The Total Solution for Low Current Measurements
Hewlett-Packard offers Advanced Technology

Introduction
HP's 4140B pA Meter/DC Voltage Source provides a stable picoampere meter with maximum resolution of $10^{-15}$A and two programmable dc voltage sources. This, along with the programmable hold and step delay function, enables you to make synchronized measurements on a device or material.

Reliable, efficient pA current measurements needed in R&D labs, production, and QA can now be made with just one instrument, the 4140B. Measurements on electronic components, insulation materials, and especially semiconductor devices are fast, convenient and accomplished with ease.

Stable Current Measurements
The 4140B makes very stable, high resolution current measurements to $\pm 1.000 \times 10^{-15}$A (1 x $10^{-15}$A maximum resolution) that were previously very difficult to make. The Zero offset cancels up to $100 \times 10^{-15}$A leakage current of test leads or fixtures in the Current (I, I-V) modes, and up to 100 pF stray capacitance in the C-V mode. The zero capability, along with low noise test leads (16053A) and electrostatic/light shielded test fixture (16055A), lets you measure low pA currents with confidence.

Synchronized pA Measurements
Two internal programmable dc voltage sources provide staircase, ramp, and stable dc level outputs. The start, stop, and step voltages can be set from $-100$ V to $+100$ V with 10 mV resolution and the hold/step delay times can be set depending on the characteristics of the device or material being tested. These features, together with the pA measurement section, provide an automatically synchronized measurement.

HP-IB* Operation
Systems integration is easily accomplished with the HP-IB interface, allowing remote programming of all front panel controls. Measurement data can be taken into the controller, processed, and then displayed in a variety of formats. This is especially effective in the manufacturing process where rapid feedback is essential.

Selectable Function/Integration Times/Line Filter
The synchronized measurement capability allows current-voltage (I-V) and capacitance-voltage (C-V) measurements in addition to the normal pA current (I) measurements. Ranging is automatic or manual (up/down).

A significant feature is the selectable integration time (short, medium, or long). This allows a trade-off of speed vs. accuracy in current measurements.

The filter function enables accurate 1 pA measurements even when noise is 1000 times greater than the DC current being measured.

Self Test/Analog Output
The automatic self test functionally verifies proper operation of the digital and analog circuitry.

The Analog Output supplies X-Y recorder outputs necessary for plotting I-V and C-V data. This includes measurement data, pen control, and upper and lower limit voltages.

*HP-IB (Hewlett-Packard Interface Bus) is Hewlett-Packard's implementation of IEEE 488-1975, ANSI Standard #MC1.1.
in Picoampere Current Measurements

**Source Current Limit**
To protect the material or device under test, the 4140B has a programmable current limit capability on both internal dc sources. Current limits of $10^{-4}$, $10^{-3}$, $10^{-2}$A are selected either manually or under HP-IB control.

**Voltage Sweep Functions**
Flexible voltage sweep control capability allows operator to optimize any current voltage measurement. Controls are AUTO/START, MAN (PAUSE) for changing step voltage/sweep direction during a measurement, STEP (1.1), and ABORT.

**Quasi-Static C-V Measurements**
A capacitance measurement utilizing a ramp voltage (quasi-static or dc C-V measurement) is employed as one method of evaluating semiconductors. In the 4140B, capacitance is calculated from the measured current $I$ that is synchronized with a ramp voltage $dV/dt$ ($C = I/dV/dt$). Capacitance change can also be displayed as a percent of $C_{OX}$ (the capacitance of the oxide layer).

**Parameter Selection/Data Entry**
Parameter selection and data entry is accomplished either manually from the front panel or via the HP-IB. Select the parameter (START V, STOP V, HOLD TIME...), enter the appropriate data (voltage, time, or ramp rate) and press the ENTER key. Each data entry is stored in memory. The measurement is then made automatically by pushing the START key.

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**Key Features**

| PARAMETER MEASURED | 1, I-V & C-V
|--------------------|---|
|                    | Can also be used as a programmable source/function generator (DC, ramp & staircase).

