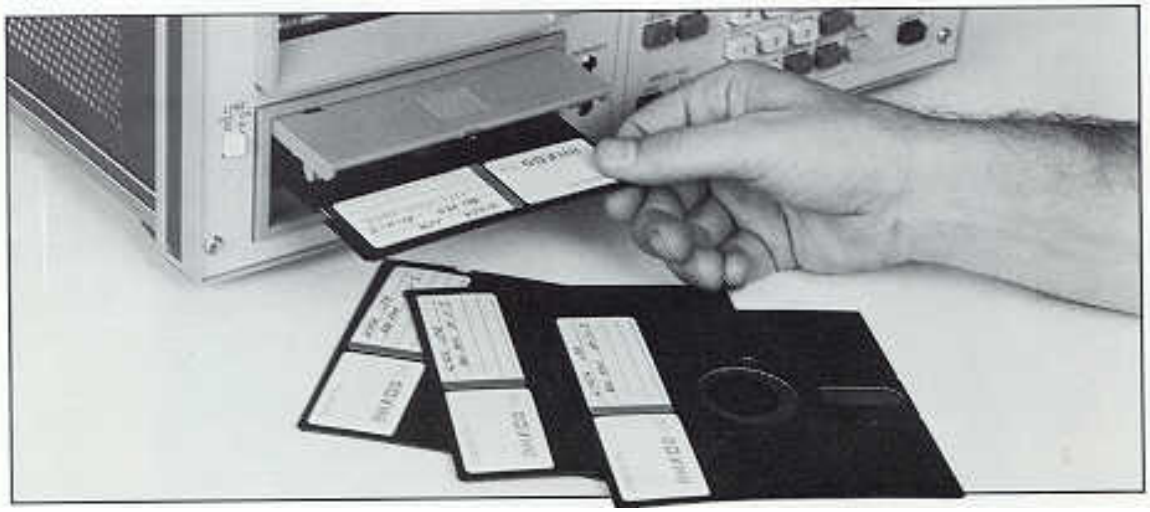
```
*** AUTO SEQUENCE SET UP ***

1  GET P  1CBVBE          <- Call up program from disc
2  SINGLE                 <- Single Sweep
3  PLOT   100, 3500, 3500, 7000   <- Output CRT display contents to plotter
4  SAVE D 1CBVBE          <- Save test results on disc
5  GET P  HFE1
6  SINGLE
7  PLOT   100, 100, 3500, 3500
8  GET P  NPN1
9  SINGLE
10 PAUSE                  <- Allows viewing of results before output to plotter
11 PLOT   3500, 3500, 7000, 7000
12 GET P  VCESAT
13 SINGLE
14 PLOT   3500, 100, 7000, 3500
15 PAGE                   <- Advance plotter page
16 WAIT   50              <- Wait time before execution of next command
17 PRINT
```



Program and Data Storage on Reliable Flexible Discs

The 4145A uses highly reliable single-sided, standard-density mini flexible disc to store measurement data and programs. A Disc Copy function can be used to transfer stored information from one disc to another.

Changing discs is quick and simple. Five discs are provided and each disc can store up to 92 kilobytes of information. Approximately 40 programs can be stored on a single disc.



Five Different Display Modes are Selectable to Suit the Evaluation Purpose

A **Schmoo Plot** can be used for map-type display when analyzing characteristics affected by two independent variables. Each characteristic value is represented by one of five different symbols. And, the cursor function can be used to highlight a single symbol and display its numeric value.

The **Matrix Display** is a numerical display of a characteristic affected by two variable parameters. Rows are formed by up to 512 VAR 1 values. Columns are formed by up to 6 VAR 2 values. Matrix elements can be measured values or functions of VAR 1 and VAR 2.

The **List Display** shows all measurement conditions, values and calculations in a list format.

