

Table 1-1. Specifications (Sheet 1 of 8)

* Specifications listed below are for the 4145A only. For 16058A specifications, refer to the 16058A Operation Note.

GENERAL INFORMATION

Basic Functions : Measures the DC current through voltage-biased devices and the DC voltage across current-biased devices; Arithmetic calculation; Displays measurement results and calculation results on a built-in CRT display; graphics analysis capabilities; storage and recall of measurement setups, measurement data, and auto-sequence programs.

Source and Measurement Units :

Stimulus/Measurement Units (SMU) : Four SMU channels. Each SMU can be programmed to function as a variable or constant DC voltage source/current monitor or as a variable or constant DC current source/voltage monitor.

Voltage Sources (Vs) : Two Vs channels. Each Vs can be programmed to function as a variable or constant DC voltage source.

Voltage Monitors (Vm) : Two Vm channels. Each Vm can measure DC voltages up to $\pm 20V$.

SOURCE/MEASUREMENT FUNCTIONS

Measurement and output accuracies are specified at $23^{\circ} \pm 5^{\circ}C$ after the instrument has been allowed to warm up for at least 40 minutes, with AUTO CAL set to ON, INTEG TIME set to SHORT and referenced to SMU common. Specified accuracy doubles for operation between $10^{\circ}C$ and $40^{\circ}C$.

Stimulus/Measurements Units (SMU) : Four SMU channels. Each SMU measures current when operating as a voltage source, or measures voltage when operating as a current source. Source and measurement ranges, resolution, and accuracy specifications are given in the tables below.

Accuracy specifications in the below tables are given as $\pm n\%$ of specified output or measured value, $\pm n\%$ of range value. I_o is output current (I), V_o is output voltage (V).

Voltage Range	Resolution	Accuracy	Max. Current
$\pm 20V$	1mV	$0.1\% + 0.05\% + 0.4\Omega \cdot I_o$	100mA
$\pm 40V$	2mV		50mA
$\pm 100V$	5mV		20mA

Table 1-1. Specifications (Sheet 2 of 8)

Current Range	Resolution	Accuracy	Max. Voltage	
±100mA	100µA	0.3%+(0.1+0.2*Vo/100)%	20V (>50mA)	
			40V (>20mA)	
±10mA	10µA		100V (≤20mA)	
				±1000µA
±100µA	100nA			
				±10µA
±1000nA	1nA			
				±100nA
±10nA	10pA			
				±1000pA

Setting Resolution: Voltage, 4·1/2 digits (1mV max.);
Current, 4 digits (1pA max.).

Measurement Resolution: Voltage, 4·1/2 digits (1mV max.);
Current, 4 digits (50fA max.).

Ranging: Automatic.

Current/Voltage Limiting (Compliance): Current output from an SMU operating as a voltage source and voltage output from an SMU operating as a current source can be limited.

Compliance Range: Current, 50pA to maximum allowable output current of each voltage range; Voltage, 0V to maximum allowable output voltage of each current range.

Accuracy: Current compliance, accuracy of current source+1% of range +10pA;
Voltage compliance, accuracy of voltage source.

Residual Resistance (Voltage Source/Current Measurement Mode): 0.4Ω.

Input Resistance (Current Source/Voltage Measurement Mode): $\geq 10^{12}\Omega$.

Capacitive Load: $\leq 1000\text{pF}$.

Table 1-1. Specifications (Sheet 3 of 8)

Voltage Sources (Vs) : Two Vs channels. Each Vs can be programmed to function as a variable or constant DC voltage source. Output ranges, resolution, and accuracy specifications are given in the table below.

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

Output Impedance : Less than 0.2Ω

Capacitive Load : $\leq 1000\text{pF}$

Voltage Monitors (Vm) : Two Vm channels. Output ranges, resolution, and accuracy specifications are given in the table below.

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

Input Impedance : $1\text{M}\Omega \pm 1\%$

Capacitance in Parallel with Output : $150\text{pF} \pm 10\%$

Table 1-1. Specifications (Sheet 4 of 8)

SPECIFICATIONS COMMON TO ALL CHANNELS

Maximum Withstand Voltage : 100V (SMU, guard terminal, Vs, and Vm)

Maximum Voltage Between Common and GND : Less than $\pm 42V$.

