The Lakeland Amateur Radio Club

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Presents

A Guide to Digital Multimeters

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What To Look For When Selecting A Multimeter

There are 4 categories to consider when selecting a multimeter.

1. Purpose vs. Cost
2. Functionality & Features
3. Usability
4. Physical Construction & Safety

Cost vs. Purpose

- What will you do with your multimeter?
  - General Household or Automotive Measurements?
    - Safety is biggest concern
  - Electronics Design Work?
    - Stay away from cheap multimeters
      - Insufficient Safety
      - Insufficient Measurement Confidence
      - Insufficient Build Quality
- You Get What You Pay For

What You Get For Your Money

- $100 & Up
  - Decent Quality
  - Designed to a reasonable Safety Standard
  - Will probably have features you require
- Under $50
  - Little Measurement Confidence
  - Don't incorporate safety
  - Manual Ranging - Technologically Outdated and Annoying
  - Low Battery Life, Input Jacks wear out
  - Probably NOT CAT II regardless of claims!
- $50 to $100
  - Reasonable Measure Confidence
  - May have some safety features
  - Auto Ranging
  - Will usually have decent quality probes

3 Basic Multimeter Functions

- Voltage Measurement
  - DC & AC Range
  - mV Range to about 1000v
  - No mV range is probably only useful for an Electrician
- Current Measurement
  - DC & AC Range
  - Separate current inputs to avoid damage to circuit or meter.
  - Cheap meters skimp on current ranges
  - 10A or 20A needed for high power measurement - HRC Fused!
  - uA, mA commonly needed for electronics - HRC Fused!
- Resistance Measurement
  - 200Ω to 20MΩ - You will commonly measure low & high Ω
  - Input Impedance - Minimum 10MΩ or meter will load circuit under test.

Other Desirable Features

Diode Test Function:	Is the beep notification quick to respond and is it latched (for "drag" tests)? Can it test LEDs?
Transistor HFE:	Gimmick used on cheap meters. Ignore this!
Relative Mode:	Can the meter display values relative to a previously measured value (difference readings)?
Temperature:	Is a temperature probe included? Can temperature be read with 0.1°C resolution?
Capacitance:	pF/nF to 1000uF. Not very accurate. Best to use LCR meter.
Frequency:	Marginally useful. What is max reading?
Min/Max:	Remembers Min/Max readings?
Automatic Hold:	Make measurements without looking at meter.
Bar Graph Display:	Does the meter have a Bar Graph display?
Input Rating:	CAT I / II / III / IV Rated Inputs?
RMS ACV Measurement:	Does the meter read True RMS on the ACV range?

