**HP 34401A Multimeter**
- 6 1/2 digit, high performance digital multimeter
- AC/DC voltage measurements
- AC/DC current measurements
- 2 and 4 wire resistance measurements
- Frequency and Period measurements
- Math functions

**Safety Tips**
Protect Yourself:
Avoid contact with Voltage or Current Source.

1) Use shrouded test leads and alligator clips.
2) Connect leads to multimeter first.
3) Do all normal connect/disconnect at source.
4) Familiarize yourself with the manual.

**Protect Instrument**

1) Inductive Devices (e.g. transformers, chokes/inductors) induce very high transient voltages.
2) Measuring resistance: Avoid contacting probes with live circuits when in resistance modes.
3) Measuring Current: Do not connect probes across voltage source.

**Starting Multimeter**

- To perform a complete self-test, hold down the **shift** key for more than five seconds as you turn on the multimeter.
- The display will indicate whether test passed. Error messages will be displayed if a failure occurs.

000.002 mVDC
Measuring ACV

**Coupling Capacitor** blocks dc; only lets ac signal through

**AC amplifier/attenuator**

**ACV Signal**

2 Vp-p AC

1 Vdc

**707.106 mVAC**

"Terminals" switch in "FRONT"

* Press **ACV**

* Note measurement indicates only the ac portion of signal

To A/D

AC to DC Converter

DC proportional to RMS value

Measuring DCV

**Integrating A/D** eliminates AC

**Protection circuit**

Input divider puts signal within amplifier's range

**1.000000 VDC**

"Terminals" switch in "FRONT"

* Press **DCV**

* Note measurement indicates only the dc portion of signal

**AC to DC Converter**

DCV Signal

2 Vp-p AC

1 Vdc

Measuring CURRENT

**Input HI terminal is NOT the same as for voltage measurement.**

**1.000000 ADC**

* SHIFT **DCV** = Measure DCI

* SHIFT **ACV** = Measure ACI

* Never hook current leads directly across a voltage source.

Measuring Resistance

**Two-Wire Technique**

**To DC Input Amplifier**

**Ohms Current Source**

**Iref**

**Protection circuit**

**Rx = 1 k**

**Iref**

* "Terminals" switch in "FRONT"

* Press 2W

* Since voltage is sensed at front terminals, measurement includes all lead resistance

* To eliminate the lead resistance:

  * Short leads together

  * Press **Null**

  * Original value will now be subtracted from each reading
Measuring Resistance
Four-Wire Technique

- Turn off “Null”
- "Terminals" switch in "FRONT"
- Press 4W
- Voltage is now sensed directly at the resistor, so lead resistance is not a factor
- Because input impedance of DC Input Amplifier is so high, no current flows through sense leads, hence no lead resistance error

4-Wire Resistor Measurement

\[ \Delta V = I_{test} \times R \]

\[ R = \frac{\Delta V}{I_{test}} \]

Continuity Test & Diode Check

- Open or Closed Circuit.
- Forward Bias

<table>
<thead>
<tr>
<th>Cont</th>
<th>= Continuity test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>= Diode check</td>
</tr>
</tbody>
</table>

Measuring Frequency & Period

33.000,0 kHz

<table>
<thead>
<tr>
<th>Freq</th>
<th>= Measure Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift</td>
<td>Period = Measure Period</td>
</tr>
</tbody>
</table>

33 kHz
**Frequency and Period**

\[ \text{Frequency} = \frac{1}{\text{Period}} \]

**Ratio Measurements**

DCV : DCV

\[ \text{Ratio} = \frac{\text{dc signal voltage}}{\text{dc reference voltage}} \]

*To enable ratio measurements, use the MEAS menu.*

**Range and Resolution**

<table>
<thead>
<tr>
<th>Range</th>
<th>100 mV</th>
<th>1 V</th>
<th>10 V</th>
<th>100 V</th>
<th>1000 V (750 VAC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Resolution</td>
<td>100 nV</td>
<td>1 μV</td>
<td>10 μV</td>
<td>100 μV</td>
<td>1 mV (750 μVAC)</td>
</tr>
</tbody>
</table>

**Resolution Choices & Integration Time**

<table>
<thead>
<tr>
<th>Integration Time**</th>
<th>Resolution Choices</th>
</tr>
</thead>
<tbody>
<tr>
<td>.02 PLC</td>
<td>Fast 4 Digit</td>
</tr>
<tr>
<td>.2 PLC</td>
<td>Fast 5 Digit</td>
</tr>
<tr>
<td>1 PLC</td>
<td>* Slow 4 Digit</td>
</tr>
<tr>
<td>10 PLC</td>
<td>* Slow 5 Digit</td>
</tr>
<tr>
<td>100 PLC</td>
<td>* Fast 6 Digit</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Fastest, Least Accurate
* Slowest, Most Accurate

* Equivalent to Pressing “Digits” key on front panel.
*In Power Line Cycles (PLC).