Source Modes (SMUs Only) : V (voltage source/current monitor),
I (current source/voltage monitor), and COM*.

Source Functions (SMUs Only) : VAR1, staircase sweep;
VAR1', synchronous (VAR1) staircase sweep;
VAR2, subordinate (VAR1) staircase sweep;
CONST, constant source (voltage or current).

* : In COM mode, output voltage is 0V and compliance is 105mA.

Voltage/Current Sweep : Output from each SMU (voltage or current) and each Vs (voltage) can be swept by assigning source function VAR1, VAR1', or VAR2.

Max. Number of Steps : 512 in single-sweep measurements, up to 575 in multi-sweep measurements.

VAR1 : Main sweep. Linear or logarithmic sweep is selectable.

Linear Sweep : Staircase sweep in accordance with the user specified START, STOP, and STEP values.

Log Sweep : Staircase sweep in accordance with the user specified START and STOP values and selected LOG step (10, 25, or 50 points per decade).

VAR2 : Subordinate linear staircase sweep in accordance with the user specified START, STEP, and NO. OF STEPS values. VAR2 source channel output is incremented one STEP each time the VAR1 source channel completes one sweep.

VAR1' : Staircase sweep synchronized with the VAR1 sweep. Sweep is made with a user specified, fixed ratio or offset value. VAR1' output is calculated as :

$$\begin{aligned} \text{VAR1}' &= a \times \text{VAR1} \text{ (fixed ratio)} \\ \text{VAR1}' &= b + \text{VAR1} \text{ (fixed offset)} \end{aligned}$$

where "a" is the user-specified ratio (from ± 0.01 to ± 10) and "b" is the user-specified offset value. Ratio and offset must be such that the VAR1' source channel does not exceed its maximum output limit.

HOLD TIME : 0 to 650 seconds, 10ms resolution (max.). Accuracy is $\pm 0.5\% + 9\text{ms}$.

DELAY TIME : 0 to 6.5 seconds, 1ms resolution. Accuracy is $\pm 0.1\% + 5xN$ for GRAPHICS and SCHMOO plots and $\pm 0.1\% + 10xN$ for LIST and MATRIX displays. Where N is the number of measurement channels used in the measurement.

Output Sequence : The order in which the source channels begin output is fully programmable.

Measurement Modes : SINGLE, REPEAT, APPEND

Integration Time (at each measurement point) : SHORT, 3.6ms; MED, 20ms at 50Hz line frequency, 16.7ms at 60Hz line frequency; LONG, 16 times MED.

Table 1-1. Specifications (Sheet 5 of 8)

DISPLAY FUNCTIONS

Display : CRT. Electrostatic focus and deflection, post accelerated. Aluminized P-31 phosphor.

Screen Size : 16cm (6.25in) diagonal.
Screen Resolution : 2048 x 2048 points.

Display Characters and Symbols : Upper-case alphabetic characters, numerics, comma, (,), @, Ω, ° (deg), ", %, #, q, k, e, m, μ, n, p, +, -, *, /, √, Δ. All are entered from the front panel.

Display Modes : GRAPHICS, LIST, MATRIX, SCHMOO, and TIME DOMAIN.

GRAPHICS Display : Two-axes (X-Y) or three-axes (Y-Y₁-Y₂) plot of measured parameters and USER FUNCTION calculations.

LIST Display : Used in conjunction with VAR1 sweep. Up to six measurement parameters and USER FUNCTION results can be displayed for each step of the VAR1 source channel.

MATRIX Display : Used in conjunction with VAR1 and VAR2 sweeps. Up to six columns of sweep-dependent measurement results or USER FUNCTION results can be displayed.

SCHMOO Display : Used in conjunction with VAR1 and VAR2 sweeps. Sweep-dependent measurement results or calculation results are displayed on an X-Y-Z graph.