<table>
<thead>
<tr>
<th>DISPLAY</th>
<th>3½ digit</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASUREMENT RANGE</td>
<td>$0.001 \times 10^{-12}$A - $1.999 \times 10^{-2}$A</td>
</tr>
<tr>
<td>BASIC ACCURACY</td>
<td>0.5%</td>
</tr>
<tr>
<td>MEASUREMENT TIME</td>
<td>Approx. 4ms - 2.56s</td>
</tr>
<tr>
<td>CALCULATED CAPACITANCE RANGE</td>
<td>0.1pF - 1999 pF</td>
</tr>
<tr>
<td>OUTPUT MODE</td>
<td>$V_A$:</td>
</tr>
<tr>
<td>OUTPUT RANGE</td>
<td>± 100V in 10mV step</td>
</tr>
<tr>
<td></td>
<td>Ramp Rate: $0.001$ V/s - $1.000$ V/s</td>
</tr>
<tr>
<td>SWEEP MODE</td>
<td>AUTO/Manual (Pause)</td>
</tr>
</tbody>
</table>

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The 16055A is specially designed for low current measurements and provides both light and electrostatic shielding. The 16055A is a standard 4140B accessory.
...In Evaluating Electronic Components

When automation is required, the 4140B can play a vital role in the evaluation of many kinds of electronic components on the production line. It offers picoampere current measurements that can be synchronized with internal source voltages (±10 mV to ±100 V) for fast, accurate, and efficient component inspection.

Typical Applications:
- Go/No go inspection in leakage current/insulation resistance measurements
- Temperature/humidity characteristics of leakage current

Types of Devices:
- Capacitors (ceramic, film, paper, misc,...)
- Mechanical devices (switches, relays, connectors,...)
- Printed circuit boards
- Cables
- Transformers

...In Semiconductor Process Evaluation

An automatic evaluation system for the semiconductor process is now possible with the 4140B. Static characteristics of diodes or FET's can be measured and plotted with 0.001 pA resolution. The threshold level can be obtained through data manipulation using the HP-IB interface. This is made possible by the high speed data output (at 4 ms maximum rate) to the HP-IB Bus.

By adding the 4275A Multi-Frequency LCR Meter, a complete evaluation of the semiconductor process can be made to 10 MHz. This includes high frequency C-V measurements, doping profiles and the analysis of minority carrier lifetimes.
Improved Reliability and Efficiency...

...In Evaluating Semiconductor Devices

The 4140B pA Meter/DC Voltage Source offers outstanding flexibility in the measurement of semiconductor devices. The capability of making current (I), current-voltage (I-V) and capacitance-voltage (C-V) measurements using the internal dc sources is standard in the 4140B. These measurements are made possible by internal ramp voltages, current ranges from ±1.000 pA to ±10 mA full scale with 0.5% basic accuracy and an auto/manual voltage sweep mode.

These features enable the user to obtain faster, more accurate results in semiconductor device testing and to increase his yield by prompt, flexible process evaluation.

Types of Devices:
- Optical devices (photo transistor, photo isolator...)
- IC's (logic, memory, linear...)
- Diodes, FET's
- MIS construction, P/N junction

Typical Applications:
- Quasi-static C-V characteristics
- Threshold voltage and static characteristics of FET's
- DC parameters of IC's
- Light/dark current of optical devices
- Electron beam secondary electron measurement

...In the Evaluation of Insulation Materials

Resistance values of approximately 0.5 ohms to $10^{17}$ ohms can be calculated from the applied voltage and measured current values. The hold and step delay timer functions allow the user to easily determine the one minute resistance value of a material. The analysis of polarization/absorption phenomena of insulating materials can also be accomplished with the 4140B.

These measurements can make a major contribution to the reliability evaluation of many kinds of insulation materials.

