The Mooshimeter – A First Look

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Introduction

While reading an electronics news item I “discovered” the Mooshimeter. After reading its specifications, I became very interested for two basic reasons. (1) I needed to add a data logger to my measurement capability, and (2) The specifications exceeded those of my current dozen plus digital multimeters, DMMs. I am especially interested in measuring the dynamic current drain of HP calculators[1].

The $120 cost of the Mooshimeter was within my budget and I ordered one[2]. The current measurement specification of 20 µV / mA burden voltage is a resistance of 20 milliohms inserted into the circuit to be measured. Usually this value is on the order of 15 ohms or more – many hundreds of times higher. This should provide a much more accurate device current measurement and would not affect the operation of the machine. The Mooshimeter is a two-channel data logger and this would allow the simultaneous measurement of voltage and current. In addition, the sample rate and data memory capabilities provide the recording of the many power states of the calculator. Moving these measurements into a spreadsheet would provide a more accurate assessment of the current drain of the machine under a wider range of operating conditions. The Mooshimeter is especially attractive because of its greater dynamic range - 24 bits, 16.7 million to 1, or 0.1 ppm.

Obvious limitations

A current trend for specialty instrument manufacturers[3] is to use a smart phone for additional computer processing, communication, and a high resolution display. Most engineers have a smart phone. More on this later. See Fig. 2.

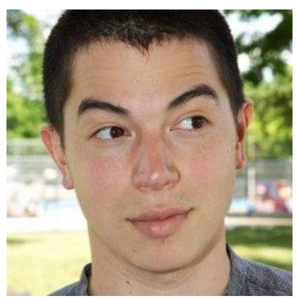


Fig. 1 - James Whong

A little Mooshimeter history

The Mooshimeter is the work of James Whong, an EE and CE graduate of Olin College of Engineering[4]. He saw the need for dynamic electrical measurements while working on automotive projects, especially the DARPA Grand Challenge. James is strong in both hardware and software and the Mooshimeter is the ideal blend of these two disciplines. See James’s Linkedin page at: https://www.linkedin.com/in/james-whong-7626507

Mooshimeter is a short form of Mooshim Multimeter. Mooshim is his mother’s dog’s name. James founded Mooshim Engineering in October 2012 in the San Francisco Bay area. See additional details at the link in note (4).

The Mooshimeter is a kick starter project and there is a lot of historical information on the Internet. When a single individual takes on a project of this complexity, it takes a lot of energy and all of his time. With most of the first build of 2,000 Mooshimeters now being used, the early adopter phase should soon pass into the production phase and worldwide use.

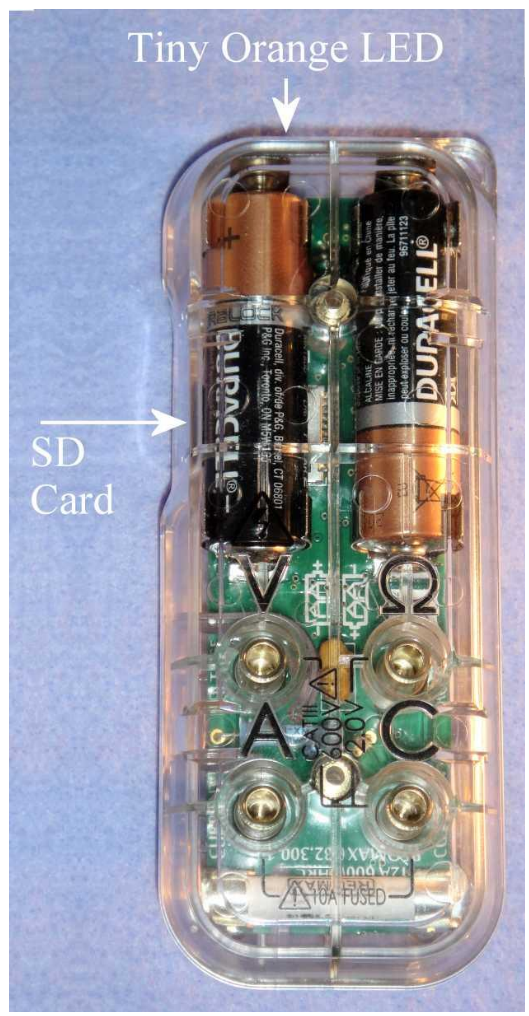


Fig. 2 – Mooshimeter without test leads.