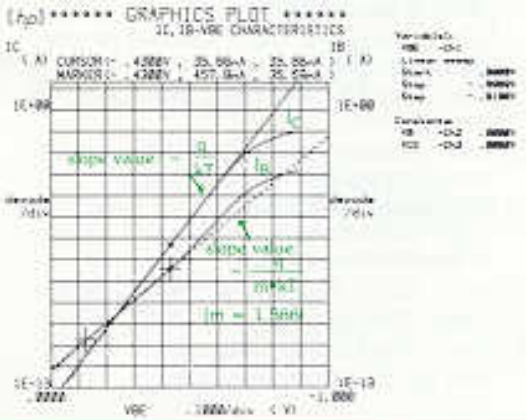
Semiconductor parameters changing as a function of time can be analyzed in the **Time-Domain**. Measurements up to 85 minutes can be done with minimum interval of 10 ms. Graphic, matrix or list display can be used.

The **Graphic Display** can be used for simultaneous display of two characteristics using double-axis format. Graphic Display can give the operator a quick grasp of overall device characteristics and compare device characteristics measured under changing conditions.

User Functions Can Calculate $h_{FE} = \frac{I_C}{I_B}$ and $I = I_0 e^{(qV/KT)}$

The 4145A provides two User Functions in which 11 front panel arithmetic operators may be used. Values of User Functions are computed simultaneous with each measurement and can be displayed in the same manner as a measurement value.

The most common constants used in semiconductor analysis are also available on front panel keys (k: Boltzmann's constant; q: electron charge; e: dielectric constant of a vacuum).



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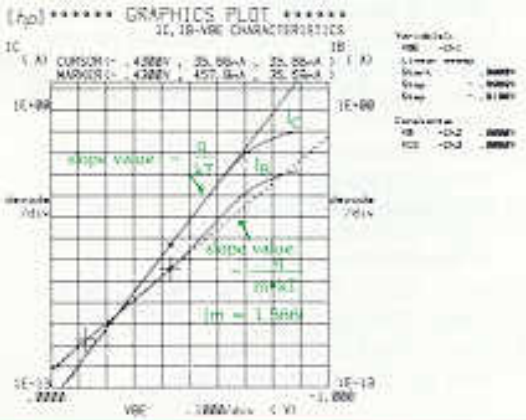


Easy-To-Use Menu and Page Format

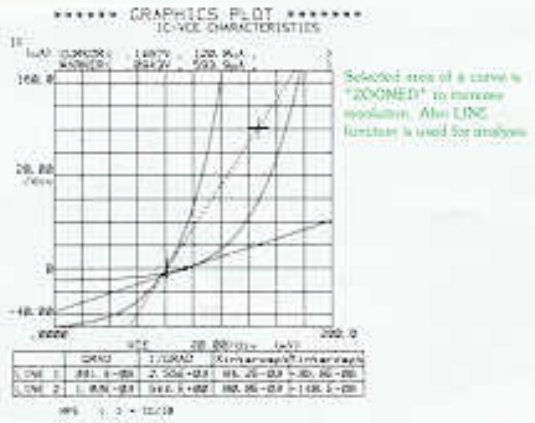
Operation is as simple as turning the pages of a book using PREV, NEXT and MENU keys. Measurement setup also can be controlled by operating the SOFT KEYS.

Interactive, Fill-In-The-Blank Programming

Interactive Programming consists of simply keying data into the blanks indicated by the display pointer (►). This is used for measurement setup, display setup including graph scaling and I/O setup. Once a program is completed, it can be stored for later use.