TIME DOMAIN Display : Measurement and calculation results are displayed on a two-axes (X-Y) or three-axes (X-Y₁-Y₂) graph as a function of time. VAR1 sweep is replaced by time.

Parameters : Initial Wait Time, 0 to 100 seconds (10ms resolution); Measurement Interval, 10ms to 10 seconds (10ms resolution); Number of Readings, 512.

Table 1-1. Specifications (Sheet 6 of 8)

ARITHMETIC AND ANALYSIS FUNCTIONS

Arithmetic Functions : Arithmetic expressions can be entered and executed directly from the front panel. Results are displayed on the CRT.

Arithmetic Operators : +, -, *, /, $\sqrt{\quad}$, EXP (Napierian constant), LOG (common log), LN (natural log), ** (exponentiation), ABS (absolute), EEX (scientific notation), and Δ (differential calculation).

Keyboard Operation : Arithmetic expressions are executed by pressing the EXECUTE key. Results are displayed on the CRT.

USER FUNCTION : Up to two USER FUNCTION can be defined as arithmetic expressions. USER FUNCTIONS are executed during measurement and the results are displayed with measurement results.

Physical Constants : Three commonly used physical constants are permanently stored in memory. The stored value of each constant has seven-digit accuracy but only the five most significant digits are displayed.

q : Electron Charge, 1.602189×10^{-19} C

k : Boltzmann's Constant, 1.380662×10^{-23} J/°K

e : Dielectric Constant of vacuum, 8.854185×10^{-12} F/m.

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

Analysis Functions :

Overlay Graph Comparison : A GRAPHIC plot can be stored and later recalled to obtain an overlay comparison of two measurements. A SCHMOO plot can also be stored, but when the RECALL key is pressed, only the stored plot is displayed. Pressing RECALL a second time redisplayes the previous plot. Only one set of data can be stored and scaling information is not included.

Auto Retrieve Function : Measurement data obtained in any display mode is automatically redisplayed whenever the display mode is changed. However, when the value of a measurement setup parameter is changed, all measurement data is cleared.

MARKER : On a GRAPHICS plot, the MARKER can be moved along a plotted curve or line. The X, Y₁, and Y₂ coordinates at the MARKER location are digitally displayed on the CRT.

INTERPOLATE : Allows positioning of the MARKER between two measurement points. The X, Y₁, and Y₂ coordinates at the MARKER location are estimated and digitally displayed on the CRT.

CURSOR : On a GRAPHICS plot, the CURSOR is two intersecting and perpendicular lines which can be positioned at any point on the graph. There are two GRAPHICS cursors : LONG and SHORT. The X, Y₁, and Y₂ coordinates at the CURSOR location are digitally displayed on the CRT.

On a SCHMOO plot the CURSOR highlights the symbol at a measurement point and only the Z-axis value is digitally displayed on the CRT.

On LIST and MATRIX displays the CURSOR is a moveable pointer (►).

Table 1-1. Specifications (Sheet 7 of 8)

AUTO SCALE : GRAPHIC plots can be automatically rescaled after measurement, providing optimum display of measurement results.

ZOOM Function (\leftrightarrow , \rightarrow , \updownarrow , \uparrow) : Used in conjunction with the CURSOR on GRAPHIC plots. Expands (\leftrightarrow , \updownarrow) or contracts (\rightarrow , \uparrow) the graph in the indicated direction and in reference to the CURSOR location.

MOVE WINDOW : Repositions the LONG or SHORT CURSOR to the exact center of the plot area and moves displayed plots in reference to the CURSOR.

LINE : Draws a straight line between two moveable cursors. X and Y axes intercepts are digitally displayed, as are the line gradient (GRAD) and gradient reciprocal (1/GRAD) values.

MASUREMENT/DISPLAY SETUP AND STORAGE FUNCTIONS

Measurement/Display Setup : Interactive fill-in-the-blank programming of channel definitions, source outputs, and measurement/display modes.

Measurement Setup Storage : The existing measurement setup can be stored in the user-area on the flexible disc and recalled later by using the SAVE and GET keys, respectively.