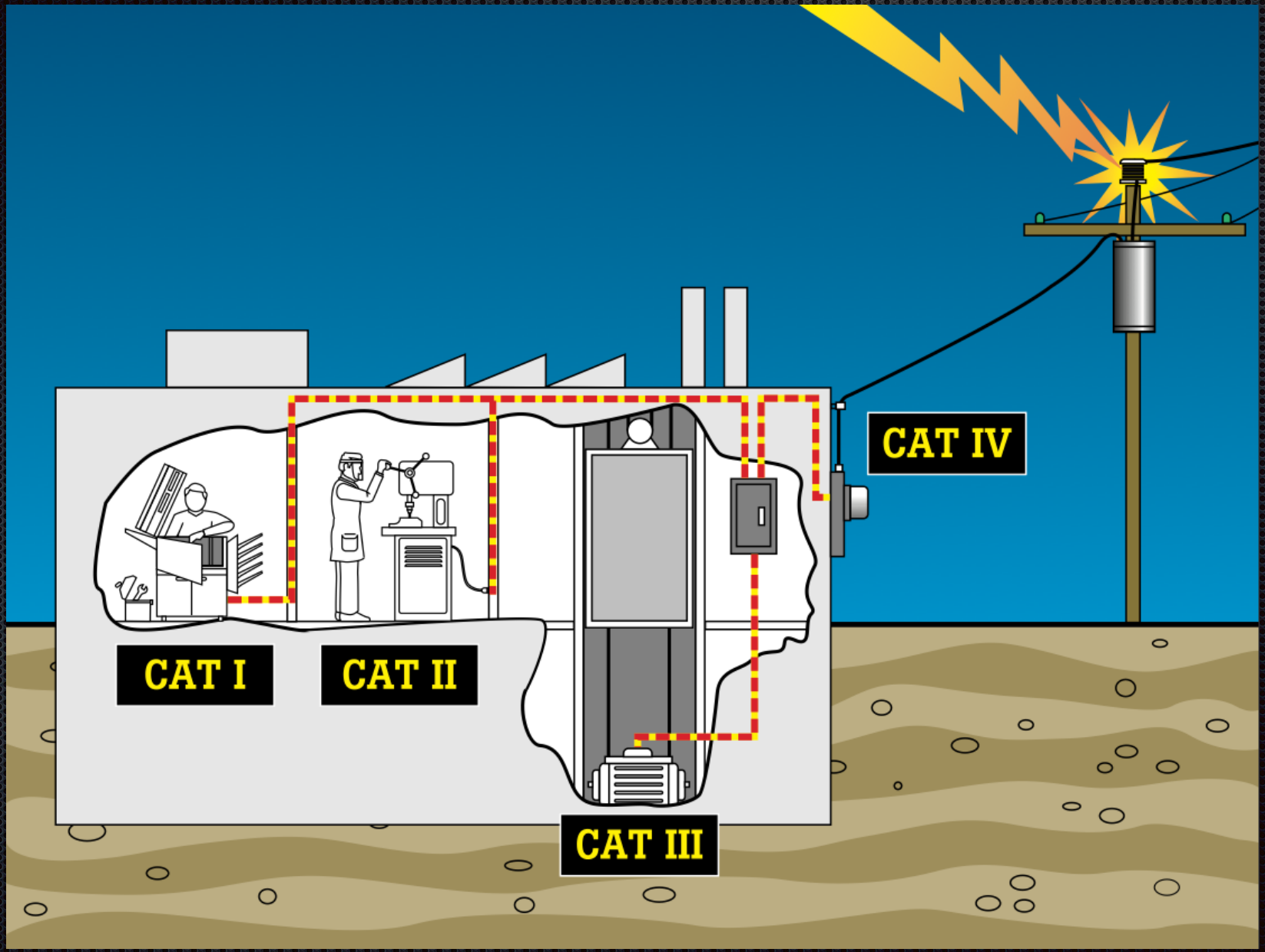
Usability

Resolution:	Does the meter have enough displayable digits for your needs? (Count rating)
Accuracy:	Does the meter's accuracy meet or exceed your requirements? 0.5% is typically good enough. Accuracy should be at least: 10 ÷ Counts × 100 = %
Display Digit Size:	Is the display easy to read from a distance (eg. Across the table)
Auto-Range Speed:	How long does the meter take to switch ranges? <1 second is considered good.
Overshoot:	Does the value displayed overshoot the actual value being read before settling to the correct value?
Display Backlight:	Does the display have a backlight to read in low-light conditions, and is the backlight evenly spread out over the display with no "hot spots"?
Display Update Speed:	Is the display capable of updating quickly enough to detect transient readings?

Physical Construction

Size/Portability:	Is it too big or bulky to move easily?
Squeak Test:	If you twist the case, does it squeak? If so, it may be poorly constructed (Low/No Safety).
Tilting Bale:	If the tilting bale is open, can you change ranges with one hand?
Range Switch/Meter Spin:	If the meter is laying flat on a table, can you change the range switch with one hand?
Display Corruption:	If you push on the display with your finger, does the display remain readable?
Battery/Fuse Replacement:	Can you replace the battery and fuse easily? Metal threaded screw inserts in case to minimize wear.
Battery Life:	300 hours or more is considered good.
Sharp / Shrouds:	Do the probes have sharp tips for small circuits and matching tip covers? Input Jacks shrouded?
Drop Test:	You WILL drop it! If you were to drop the meter from a height of 3' (such as off of a table), would it survive?
Probe Rating:	CAT I, CAT II, CAT III, CAT IV (to match meter)