Eight Functions for Complete Test Results Analysis

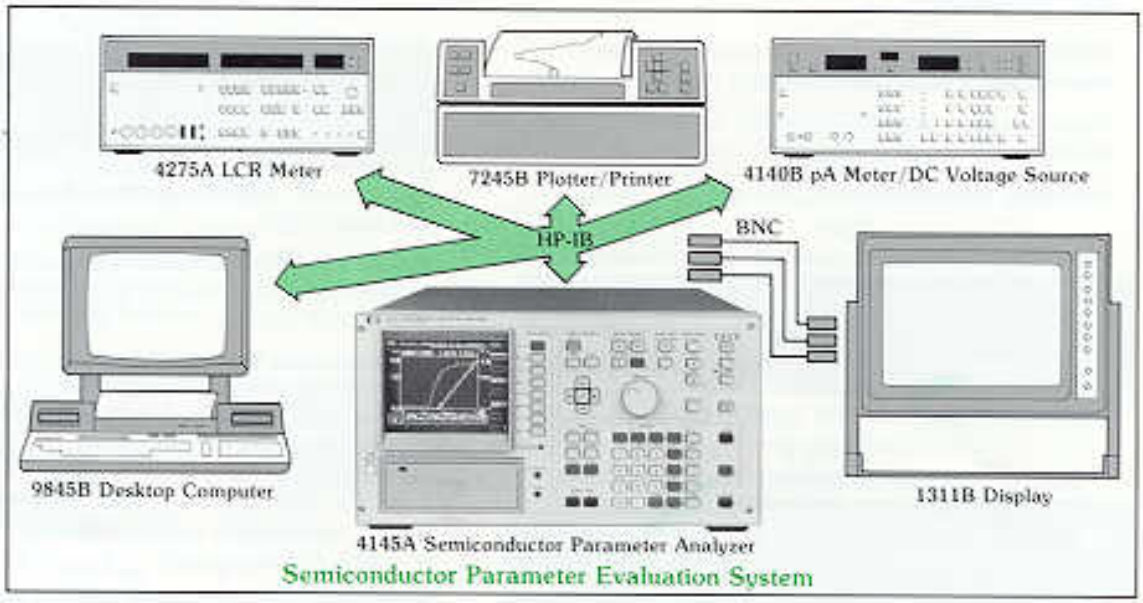
- ☐ Marker Function for numeric characteristic value readout.
- ☐ Cursor Function for reading the numeric value of any graphic point.
- ☐ Line Function for direct readout of slope (gradient) plus X and Y intercepts.
- ☐ Line Control Function for changing contact line position.
- ☐ Auto Retrieve Function to display measurement data in a different format.
- ☐ Comparison functions provided by STORE and RECALL using an Overlay Display or Double-Axis format.
- ☐ Auto Scale Function optimizes graphic display scaling.
- ☐ Zoom Function to expand (x2) or contract (x0.5) the displayed graphic.



HP-IB Provides the Interface for System Expansion

The 4145A uses both HP-IB and HP-GL (Hewlett-Packard Graphics Language). It is easy to interface other measuring instrumentation and controllers for laboratory automation or to construct a process evaluation system that best suits your needs. The accompanying diagram shows a complete semiconductor evaluation system capable of performance under the most rigid quality standards. It consists of the 4275A LCR Meter (capacitance resolution: 0.00001 pF), 4140B pA Meter (resolution: 0.001 pA), the 9845B System Controller, 7245B Plotter/-Printer, and the 1311B Large Screen CRT Display. C-V characteristics and semiconductor dc parameters, including current in the pA range, can be measured with this system. HP-GL provides a full range of graphics capability on the 4145A high resolution CRT. The Plot Function and External CRT Output also lets the operator view test results on the large screen monitor. Or, the operator can obtain plots and printouts in a number of formats suitable for record and filing purposes. If a multicolor plotter (9872C/T) is used, the 4145A automatically changes pen color.

HP-IB is an implementation of IEEE-488 and ANSI-MC 1.1 standards.



Semiconductor Parameter Evaluation System

SMU (Stimulus and Measurement Unit)

The 4145A has four SMUs. Each SMU can be used in two modes: 1) current source and voltage monitor or 2) voltage source and current monitor. SMU mode is easily controlled from the front panel or from an external HP-IB controller.