Measurement Data Storage : The existing measurement results can be stored in the user-area on the flexible disc and recalled later by using the SAVE and GET key, respectively.

Auto-Sequence Program : A series of different measurements can be programmed for automatic execution. The maximum number of program steps is 24, and useable commands are GET, SINGLE, SAVE D, PLOT, PRINT, PAUSE, WAIT, and PAGE.

Storage Medium : 5.25 in. single-sided, single-density, soft-sectored mini flexible disc.

User-Area : 92K bytes.

Number of User Records : 131

Record Allocation : Measurement setup (file type P), 3 records;
Measurement data (file type D), 12 records;
Auto-sequence program (file type S), 1 record.

Table 1-1. Specifications (Sheet 8 of 8)

GENERAL SPECIFICATIONS

Data Input/Output :

External CRT Analog Output : From 0 to +1 Vdc, X and Y outputs (in series with approx. 330Ω) Z output (in series with approx. 240Ω), via rear panel BNC connectors. Frequency Bandwidth, DC - 2MHz.

External Plotter/Printer Output : Measurement data and all data appearing on the CRT may be output via the HP-IB to an HP plotter/printer operated in the LISTEN ONLY Mode. Output is initiated using the PLOT or PRINT key.

HP-GL Control : The CRT of the 4145A may be program controlled in the Graphics Display Mode via an HP-IB compatible Controller.

HP-IB and Remote-Control Functions : The 4145A may be interfaced to any HP controller or other instrument having HP-IB interface capability. (HP-IB is Hewlett-Packard's implementation of IEEE-488 and ANSI-MC.1.1 standards.)

Self-Test Function : At power ON, the 4145A automatically verifies its own operational status. HP-IB and DIAGNOSTICS page allow Self-Test to be performed at any time.

Operating Temperature Range: 10°C to $+40^{\circ}\text{C}$; $\leq 70\%$ RH (40°C)
Permissible Temperature Change: $\leq 1^{\circ}\text{C}/5$ min.;
Maximum Wet-bulb temperature : 29°C

Power Requirements : 100/120/220V $\pm 10\%$; 240V -10% + 5% ;
48 - 66Hz; Max. 270VA

Dimensions : 426W x 235H x 612D (mm) (approx.)

Weight : Approx. 27kg
Approx. 33kg (including accessories)

Table 1-2. Reference Data (Sheet 1 of 3)

REFERENCE DATA

(The following information is reference data only. It is not guaranteed specifications, nor does it include Test Fixture specifications.)

Measurement Time : (Response time + ranging time + integration time)/1 point measurement

Response Time : The following calculation is applicable where current range does not change (settling and set-up time + SMU wait time).

Current Range	Settling and Set-Up Time	SMU Wait Time
100nA - 100mA	2.7ms	0.2ms
1nA - 10nA		47.5ms

Ranging Time : 4ms - 74ms (depending on range)

Measurement Time : (Ranging time must be added.)

Settling and Set-Up Time	Delay Time	SMU Wait Time	Ranging Time	Integration Time
← 2.7ms →	Setting Value	0.2ms or 47.5ms	4ms ? 74ms	3.6ms ? 320ms

Example : Minimum measurement time = 2.7ms + 0.2ms + 3.6ms = 6.5ms. In the Graphics Display Mode, write time (≥5.6ms) must be added.

	60Hz	50Hz
Long	267	320
Med	16.7	20
short	3.6	
	(ms)	(ms)

Table 1-2. Reference Data (Sheet 2 of 3)

STIMULUS/MEASUREMENT UNIT (SMU)

Offset Current when operated as a Voltmeter : $6\text{pA} + 2\text{pA} \times V_o/100$

Offset Voltage when operated as a Current Meter : $10\text{mV} + 0.4\Omega \times I_o$

Noise Characteristics : (all values typical)

Voltage Source Noise : 0.01% of range (RMS)

Current Source Noise : 0.1% of range + $3\text{pA} + 0.01\text{pA} \times C_g$ (RMS)

(C_g : Guard capacitance in pF)

Voltage Monitor : 0.02% of range (peak-to-peak)

Current Monitor : 0.3% of range + 10pA
(peak-to-peak)

Output Overshoot : (all values typical)

Voltage Source Overshoot : 5mV

Current Source Overshoot : 1% or less

Current Range Switching Transient Noise : (All values typical)

Range Increment : 0.01% of voltage range + 10mV

Range Decrement : When switching into 10nA or 1nA range, $10\text{mV} + 100/(10 + C_x)\text{mV}$ where C_x = load capacitance (pF); when switching into all other ranges, 10mV.