CAT Ratings



CAT Ratings

Overvoltage category	In brief	Examples
CAT IV	Three-phase at utility connection, any outdoor conductors	• Refers to the "origin of installation"; i.e., where low-voltage connection is made to utility power. • Electricity meters, primary overcurrent protection equipment. • Outside and service entrance, service drop from pole to building, run between meter and panel. • Overhead line to detached building, underground line to well pump.
CAT III Three-phase	distribution, including single-phase commercial lighting • Equipment	in fixed installations, such as switchgear and polyphase motors. • Bus and feeder in industrial plants. • Feeders and short branch circuits, distribution panel devices. • Lighting systems in larger buildings. • Appliance outlets with short connections to service entrance.

CAT II	Single-phase receptacle connected loads	• Appliance, portable tools, and other household and similar loads.
		• Outlet and long branch circuits.
		  • Outlets at more than 10 meters (30 feet) from CAT III source.
		  • Outlets at more that 20 meters (60 feet) from CAT IV source.

CAT I	Electronic	• Protected electronic equipment. • Equipment connected to (source) circuits in which measures are taken to limit transient overvoltages to an appropriately low level. • Any high-voltage, low-energy source derived from a high-winding resistance transformer, such as the high-voltage section of a copier.

Measurement Resolution

Resolution - The amount of detail (or precision) in the reading

3½ digit	Display to ±1,999	(2,000 count)	5v = 5.00
3⅔ digit	Display to ±2,999	(3,000 count)	5v = 5.00
3¾ digit	Display to ±3,999	(4,000 count)	5v = 5.00
3? digit	Display to ±5,999	(6,000 count)	5v = 5.000
4½ digit	Display to ±19,999	(20,000 count)	5v = 5.000
5½ digit	Display to ±199,999	(200,000 count)	5v = 5.0000
6½ digit	Display to ±1,999,999	(2,000,000 count)	5v = 5.00000
7½ digit	Display to ±19,999,999	(20,000,000 count)	5v = 5.000000

To measure 5.000 Volts (with millivolt precision), we would need a volt meter with at least a 6000 count, or we would lose one digit of precision.

Measurement Accuracy

A 2,000,000 count meter does us no good if the display reads 1.733261, but the actual voltage being measured is 1.5 volts.

Accuracy is the ability to measure a value CORRECTLY

- Accuracy is usually specified as a percentage of the reading ± some number of digits. (eg. 0.5% ±4 digits)
- Each measurement function (DCV, ACV, DCA, ACA, mV, mA, Ω), as well as each range of each function, typically has its own accuracy rating.

For example, measuring 1.0v on a 2000 count meter with an accuracy 0.5% ±4 digits:

Minimum Reading: 1.0 - 0.005 - 0.004 = 0.991
Maximum Reading: 1.0 + 0.005 + 0.004 = 1.009
or 1.000v ± 0.009v

Sometimes we can accept reduced accuracy if we have sufficient resolution, but only if we are measuring delta values

Expected Accuracy

Expected Accuracy (in %) = 10 ÷ Counts × 100

Counts	Digits	% Accuracy
2000	3 ½	0.5%
3000		0.33%
4000	3 ¾	0.25%
6000	3 ¾	0.17%
10000		0.1%
20000	4 ½	0.05%
500000	5 ¾	0.002%

Example Feature Comparisons

- Harbor Freight 37772
- Extech EX330
- Extech EX430
- Fluke 87-V

Harbor Freight 37772 Multimeter

- Cost: About $20
- 2000 Count
- Manual Range Selection
- No Input Protection on 10A Range!