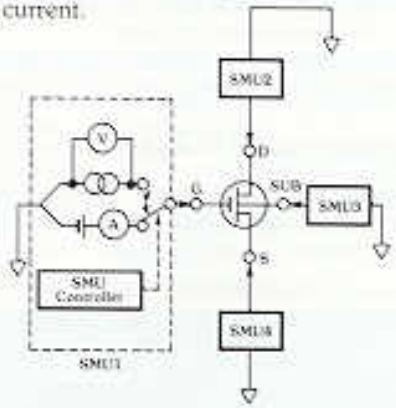
By using the SMU technique, a complete set of dc semiconductor wafer measurements can be made with one probing. This eliminates instabilities caused by changing connection at the DUT and adds up to highly reliable measurements.

Each SMU covers wide output and measurement range up to 100 mA and 100 V with resolution of 1 pA and 1 mV. Plus, SMU outputs can be swept and can be limited for DUT protection against overcurrent and overvoltage.

The example below shows four SMUs connected to a Field-Effect-Transistor (FET).

As shown in the equivalent circuit, each SMU is controlled to operate as: voltage source/current monitor, or current source/voltage monitor.

For example, in a drain current vs. drain voltage characteristics measurement, all SMUs are set in the voltage source/current monitor mode. SMU1 and SMU2 operate as swept voltage sources. SMU2 monitors drain current. After completing this test, a voltage breakdown test can be done. SMU2 must be changed to operate as current source/voltage monitor and measure breakdown voltage at the desired constant current.



Specifications

Measurement

SMU Characteristics

Each SMU can be programmed to source voltage and monitor current, or conversely to source current and monitor voltage. Tables 1 and 2 specify both the measuring and sourcing parameters.

Each SMU can also be programmed to COM mode. This sets voltage at 0 volts and current compliance limit at 105 mA. See "Reference Data" section on page 13 for more information on SMUs.

SMU output/measurement resolution: dc volts = 4½ digits, dc current = 4 digits. See Tables 1 and 2 for details.

Voltage measurement input resistance/current source output resistance: $\geq 10^{12}\Omega$

Voltage source output resistance/current measurement input resistance: 0.4Ω.

Maximum capacitive load: 1000 pF

Table 1

SMU Voltage Range, Resolution and Accuracy

Voltage Range	Resolution	Accuracy[1,2]	Max. Current[3]
± 20 V	1 mV	± (0.1% of reading + 0.05% of range + 0.4Ω x I_{out}[*])	100 mA
± 40 V	2 mV		50 mA
± 100 V	5 mV		20 mA

[*] I_{out} is SMU output current in amps.

Table 2

SMU Current Range, Resolution and Accuracy

Current Range	Resolution	Accuracy[1,2]	Max. Voltage[4]
± 100 mA	100 µA	± (0.3% + 30.1 + 0.2 x V_{out}[*] 100 %)	20 V (I > 50 mA) 40 V (20 mA < I ≤ 50 mA) 100 V (I ≤ 20 mA)
± 10 mA	10 µA		100 V
± 1000 µA	1 µA		
± 100 µA	100 nA		
± 10 µA	10 nA		
± 1000 nA	1 nA	± (0.5% + 0.1 + 0.2 x V_{out}[*] 100 %)	
± 100 nA	100 pA		
± 10 nA	10 pA	± (1% + 0.1 + 0.2 x V_{out}[*] 100 % + 5 pA)	
± 1000 pA	1 pA[**]		

[*] V_{out} is SMU output voltage in volts.
[**] 50 fA resolution in current monitor mode.

1. Accuracy specifications are given as ± % of reading when measuring or ± % of setting when sourcing.
2. Accuracy tolerances are specified at 23°C ± 5°C, after a 40 minute warm-up time, with AUTO CAL on, and specified at the rear panel connector terminals referenced to SMU common. Tolerances are doubled for the extended temperature range of 10°C to 40°C.
3. Maximum current when SMUs are sourcing voltage.
4. Maximum voltage compliance when SMUs are sourcing current.