Guard Capacitance : $\leq 700\text{pF}$

Guard Potential Offset : 1mV (typical)

Guard Current Induced Potential Error : $100\Omega \times I_g$ (I_g = guard current)

Voltage Sources (V_s)

Output Noise : 6 mVrms (typical)

Voltage Monitors (V_m)

Noise Level : 0.3mVp-p at 2V-range (when Integration time is set to MED or LONG), 3mVp-p at 20V range.

REFERENCE DATA COMMON TO ALL UNITS

Noise Rejection : (Integration time set to MED or LONG.)

Normal Mode Rejection : $\geq 60\text{dB}$ (typical)

Common Mode Rejection : (all values typical)

Current Source/Measurement : $\leq 1\text{pA}/1\text{V}$

Table 1-2. Reference Data (Sheet 3 of 3)

ACCESSORIES FURNISHED WITH 4145A

16058A Test Fixture (includes the following subcomponents)

- 16058-60003 Personality Board
- 16058-60004 Teflon Blank Board
- 16058-60005 Socket Board (Transistor)
- 16058-60006 Socket Board (24-pin DIP)
- 16058-60007 Socket Board (18-pin DIP)
- 16058-60008 Socket Board (Diode)
- 16058-60009 Socket Board (8-pin package)
- 16058-60010 Socket Board (10-pin package)
- 16058-60011 Socket Board (12-pin package)
- 16058-61600 Connection Cable (large-to-small), 12 ea.
- 16058-61601 Connection Cable (small-to-small), 8 ea.
- 16058-61602 Miniature Clip Lead, 8 ea.
- 16058-61603 Triaxial Cable (1.5m), 4 ea.
- 16058-61604 Fixture System Cable
- 16058-60100 Accessory Case

22 pin Socket Board
16147-60001 INS/Judy
Nov 1984

28 pin Socket Board
16147-60002

- 04145-60001 Connector Plate
- 04145-61622 Triaxial Cable (3m), 4 ea.
- 04145-61630 BNC Cable (3m), 4 ea.
- 04145-61623 Shorting Connector
- 04145-61100 Software Discs (5 per box)
(including P/N 9164-0168 Head Cleaning Disc)

OPTIONS

- Option 907: Front Handle Kit (HP P/N 5061-0091)
- Option 908: Rack Flange Kit (HP P/N 5061-0079)
- Option 909: Rack and Handle Kit (HP P/N 5061-0085)
- Option 910: Extra Manual (HP P/N 04145-90000)

TRIAx TO BNC CABLE 85014-60002 @445

Table 1-3. Accessories Supplied (Sheet 1 of 5)