Integration times of .02 and .2 do not provide power-line noise rejection characteristics.
RMS: Root-Mean-Square

* RMS is a measure of a signal's average power. Instantaneous power delivered to a resistor is: $P = \frac{[v(t)]^2}{R}$. To get average power, integrate and divide by the period:

$$P_{avg} = \frac{1}{T} \int_{t_0}^{t_0+T} \frac{[v(t)]^2}{R} \, dt = \frac{(V_{rms})^2}{R}$$

Solving for $V_{rms}$:

$$V_{rms} = \sqrt{\frac{1}{T} \int_{t_0}^{t_0+T} [v(t)]^2 \, dt}$$

* An AC voltage with a given RMS value has the same heating (power) effect as a DC voltage with that same value.

* All the following voltage waveforms have the same RMS value, and should indicate 1.000 VAC on an rms meter:

<table>
<thead>
<tr>
<th>Waveform</th>
<th>Vpeak</th>
<th>Vrms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sine</td>
<td>1.414</td>
<td>1</td>
</tr>
<tr>
<td>Triangle</td>
<td>1.733</td>
<td>1</td>
</tr>
<tr>
<td>Square</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>DC</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

+ All = 1 WATT

AC-Coupling vs. DC-Coupling

AC-Coupling-Advantage

* Removes DC portion of signal

AC-Coupling-Disadvantage

* Low frequency waveforms can be cut-off

Voltage measurements

**Peak to Peak**

$$V_{rms} = V_p \times 0.707 \text{ (Sine wave)}$$
The DIGITAL MULTIMETER
Hints for Accurate Measurements:

- Measure as near full scale as possible
- Use a Ratio measurement whenever possible.
- Before measuring, short the test leads together to check for offsets. (Exception: RMS AC measurements)

Advanced Functions & Measurement Principles

Menu at a Glance

Menu is organized in a top-down tree structure with 3 levels

To turn on menu   Shift    On/Off
To move left or right
<    >
To move up or down
V    A
To enter command

Math Functions

To make null (relative) measurement

To store min/max readings

To make dB measurements    Shift    dB

To make dBm measurements    Shift    dBm

Limit testing   (Access through Menu)
**Triggering**

Auto-trigger: Continuously takes readings at fastest rate possible for present configuration. Default.

Single trigger: Manual trigger by pressing **Single**. One reading or specified number of readings (Sample count).

Number of samples: Number of readings meter takes with each trigger: 1 to 50,000. Default is 1.

Reading hold: Select by pressing **Shift** Auto/Hold. Captures and holds a stable reading on the display.

---

**High Z Termination**

\[
Vs = \left( 1 + \frac{Ro}{Zin} \right) Vm
\]

\[
Vs = 2 \times Vm
\]

\[
Vm = \frac{1}{2} \times Vs
\]

*Vm will not equal Vs, if Zin = Ro, but the ratio between them is 2:1.

---

**50 Ω Termination**

\[
Vs = \left( 1 + \frac{50\Omega}{50\Omega} \right) Vm
\]

\[
Vs = 2 \times Vm
\]

\[
Vm = \frac{1}{2} \times Vs
\]

---

**Loading Errors (DC volts)**

\[
Vs = \text{ideal DUT voltage}
\]

\[
Rs = \text{DUT source resistance}
\]

\[
Ri = \text{multimeter input resistance} \quad (10 \, \text{MΩ} \text{ or } > 10 \, \text{GΩ})
\]

\[
\text{Error(\%) } = \frac{100 \times Rs}{Rs + Ri}
\]
**Leakage Current Errors**

$I_{b} = \text{multimeter bias current}$  
$R_{s} = \text{DUT source resistance}$  
$C_{i} = \text{multimeter input capacitance}$  
Error($v$) $\approx I_{b} \times R_{s}$

**Common Mode Rejection (CMR)**

$V_{f} = \text{float voltage}$  
$R_{s} = \text{DUT source resistance}$  
$R_{i} = \text{multimeter isolation resistance}$  
Error($v$) $= \frac{V_{f} \times R_{s}}{R_{s} + R_{i}}$