SMU Voltage/Current Compliance Limit:

Compliance voltage and current resolution are the same as listed in Table 1 and Table 2. An exception is that maximum compliance current resolution is 50 pA.

Compliance voltage accuracy is the same as listed in Table 1. Compliance current accuray is ± (1% of range + 10 pA).

Voltage/Current Sweep Characteristics

Each SMU source can be swept using Variable 1 (VAR 1), Variable 2 (VAR 2) or Synchronously Variable (VAR 1') mode.

Variable 1: Variable 1 can be swept linearly or logarithmically.

Linear sweep is a staircase output of voltage or current. Sweep parameters include START, STOP and STEP levels. These parameters can be varied by the user.

Log sweep is also a staircase, but at 10, 25 or 50 points per decade. The maximum number of data points is limited to 512 for a single VAR 1 sweep or 570 for a multiple sweep.

Time domain sweep is accessed when VAR 1 is not assigned a source function. An initial WAIT time and a time interval are specified. Wait time is specified up to 100s with resolution of 10 ms. Measurement interval is specified up to 10s with resolution of 10 ms. Maximum number of data points is 512.

Variable 2: Variable 2 sweep is a staircase with specified number of steps. Variable 2 is incremented after completion of each VAR 1 sweep.

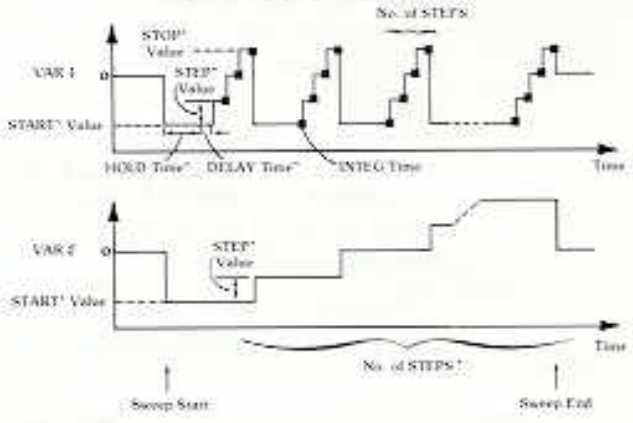
Synchronously Variable (VAR 1'): VAR 1' output provides a sweep synchronous with VAR 1 but at output levels proportional to a fixed ratio or offset relative to VAR 1. The ratio is defined as VAR 1' = a x VAR 1, where a is a fixed ratio of ±0.01 to ±10. An offset is defined as VAR 1' = b + VAR 1, where b is any value that will not cause VAR 1' to exceed the maximum allowable source current or voltage compliance.

Hold Time: Hold time is defined as the delay from application of initial output level to start of the first delay time. See Figure 1. Hold time can be varied from 0 to 650s ± (0.5% + 9 ms) with 10 ms resolution.

Delay Time: Delay time is defined as the delay time from application of step output level to start of measurement. See Figure 1. Delay time can be set from 0 to 6.5s ± (0.1% + 5×N* ms) with 1 ms maximum resolution.

*N: number of monitor channels.

Figure 1. Sweep Sequence



Note: *Setting Value

Voltage Sources (Vs) Characteristics

Output resistance: ≤ 0.2Ω

Maximum capacitive load: 1000 pF

Table 3
Vs Voltage Output Range.
Also see "Reference Data" section

Output Voltage Range	Resolution	Accuracy	Max. Output Current
± 20 V	1 mV	± (0.5% of setting + 10 mV)	10 mA

Voltage Monitors (V_m) Characteristics

Input resistance: 1 MΩ ± 1% paralleled by 100 pF ± 10%

Table 4
V_m Voltage Measurement Range.
Also see "Reference Data" section

Measurement Voltage Range	Resolution	Accuracy
± 2 V	100 µV	± (0.5% of reading + 10 mV)
± 20 V	1 mV	± (0.2% of reading + 10 mV)

Characteristics Common SMU, Vs and V_m

Maximum allowable terminal voltage: 100 V peak across SMU and V_m input terminals, or SMU and Vs output terminals, or between those terminals and guard; and 42 V maximum from Common to Ground.