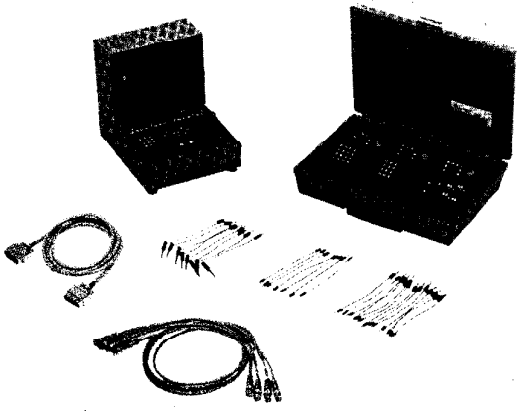
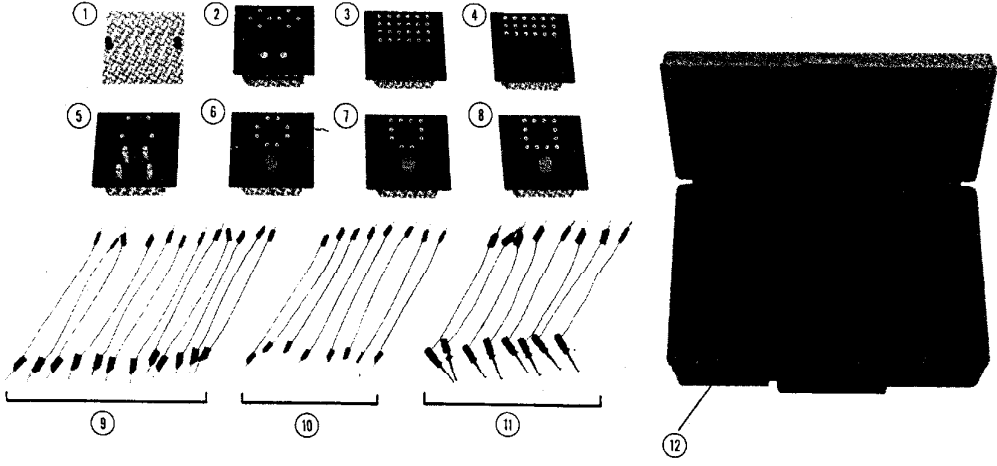
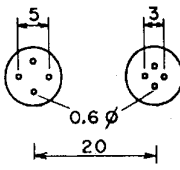
Configuration	Description	
	<p>16058A Test Fixture</p> <p>Shielded Test Fixture for measurement of discrete components. Equipped with safety lid.</p> <p>Following subcomponents are furnished with the 16058A.</p> <p>16058-60003 Personality Board 16058-61603 Triaxial Cables, 1.5m, 4 ea. 16058-61604 System Cable Socket Board/Connection Cable Set* (Contents are shown below.)</p>	
<p>* Socket Board/Connection Cable Set (included in the 16058A)</p>		
		
No.	Dimension of Socket (Unit in mm)	HP P/N and Description
①		Blank teflon board for measurement of high resistance devices.
②		Socket Board with two sockets. For measurement of four-pin devices, such as transistors.

Table 1-3. Accessories Supplied (Sheet 2 of 5)

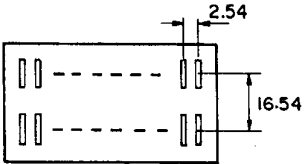
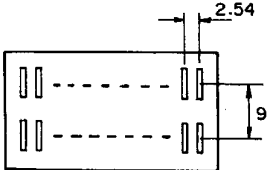
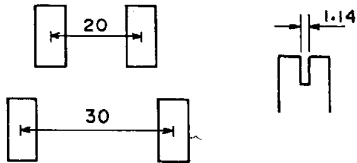
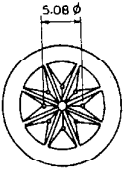
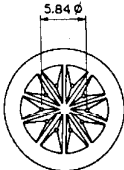
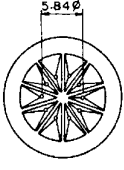
No.	Dimension of Socket (Unit in mm)	HP P/N and Description
③		<p>16058-60006 : Socket Board for 24 pin DIP ICs.</p>
④		<p>16058-60007 : Socket Board for 18 pin DIP ICs.</p>
⑤		<p>16058-60008 : Socket Board with two pairs of sockets for measurement of axial lead devices such as diodes.</p>
⑥		<p>16058-60009 : Socket Board with an 8-pin socket.</p>
⑦		<p>16058-60010 : Socket Board with a 10-pin socket.</p>
⑧		<p>16058-60011 : Socket Board with a 12-pin socket.</p>

Table 1-3. Accessories Supplied (Sheet 3 of 5)