Typical Applications:
- Change of insulation resistance vs. temperature and humidity
- Analysis of Absorption/Polarization phenomena

Types of Materials:
- Film (plastics, mylar, paper...)
- Liquid (insulation, varnish...)
- Solids (glass, ceramic, rubber...)
- Conductive rubber
Specifications

4140B Characteristics and Specifications
Measurement Functions: I, I-V and C-V

I (Current): Operates as independent picoammeter and programmable voltage sources

I-V (Current-Voltage): I-V characteristic measurements using the programmable staircase or linear ramp voltage source

C-V (Capacitance-Voltage): Quasi-static C-V characteristic measurement using the linear ramp source

Voltage Sources: Two separate sources (VA and VB)
VA: * 100 volt programmable source/function generator
VB: & 100 volt programmable DC voltage source

Measurement Function/Source Selection:
Voltage Sweep: Auto or Manual (Pause)

Current Measurements

Displays: Current, 3½ digits with 2 Digit Annunciator
Voltage, 3½ digits

Measurement Range: +1.000 x 10⁻¹²A to 1.000 x 10⁻²A full scale in 11 ranges

Overrange Capability: 100% on all ranges

Range Selection: Auto and Manual

Measurement Accuracy/Integration Time:

<table>
<thead>
<tr>
<th>Range</th>
<th>Accuracy* (± (% of rdg + counts))</th>
<th>Integration Time** (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10⁻¹² - 10⁻¹⁰</td>
<td>± 0.5 %</td>
<td>Short: 20, Medium: 80, Long: 320</td>
</tr>
<tr>
<td>10⁻¹⁰ - 10⁻⁸</td>
<td>± 2 %</td>
<td>Short: 80, Medium: 320, Long: 1.28</td>
</tr>
<tr>
<td>10⁻⁸ - 10⁻⁶</td>
<td>± 5 %</td>
<td>Short: 1.64, Medium: 640, Long: 2.56</td>
</tr>
</tbody>
</table>

*Accuracy for long integration time with line filter on 23°C ± 5°C, humidity < 70%. For short and medium integration times, see Reference Data section.

**Integration times specified at 50 Hz. For 60 Hz operation, multiply time by 5/6.

Voltage Burden: ≦ 10μV at full scale

Internal emf: ≦ 100 μV

Maximum Input (Peak Value):
Between Hi and Lo, ±2V on 10⁻² - 10⁻³A ranges
±30V on 10⁻⁴ - 10⁻⁵A ranges
±120V on 10⁻⁶ - 10⁻¹²A ranges
Between Lo and Guard, ±200V

Zero Offset: Cancels leakage current of test leads or test fixtures

Offset Range: 0 - ± 100 x 10⁻¹²A

Trigger: INT, EXT and HOLD/MAN

Input Terminal: Triaxial

Capacitance-Voltage (C-V) Measurement

Note: Capacitance is a calculated value derived from the following equation: C/F = measured current value (A)/ramp rate (V/s)

Measurement Ranges: 0.0pF - 199.9pF and 200.0pF - 1999pF F.S. in two ranges

Ranging: Auto

% C: Capacitance change of device under test is displayed as a percent of the set value of the oxide capacitance (Cox = 100%)

% C Range: 0.0% - 199.9%

Cox Setting Ranges (2 ranges): 0.1pF - 199.9pF and 200pF - 1999pF

Capacitance Calculation Accuracy: Accuracy is dependent on accuracy of both the current measurement and ramp voltage. (See chart in reference data.)

Zero Offset: Cancels stray capacitances of test fixtures and test leads.

Offset Range: 0 - 100pF

High Speed I Data Output: Available with HP-IB interface.
Outputs current measurement data at 4ms intervals (maximum rate). Refer to reference data for typical accuracies.

DC Voltage Sources

Output Modes, VA: ∫ / ∫ / ∫ / ∫ / ∫ / ∫ / ∫ / ∫
VB: ___

Voltage Ranges (VA and VB): 0 - ± 10.000V and 0 ± 100.0V in two ranges, auto range only.