Display

CRT Size: 152.4 mm (6 inch) diagonal CRT.

CRT Visible Area: 116 mm (4.6 inches) x 92 mm (3.6 inches).

Screen Resolution: 2048 x 2048 points.

External CRT Analog Output: X, Y and Z outputs of 0 to 1 Vdc into 330Ω for X and Y, and 240Ω for Z output, are available at rear panel BNC connectors.

Analysis

Calculation

The 4145A does calculations with 7 digit resolution and displays 5 digits.

Constants Available on the Keyboard:

Keyboard constants are stored in memory as follows:

q: Electron charge (1.602189×10^{-19} Coulomb)
k: Boltzmann's Constant (1.380662×10^{-23} J/°K)
e: Dielectric constant of a vacuum (8.854185×10^{-12} F/m)

The following unit symbols are also available on the keyboard:

m(10^{-3}), µ(10^{-6}), n(10^{-9}), p(10^{-12})

Analysis Functions:

Overlay Comparison: STORE and RECALL capabilities permit a graphical presentation of results which can be stored and later recalled and superimposed on an existing display. While in the Schmoo Display Mode, stored data and present data are alternately displayed, with the RECALL key acting as a toggle switch. Only one set of data can be stored. Scaling information is not included.

Marker: In the Graphics Display Mode a marker may be superimposed on both the X-Y1 and X-Y2 traces. A numeric display of their coordinates is displayed.

Interpolate: In the Graphics Display Mode a linear interpolation between two adjacent measurement data points is provided. Interpolated values of X-Y1 and X-Y2 are displayed at maximum display resolution of 2048 x 2048 points.

Cursor: In the Graphics Display Mode the coordinates of the intersection of moveable vertical and horizontal lines is displayed. A cursor is available for both X-Y1 and X-Y2 graphs. In the List and Matrix Displays a flashing arrow indicates a selected row of data. In the Schmoo Display, the Z-axis value of the intensified symbol is displayed.

Auto Scale: In the Graphics Display Mode, X and Y scale factors are automatically adjusted to yield optimum display of measured data.

Zoom Function (← → → ← ↑↓): In the Graphics Display Mode, the ZOOM function expands by two or contracts to ½ the area surrounding the cursor.

Line: In the Graphics Display Mode, two variable slope lines can be displayed. These lines can be used as tangents to determine slope and X and Y intercepts of dc characteristics curves.

Move Window: In the Graphics Display Mode, the MOVE WINDOW centers the display around the cursor.

General Specifications

Self-Test Function: When power is turned ON, the 4145A automatically sequences through a self-test that verifies operational status of major functional blocks. Self-test can be actuated via HP-IB or via keyboard operation.

Operating Temperature Range: +10°C to +40°C; ≤ 70% RH at 40°C, permissible temperature change ≤ 1°C/5 min; maximum wet-bulb temperature 29°C.

Power Requirements: 100/120/220 V ± 10%; 240 V − 10% + 5%; 48 to 66 Hz; 270 VA max.

Dimensions: 426 mm (16.75 in)W x 235 mm (9.06 in) H x 612 mm (24.1 in)D

Weight: 27 kg (59 lbs) approximately for 4145A mainframe. 33 kg (73 lbs) includes mainframe and furnished accessories.

Reference Data

Reference data are typical values given for information purposes.

Stimulus/Measurement Unit (SMU)

Measurement Time: Measurement time = response time + ranging time + integration time.

SMU response time includes setup and settling time plus wait time. Wait time is microprocessor controlled and dependent on current range, as shown in Table 5.