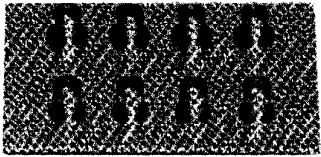
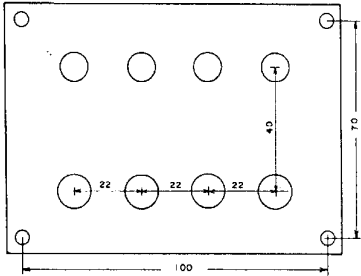
No.	Dimension of Socket (Unit in mm)	HP P/N and Description
⑨	Cable length : Approx. 115	16058-61600 : Connection Cable (large-to-Small) used for interconnecting the Personality Board to the Socket Board. Twelve cables are furnished.
⑩	Cable length : Approx. 115	16058-61601 : Connection Cable (small-to-small) used for interconnecting the Connection Switch to the Socket Board. Eight cables are furnished.
⑪	Cable length : Approx. 115	16058-61602 : Miniature Clip Lead used for direct connection to DUT. Eight leads are furnished.
⑫		16058-60100 : Carrying-case for all 16058A accessories.
Configuration		Description
		<p>Connector Plate (04145-60001) :</p> <p>Connector Plate for measurements made without the 16058A. For example, direct connection for a wafer probe. Dimensions are given below.</p> 

Table 1-3. Accessories Supplied (Sheet 4 of 5)

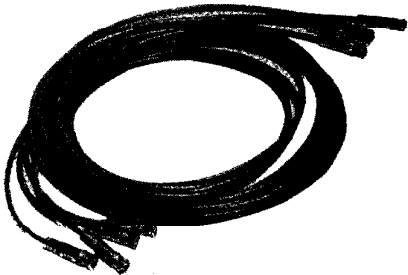
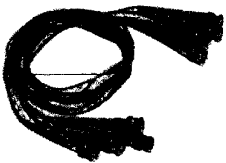

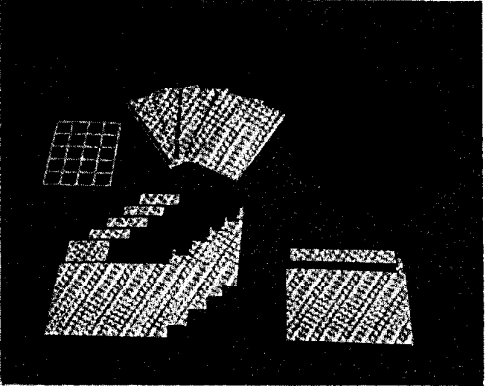
Configuration	Description
	<p>Three-meter triaxial (m) Cable (04145-61622):</p> <p>Triaxial (m) cable for connection between the 4145A's SMU terminals and the Connector Plate. Cable length is 3m. Four cables are furnished. Refer to Figure 3-35 for the usage.</p>
	<p>Three-meter BNC (m) Cable (04145-61630):</p> <p>BNC (m) cable for connection between the 4145A's Vs or Vm terminals and the Connector Plate. Cable length is 3m. Four cables are furnished. Refer to Figure 3-35 for the usage.</p>
	<p>Shorting Connector (04145-61623):</p> <p>Allows SMU output voltage to exceed $\pm 42V$ when the 16058A Test Fixture is not used. With the Shorting Connector connected to the System Cable connector on the rear panel, the instrument's fixture-lid-open detector is disabled, and the instrument assumes a fixture-lid-closed condition.</p> <p style="text-align: center;">WARNING</p> <p>A POTENTIAL SHOCK HAZARD EXISTS WHEN THE SHORTING CONNECTOR IS CONNECTED TO THE 4145A. DO NOT TOUCH THE OUTPUT TERMINAL OR INNER CONDUCTOR OF SMU DURING MEASUREMENT.</p>

Table 1-3. Accessories Supplied (Sheet 5 of 5)

Configuration	Description
	<p><i>16261A only available</i></p> <p>Software Discs (04145-61100):</p> <p>Disc set includes 5 Software Discs, Cleaning Disc (P/N: 9164-0168), labels, and write-protect tabs. If extra discs are required, order the 16261A Software Disc Set. It contains 5 software Discs.</p> <p>Note</p> <p>Software discs cannot be purchased individually.</p>