Maximum Current: 10 mA, both sources.

Voltage Sweep: Auto and Manual (Pause), up/down step in manual (Pause) mode. Sweep abort is standard

Operating Parameter Setting Ranges:
Start Voltage and Stop Voltage, 0 - ± 10.000V, 0.01V steps; 0 - ± 100.0V, 0.1V steps
Step Voltage, 0 - ± 10.000V, 0.01V steps; 0 - ± 100.0V, 0.1V steps
Hold Time, 0 - 1999 seconds in 1.0s increments
Step Delay Time, 0 - 10.00 seconds in 0.1s increments
Ramp Rate (V/dt), 0.001V/s - 1.000V/s in 0.001V/s increments

Accuracy (at 23°C ± 5°C):

Output Voltage, ± 10V, ± (0.07% + 11mV) ± 100V, ± (0.09% + 110mV)

Ramp Rate*,
± (0.2% + 10 μV/s) - 0.00001 x Start Voltage (V) ;
(0.2% + 80 μV/s) - 0.0001 x Start Voltage (V)
if absolute value of start or stop voltage is > 10V.

*Specified only when:
1. Temperature change is < 3.6°C/hour
2. Time after start of ramp is ≥ 2 seconds

Ramp Linearity (%):
± (0.1% + 0.0003 V/s - 0.0003 V/s) - 0.001 x Start Voltage (V) ;
Ramp Rate (V/s) x (Hold Time + 2s)
if absolute value of start or stop voltage is > 10V

Typical Values:
± 0.5%, ± 10V
< 5% if absolute value of start or stop voltage is > 10V

Start/Stop Voltage (ramp only): ± 20mV, ± (200mV if absolute value of start or stop voltage is > 10V)

Display of Output Voltage (ramp only): ± (0.05% of rdg. + 16mV), ± (0.09% of rdg. + 160mV) if absolute value of start or stop voltage is < 10V

Step Voltage/Hold Time: Accuracy is dependent on accuracy of power line frequency (50 Hz or 60 Hz)

Current Limit: 100μA, 1mA and 10mA, ± 10% (VA and VB)

Output Terminals: BNC; L-GND
Reference Data

Current Measurement

<table>
<thead>
<tr>
<th>Range</th>
<th>Integration Time</th>
<th>Current Measurement Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^{-2} - 10^{-9}</td>
<td>0.5 + 4</td>
<td>0.5 + 3</td>
</tr>
<tr>
<td>10^{-10}</td>
<td>2 + 4</td>
<td>2 + 3</td>
</tr>
<tr>
<td>10^{-11}</td>
<td>5 + 8</td>
<td>5 + 4</td>
</tr>
<tr>
<td>10^{-12}</td>
<td>5 + 13</td>
<td>5 + 10</td>
</tr>
</tbody>
</table>

Current Measuring Times:
- 20 ms to 3.76 sec when ranging up. (3.76 sec is full ranging time from 10^{-12} amp range to 10^{-10} amp range.)
- 340 ms to 7.76 sec when ranging down. (7.76 sec is full ranging time from 10^{-12} amp range to 10^{-10} amp range.)

Warmup Time: > 1 hour

Typical Response Times, 0.90% of Final Value:

<table>
<thead>
<tr>
<th>Measurement Range (A)</th>
<th>Response Times</th>
</tr>
</thead>
<tbody>
<tr>
<td>10^{-2} to 10^{-6}</td>
<td>≤ 1 ms</td>
</tr>
<tr>
<td>10^{-6} to 10^{-7}</td>
<td>≤ 3 ms</td>
</tr>
<tr>
<td>10^{-7} to 10^{-9}</td>
<td>≤ 15 ms</td>
</tr>
<tr>
<td>10^{-9}</td>
<td>≤ 15 ms</td>
</tr>
</tbody>
</table>

Capacitance Calculation Accuracy (% rdg. + counts):