Table 5.
SMU Response Time

Current Range	Setup/Settling Time	SMU Wait Time
100 nA to 100 mA	2.7 ms	0.2 ms
1 nA and 10 nA		47.5 ms

Ranging time is dependent on number of ranges required during measurement. Lower ranges require more ranging time than the higher ranges. Ranging time can vary from 4 ms to 74 ms.

Integration time is 3.6 ms in SHORT, 16.7 ms in MED at 60 Hz line frequency (20 ms at 50 Hz); and 267 ms in LONG at 60 Hz (320 ms at 50 Hz).

Example: minimum measurement time = 2.7 ms + 0.2 ms + 3.6 ms = 6.5 ms/point

Notes: 1. In the Graphics Display Mode, a CRT write time of 5.6 ms per point must be added to measurement time.

2. Delay time, if included in a measurement, must also be added to total measurement time.

Offset current of voltage measurement: 6 pA + 2 pA x (V_{out}/100).

Offset voltage of current measurement: 10 mV + 0.4Ω x I_{out}.

Noise Characteristics

Voltage source noise: 0.01% of range (rms).

Current source noise: 0.03% of range + 3 pA + 0.005 pA x Cg* (rms).

Voltage monitor: 0.02% of range (peak to peak).

Current monitor: 0.3% of range + 10 pA (peak to peak).

*C_g is externally added capacitance from the guard terminal to center conductor, and expressed in pF.

Output Overshoot

Voltage source: 5 mV

Current source: ≤ 1%

Current Range Switching Transient Noise

Range increment: 0.01% of voltage range + 10 mV.*

Range decrement: 10 mV.*

Maximum internal guard to ground capacitance: 700 pF

Guard potential offset: 1 mV

Guard current induced voltage error: 1000 x Ig where Ig is the guard current.

*When switching between 10 nA and 100 nA ranges, add 120/(3 + C_x) mV where C_x is the load capacitance in pF.

Voltage Source (Vs)

Output noise: 6 mV rms

Voltage Monitor (V_m)

Noise level at input: 0.3 mV p-p on 2 V range*
3 mV p-p on 20 V range

*With integration time set to MED or LONG

Stimulus/Measurement Units (SMU) and Voltage Monitors (V_m)

Noise rejection guidelines are valid when line frequency is either 50 Hz or 60 Hz.

Normal mode noise rejection: ≥ 60 dB

Common mode noise rejection:

Current monitor: ≤ 2 pA/V*

*With integration time set to MED or LONG

Ordering Information

Standard Instrument	Price**
4145A Semiconductor Parameter Analyzer	$19,220.00

Accessories Furnished

16058A Test Fixture
04145-60001 Connector Plate
04145-61622 Triaxial Cable (3m), 4 ea.
04145-61630 BNC Cable (3m), 4 ea.
04145-61623 Shorting Connector
04145-61100 5 System Discs with a Head Cleaning Disc (P/N 9164-0168)

Options	Price**
Option 907: Front Handle Kit (HP P/N 5061-0091)	$ 80.00
Option 908: Rack Flange Kit (HP P/N 5061-0079)	$ 28.00
Option 909: Rack and Handle Kit (HP P/N 5061-0085)	$ 100.00
Option 910: Extra Manual (HP P/N 04145-90000)	$ 100.00

4145A Rear Panel includes 4 triax connectors for SMUs, 2 each BNCs for V_S and V_m, 16058A test fixture connector, and HP-IB connector.

Domestic U.S. Prices Only.**

For more information, call your local HP Sales Office or nearest Regional Office: • Eastern (201) 265-5000, • Midwestern (312) 255-9800, • Southern (404) 955-1500, • Western (213) 970-7500, • Canadian (416) 678-9430. Ask the operator for instrument sales. Or write Hewlett-Packard, 1501 Page Mill Road, Palo Alto, CA 94304. **In Europe:** Hewlett-Packard S.A., 7, rue du Bois-du-Lan, P.O. Box, CH 1217 Meyrin 2, Geneva, Switzerland. **In Japan:** Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168.

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