Extech EX-330 Multimeter

- Cost: About $59
- 4000 Count
- Fused Input Protection for 10A current measurement
- Auto-Ranging
- Measures Temperature
- Non-Contact Voltage Detection
- Max / Hold / Relative Measurements
- CAT II - 1000v / CAT III - 600v
- Temperature / Frequency / Capacitance Ranges
- Deep surround / Blast Protection
- mA/uA on Voltage Input Jack

Extech EX-430 Multimeter

- Cost: About $95 (Sale on Amazon for $29)
- Adds True RMS AC Volts measurement
- 20A Max Current measurement – Ceramic Fused
- 400mA Current measurement – Ceramic Fused
- CAT II - 1000v / CAT III - 600v
- Backlight
- Separate input jacks for current measurements

Fluke 87-V Multimeter

- Cost: About $300
- 6000 Count with 20,000 Count Hi-Res Mode
- 10A Max Current measurement - HRC Fused
- 400mA Max Current measurement - HRC Fused
- CAT II - 1000v / CAT III - 600v
- Backlight
- Separate input jacks for current measurements

Example Accuracy Calculations

- Harbor Freight 37772
- Extech EX330
- Extech EX430
- Fluke 87-V
- Keithly 177
- HP 3457A

Harbor Freight 37772 Multimeter

- Example: Measuring a 5.0000 volt source
  - Meter is 2000 count with Accuracy of ±(0.5% of reading + 1 digits)
  - Meter will use 20V scale since 5V is too large for 2V scale
  - Resolution is 0.01V on the 20V scale
  - Highest Reading = 5.00 * 1.005 + 0.01 = 5.04
  - Lowest Reading = 5.00 * 0.995 - 0.01 = 4.96
  - Range is 4.96V to 5.04V (A range of 0.08V) (±0.04V)

Extech EX-330 Multimeter

- Example: Measuring a 5.0000 volt source
  - Meter is 4000 count with Accuracy of ±(1.0% of reading + 2 digits)
  - Meter will use 40V scale since 5V is too large for 4V scale
  - Resolution is be 0.01V on the 40V scale
  - Highest Reading = 5.0000 * 1.01 + 0.02 = 5.07
  - Lowest Reading = 5.0000 * 0.99 - 0.02 = 4.93
  - Range is 4.93V to 5.07V (A range of 0.14V) (±0.07V)

Extech EX-430 Multimeter

- Example: Measuring a 5.0000 volt source
  - Meter is 4000 count with Accuracy of ±(0.5% of reading + 2 digits)
  - Meter will use 40V scale since 5V is too large for 4V scale
  - Resolution is be 0.01V on the 40V scale
  - Highest Reading = 5.0000 * 1.005 + 0.02 = 5.05
  - Lowest Reading = 5.0000 * 0.995 - 0.02 = 4.95
  - Range is 4.95V to 5.05V (A range of 0.10V) (±0.05V)

Fluke 87-V Multimeter

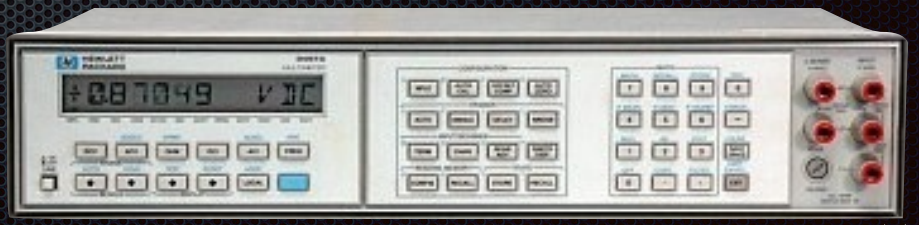
- Example: Fluke 87-V measuring a 5.0000 volt source
  - Meter is 6000 count with Accuracy of ±(0.05% of reading + 1 digits)
  - Hi-Res mode with 20000 count with ±10 digits of accuracy
  - Meter will use 6V scale
  - Resolution is be 0.001V on the 6V scale
  - Highest Reading = 5.0000 * 1.0005 + 0.001 = 5.004
  - Lowest Reading = 5.0000 * 0.9995 - 0.001 = 4.996
  - Range is 4.9965V to 5.0035V (A range of 0.008V) (±0.004V)