You are on your own – Caveat Emptor

Getting involved with a product of this nature is risky and it demands a lot of time because you are in undocumented territory. For me it was especially challenging because I did not even have an Apple Account and only a minimal memory iPhone 5. I had three new areas to get up to speed with, the iPhone, Bluetooth, and a software-based multimeter. I am still learning and this article is just a "first look." If time allows more articles will follow.

When you open the plain white cardboard box, you see two items. A gray "hard" carrying case with the Mooshimeter and test leads and a 4-1/2" x 5-1/2" "instruction sheet." See Fig. 3. The two AA cells are installed and when you take it out of the case, you see the Mooshimeter as shown in Fig. 2. The reverse side of the card says to download the iOS or Android App.

Fig. 3 – This is what you get. Also see page 5 Fig. 7a.

"Having Trouble?" the card asks. Visit moosh.im/support OR Email: support@moosh.im

What is the extension .im? .im is instant messaging and both sender and receiver must be on line at the same time[5]. From what I have observed im is favored by younger computer users. Can I just send an im and expect a response on my desktop computer? While .im is great for its intended purpose it is NOT as suitable for a company selling a product. Poor James. He is now in the make or break position for his young company. He needs to finish selling his first batch and hopefully his cash flow will allow him to add a technical support person.

You won't find a phone number for Moohsim Engineering on line either. You cannot stomp programming bugs if the phone keeps ringing.

Time and more time

Since I "stumbled" on the Mooshimeter on line, I have seen several of the videos that help explain the development/production/operation issues. Several Internet suppliers have added the Mooshimeter to their product line and all quote from the same source. As Circuit Specialists, CS, did in Appendix A.

When you first look at the Mooshimeter, you notice that the only obvious controls or user operational parts are the four test lead sockets. You will probably also "discover" that there is a tiny orange status LED that tells you that the Mooshimeter is "working." See Fig. 4 and Fig. 5. This LED is hidden and unless it is flashing – as it should be – you probably could not find it with a magnifying glass. It is very tiny. I added the felt pen mark as shown in Fig. 4c.

Because you will probably use the Mooshimeter positioned as shown in Fig. 2, I am referencing all views of the circuit board using the top, bottom and sides as shown. You cannot see the status LED in this operating position. It is located at the furthest position from you, and "hidden" under the circuit board. I presume that the status LED is located for the convenience of testing or perhaps reducing the effects of its “noise” on the operation of the low-level circuits. It certainly was not located for user convenience. If it were the terminal lettering would be turned upside down.