<table>
<thead>
<tr>
<th>Voltage Range (V)</th>
<th>Capacitance Range (pF)</th>
<th>Ramp Rate</th>
<th>Voltage Range (V)</th>
<th>Capacitance Range (pF)</th>
<th>Ramp Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 10</td>
<td>0.001 - 0.01</td>
<td>± (0.5 + 6)</td>
<td>± (0.5 + 10)</td>
<td>± (2 + 10)</td>
<td>± (5 + 100)</td>
</tr>
<tr>
<td>± 100</td>
<td>± (5 + 0.08)</td>
<td>± (0.3 + 0.2)</td>
<td>± (2 + 0.2)</td>
<td>± (0.7 + 0.2)</td>
<td>± (0.8 + 0.2)</td>
</tr>
</tbody>
</table>

Analog Output (I, C and Va)

Output Voltages:

<table>
<thead>
<tr>
<th>Output</th>
<th>Data Range</th>
<th>Output Voltage</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Va</td>
<td>0 ± 10V</td>
<td>± 10.1 ± 100V</td>
<td>1 mV/count</td>
</tr>
<tr>
<td></td>
<td>± 1.000V</td>
<td>± 10.1 ± 10.00V</td>
<td>10 mV/count</td>
</tr>
<tr>
<td>I</td>
<td>± 5.000V</td>
<td>± 5.000V</td>
<td>5 mV/count</td>
</tr>
<tr>
<td>C</td>
<td>100 pF</td>
<td>0.5V</td>
<td>5 mV/count</td>
</tr>
<tr>
<td></td>
<td>1000 pF</td>
<td>5V</td>
<td>5 mV/count</td>
</tr>
<tr>
<td></td>
<td>100% (I/D)</td>
<td>5V</td>
<td>5 mV/count</td>
</tr>
</tbody>
</table>

Accuracy: ± (0.5% + 20 mV)

Low Pass Filter: 3 position: OFF, 0.22s ± 20% and 1s ± 20% applied to both Va and I/C data outputs

Pen Lift Output: TTL Low Level (≤ 0.8V) during sweep period in I-V and C-V functions

Recorder Output Scaling: Pushbutton scaling of lower left and upper right limits of X-Y recorder

DC Voltage Source

Output Resistance: ≤ 1Ω
Output Impedance: ≤ 1Ω at 10 Hz, ≤ 100Ω at 100 Hz

Programming Speed: For (1V/ms slew rate): Approx. 2.5 ms

Timing: Approx. 30 ms

Note: Leakage current through resistance of DUT and test leads causes additional error.

I-V and/or C-V Trigger Cycle (minimum values):
- 25ms (Va Mode: V, A)
- 50ms (Va Mode: V, C)

Trigger (Minimum Triggering Interval):

Trigger | Function | High Speed I Data Output |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>INT</td>
<td>Approx. 200 ms</td>
<td>Approx. 10 ms*</td>
</tr>
<tr>
<td>EXT***</td>
<td>&gt; Integration Time</td>
<td>&gt; 4 ms</td>
</tr>
<tr>
<td>MAN****</td>
<td>&gt; 3 ms</td>
<td>-</td>
</tr>
</tbody>
</table>

- 50 Hz line frequency. For 60 Hz operation, multiply by 5/6.
- *External trigger from "1" state to "0" state > 1 μs duration.
- *** Triggered by front panel Ext/Man key.
- **** Available only with HP-IB Interface

1 Allowable max source capacitance ≤ 2000 pf for current measurements.
HP-IB Interface

HP-IB Interface Functions:
SH1: Source Handshake Capability
AH1: Acceptor Handshake Capability
T5: Talker Capabilities of Basic Talker, Serial Poll and Unaddress if MLA
L4: Listener Capabilities of Basic Listener and Unaddress
SR1: Service Request Capability
RL1: Remote/Local Capability
DC1: Device Clear Capability
DT1: Device Trigger Capability