Kiethley 177 Microvolt DMM

- Example: Kiethley 177 measuring a 5.0000 volt source
  - Meter is 20,000 count with Accuracy of ±(0.03% of reading + 1 digit)
  - Meter will use 20V scale
  - Resolution is be 0.001V on the 20V scale
  - Highest Reading = 5.0000 * 1.0003 + 0.001 = 5.003
  - Lowest Reading = 5.0000 * 0.9997 - 0.001 = 4.997
  - Range is 4.997V to 5.003V (A range of 0.006V) (±0.003V)

HP 3457A Multimeter

- Example: HP 3457A measuring a 5.0000 volt source
  - Meter is 3,030,000 count with Accuracy of ±(0.0035% of reading + 19 digits)
  - Meter will use 30V scale
  - Resolution is be 0.00001V on the 30V scale
  - Highest Reading = 5.0000 * 1.000035 + 0.00019 = 5.000365
  - Lowest Reading = 5.0000 * 0.999965 - 0.00019 = 4.999635
  - Range is 4.999635V to 5.000365V (A range of 0.00073V) (±0.000365V)



Basic Multimeter Comparison

	Count	DC Volts	DC Volts	Ohms	Ohms	DC Amps	DC Amps	DC Amps	Diodes		
		5.000 v	1 mv	100KΩ	1.0Ω	150 mA	1 mA	10 uA	Vf	Speed	LED
Harbor Frt 37772 ($20)	2,000	±0.04 V (± 40 mV)	±0.105 mV (± 105 uV)	±0.9 kΩ (± 900 Ω)	±0.308 Ω (± 308 mΩ)	±2.35 mA (± 2350 uA)	±0.009 mA (± 9000 nA)	±0.18 uA (± 180 nA)	2.6	Slow	R
Extech EX-330 ($52)	4,000	±0.07 V (± 70 mV)	±0.205 mV (± 205 uV)	±1.4 kΩ (± 1400 Ω)	±0.412 Ω (± 412 mΩ)	±2.55 mA (± 2550 uA)	±18 uA (± 18000 nA)	±0.5 uA (± 500 nA)	1.5	Fast	-
Extech EX-430 ($99)	4,000	±0.05 (± 50 mV)	±0.203 mV (± 203 uV)	±1.2 kΩ (± 1200 Ω)	±0.408 Ω (± 408 mΩ)	±2.55 mA (± 2550 uA)	±18 uA (± 18000 nA)	±0.5 uA (± 500 nA)	1.5	Fast	-
Keithley 177 ($45)	20,000	±0.002 V (± 2 mV)	±0.003 mV (± 3 uV)	±0.05 kΩ (± 50 Ω)	±0.0035 Ω (± 3.5 mΩ)	±0.31 mA (± 310 uA)	±0.0003 mA (± 300 nA)	±0.004 uA (± 4 nA)	-	-	-
Fluke 87-V ($380)	6,000	±0.00700 (± 7 mV)	±0.101 mV (± 101 uV)	±0.7 kΩ (± 700 Ω)	±0.202 Ω (± 202 mΩ)	±1.7 mA (± 1700 uA)	±0.022 mA (± 22000 nA)	±0.020 mA (± 20000 nA)	7.2	Slow	R
HP 3457A ($250)	3,000,000	±0.000365 V (± 0.365 mV)	±0.00369 mV (± 3.69 uV)	±0.0049 kΩ (± 4.9 Ω)	±0.203215 Ω (± 203 mΩ)	±0.1254 mA (± 125.4 uA)	±0.000304 mA (± 304 nA)	±0.0124 uA (± 12.4 nA)	-	-	-
BK 879B ($285)	40,000	-	-	±720 kΩ (± 720 Ω)	±0.0202 Ω (± 20.2 mΩ)	-	-	-	-	-	-

http://www.LakelandARC.org

Basic Multimeter Comparison (cont'd)