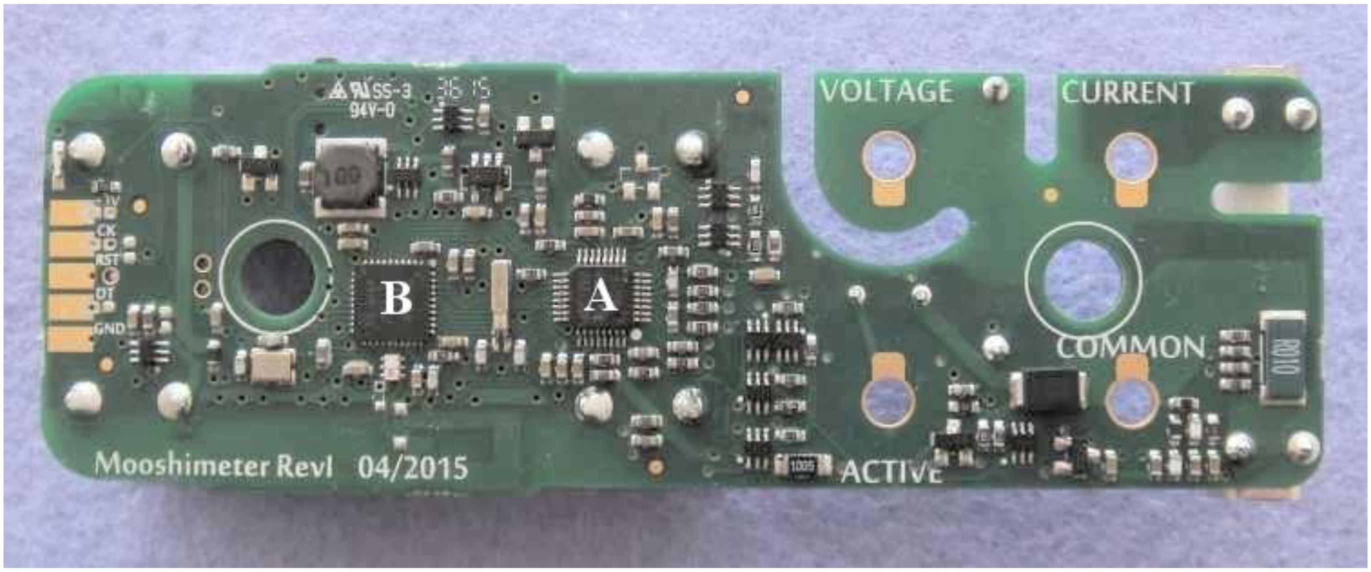


Fig. 4a – Underside of PCB. Top end is to the left.

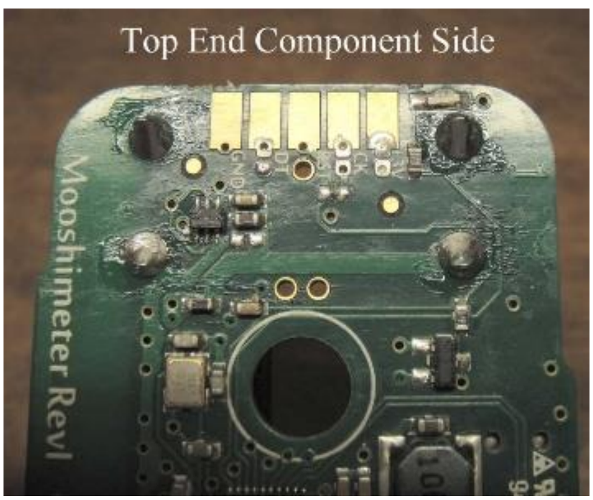


Fig. 4b – PCB Top end. Status LED top right.

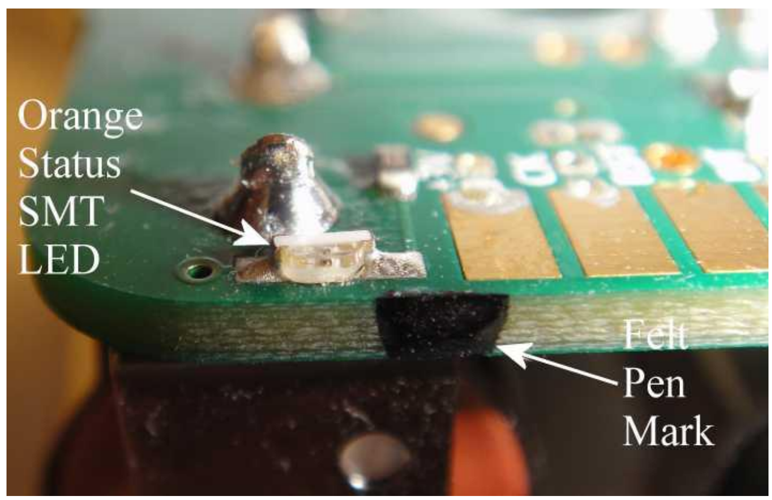


Fig. 4c – Tiny SMT Status LED.

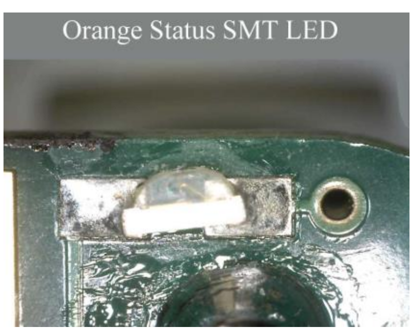


Fig. 5a - LED “angle” soldered.