Remote Controlled Functions: Measurement function, current range, integration time, 1 data output trigger, voltage sweep controls, current limit, VA and Va voltages, zero (offset), self test and parameter settings (voltage, sweep, hold, delay times)

Data Output: Measured Data (I, C and VA)
Voltage Settings (VA and VB)
Parameter Settings
Set Value of Cox
Front Panel Key Status

IEEE 488-1975 ANSI STD MC1.1

General Information

Operating Temperature: 0°C to 40°C
Relative Humidity: ≤ 70% at 40°C
Power: 100, 120, 220V ± 10%, 240V ± 5% - 10%; 48-66 Hz, 135VA maximum with any option
Dimensions: 426 mmW x 177 mmH x 498 mmD (16.5" x 7" x 19.6")
Weight: 14.4 kg (31.7 lbs.)
Accessory Furnished: 16053A Test Leads and 16055A Test Fixture

16053A Test Leads: Consists of one tri-axial cable, two each BNC-BNC cables and one connection plate with mating female panel-mount connectors (P/N 16053-61001). Cables are one meter in length. The 16053A is useful for connecting to probe or user designed test fixtures.

16055A Test Fixture: For general device measurements. Provides electrostatic and light shielding for stable pA current measurements. Consists of test fixture, two connection plates (one for clip leads and one for T-05 10 pin sockets) to allow easy connection to devices under test. Also furnished is a kit containing one each 8, 10, and 12 pin socket, 10 each clip leads, and 10 each connection leads for TO-5 sockets.

Accessories Available

16054A Connection Selector: Provides a simple method to select appropriate connection of low lead for the pA meter section. Use in conjunction with the 16053A. Cannot be used with 16055A Test Fixture.

16056A Current Divider (10:1): For use only on the 10 mA range to extend the measurement capability to 100 mA.

Available Accessories/Recommended Parts

<table>
<thead>
<tr>
<th>Description</th>
<th>HP Part/Model #</th>
</tr>
</thead>
<tbody>
<tr>
<td>HP-IB Cable 0.5m</td>
<td>10631D</td>
</tr>
<tr>
<td>1.0m</td>
<td>10631A</td>
</tr>
<tr>
<td>2.0m</td>
<td>10631B</td>
</tr>
<tr>
<td>3.0m</td>
<td>10631C</td>
</tr>
<tr>
<td>Triaxial Connectors</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>1250-0687</td>
</tr>
<tr>
<td>Male</td>
<td>1250-1413</td>
</tr>
<tr>
<td>16055A Accessories</td>
<td></td>
</tr>
<tr>
<td>Connection plate for clip leads</td>
<td>16055-65001</td>
</tr>
<tr>
<td>Connection plate with TO-5 socket (10 pin)</td>
<td>16055-65002</td>
</tr>
<tr>
<td>Clip leads (5 each)</td>
<td>16055-65003</td>
</tr>
<tr>
<td>Connection leads for TO-5 socket (5 each)</td>
<td>16055-65004</td>
</tr>
<tr>
<td>TO-5 socket (8 pins)</td>
<td>1200-0238</td>
</tr>
<tr>
<td>TO-5 socket (10 pins)</td>
<td>1200-0239</td>
</tr>
<tr>
<td>TO-5 socket (12 pins)</td>
<td>1200-0240</td>
</tr>
<tr>
<td>Triaxial cable (1m)</td>
<td>16053-61002</td>
</tr>
<tr>
<td>BNC-BNC cable (1m)</td>
<td>16053-61003</td>
</tr>
<tr>
<td>Connection plate for 16053A</td>
<td>16053-61001</td>
</tr>
</tbody>
</table>

Ordering Information

4140B pA Meter/DC Voltage Source

Options
Option 907 Front Handle Kit (P/N 5061-0090)
Option 908 Rack Flange Kit (P/N 5061-0078)
Option 090 Rack and Handle Kit (P/N 5061-0084)
Option 910 Extra Manual

Accessories
16054A Connection Selector
16056A Current Divider (10:1)