	Cap	Cap	Cap	Cap	CAP	AC Volts	AC Volts	AC Volts	Freq	Freq	Temp	Ind
	Max	2200 uF	22 uF	1 pF	ESR	35	16	RMS	10 MHz	1 MHz		
Harbor Frt 37772 ($20)	20 uF	-	-	±0.003 nF (± 3 pF)	-	±0.58 V (± 580 mV)	±0.158 V (± 158 mV)	-	X	X	±3°C	-
Extech EX-330 ($52)	200 uF	-	±0.81 uF (± 810 nF)	±0.040 nF (± 40 pF)	-	±0.555 V (± 555 mV)	±0.27 V (± 270 mV)	-	±0.02 MHz (± 20 KHz)	±0.011 MHz (± 11 KHz)	±4°C	-
Extech EX-430 ($99)	100 uF	-	±0.81 uF (± 810 nF)	-	-	±0.585 V (± 585 mV)	±0.3 V (± 300 mV)	Y	±0.19 MHz (± 190 KHz)	±0.019 MHz (± 19 KHz)	±4°C	-
Keithley 177 ($45)	-	-	-	-	-	±0.325 V (± 325 mV)	±0.095 V (± 95 mV)	Y	-	-	-	-
Fluke 87-V ($380)	9999 uF	±24 uF (±24.0 uF)	±0.42 uF (± 420 nF)	-	-	±0.195 V (± 195 mV)	±0.1 V (± 100 mV)	Y	X	X	±1°C	-
HP 3457A ($250)	-	-	-	-	-	±0.0781 V (± 78.1 mV)	±0.02196 V (± 21.96 mV)	Y	-	±0.0001 MHz (± 0.1 KHz)	-	-
BK 879B ($285)	20000 uF	±44.2 uF (±44.2 uF)	±0.156 uF (± 156 nF)	±0.045 pF (± 0.045 pF)	Y	-	-	-	-	-	-	Y

More Than One Multimeter?

- Advantages of having more than one multimeter
  - 2 multimeters allow you to measure voltage and current at the same time.
  - You can tell if either meter is out of calibration.
  - Pocket Multimeters can be useful for automotive applications. Keep one in your toolbox.

Multimeter Accessories

- Various Test Lead Ends
  - Alligator Clips
  - Micro Clips
  - 0.1" Female Header Clips
  - Tweezer Leads
  - Radio Shack Test Lead Kit 278-0039

Other Resources

- Dave Jones - EEVBLOG (http://www.eevblog.com)
  - #6 (Part 2) - Why Cheap Multimeters Suck
  - #10 (Part 1) - More cheap Chinese Multimeters
  - #10 (Part 2) - Fluke 87V Multimeter Review
  - #26 - Multimeter Counts, Accuracy, Resolution & Calibration
  - #75 - Digital Multimeter Buying Guide
  - #84 - High Energy Multimeter Destruction
  - #91 - $50 Multimeter Shootout
  - #99 (Parts 1 & 2) - $100 Multimeter Shootout
  - #373 - Multimeter Input Protection Tutorial
- Martin Lorton's YouTube Channel (http://youtube.com/mjlorton)

Hands-On Testing

Voltage References

- 1.9000v (±0.04% Accuracy)
  - 2000 Count Meters
- 3.0000v (±0.02% Accuracy)
  - 3000 Count Meters
- 3.9000v (±0.02% Accuracy)
  - 4000 Count Meters
- 5.9000v (±0.01% Accuracy)
  - 6000 Count Meters
- 10.0000v (±0.01% Accuracy)
  - Higher Range
- 2.048v (±0.01% Accuracy)
  - 11-bit D/A (1mv/bit)
  - 12-bit D/A (500uV/bit)
  - 13-bit D/A (250uV/bit)
  - 14-bit D/A (125uV/bit)
- 4.096v (±0.01% Accuracy)
  - 12-bit D/A (1mv/bit)
  - 13-bit D/A (500uV/bit)
  - 14-bit D/A (250uV/bit)

Hands-On Testing

Precision Resistors

- 1,000Ω
  - 0.01% Tolerance (±0.1Ω)
  - ±2ppm/°C
  - Vishay Y07851K00000T9L
- 10,000Ω
  - 0.005% Tolerance (±0.5Ω)
  - ±0.2ppm/°C
  - Vishay Y145310K0000V9L

The End