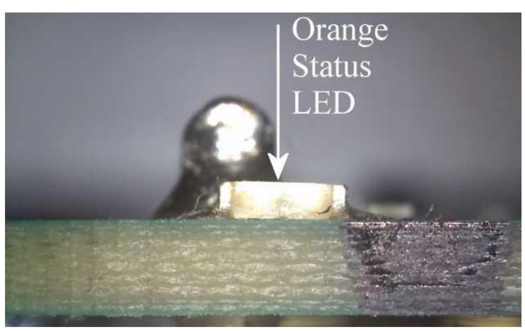


Fig. 5b - Looking at the tiny status LED.

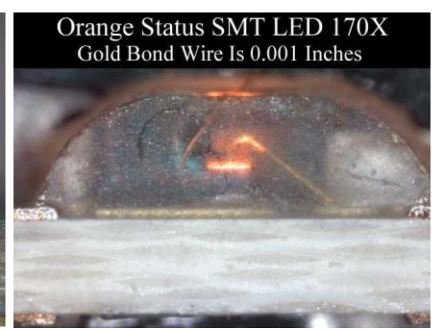


Fig. 5c - Status LED at 170X.

You may also have “discovered” that a Micro SD card is used for the data recording. The Mooshimeter works without the Micro SD card and most suppliers will sell it as an extra – include it as a “bonus.”.

Experienced iPhone users (not me) will probably have no trouble down loading the App. I did because I made an email address error completing Apples Account Application form on the iPhone. They require you to receive an email to complete the process. Have you ever tried to call Apple Support? Keep refreshments handy, you will be a while. The support person was patient and did a superb job of helping me to correct the omission of the "cf" in my email address. We had to try several times using different methods.

Once you have an apple account you must open the App Store app and search for "Mooshimeter". Download the app and you are ready to see the Mooshimeter work as shown in the videos.

Because the Bluetooth system uses a transceiver, Mooshim Engineering ships the Mooshimeter in a Hibernation mode. You will know that it is in hibernation because the status indicator will blink once every ten seconds. That is a long time to wait, especially when you are not sure where to look for the flash. The instruction sheet says to short the "C" and "**Ω**" leads together for longer than ten seconds so at the next flash the system will detect the low resistance and come alive. When this happens the status LED will flash every 2 seconds. The Mooshimeter is now ready to Bluetooth communicate with a smart phone. See additional comments in the **Questions and issues** section.

The Mooshimeter hardware "user interfaces"

The shirt pocket Mooshimeter has the following user hardware interfaces.

1. A hidden tiny (185 mil wide) flashing **orange status LED indicator**.
2. **Four banana sockets** for the test leads on the bottom end of the case. These use standard 3/4" spacing so you may insert two plugs at one time. More on this under **Test leads**. The four sockets unplug from the circuit board for disassembly. See the © 2014 User's Guide you must download from the Mooshim website. An active pdf link is also at the end of appendix A.
3. **Two AA cells** for power. The well-made cell holders are sturdy with nicely identified polarity marks.
4. A special **ten-ampere fuse** on the bottom end of the circuit board is used as a 20 m**Ω** ammeter shunt for current measurement. The User's Guide explains how to test it using the Mooshimeter and to buy replacements from Mooshim Engineering. The fuse is a 6x32mm Reomax 632.300.12
5. A micro **SD card slot** on the upper left side. Use only a FAT32 formatted SD card to a maximum of 32 Gigabytes. Others will not work. Handle these cards with care because they are very delicate.
6. A hardware **reset button** next to (above) the SD card slot. The User's guide says to hold for five seconds to reset the Mooshimeter. The Mooshimeter will then be ready to communicate with a smart phone flashing every two seconds.

The clear polycarbonate Mooshimeter case must be opened by removing two #0/1 Philips head stainless steel screws for access to items 3 - 6 above

Mooshimeter measures eight electrical parameters (plus internal temperature)

See the range tables in the User's Guide pdf pages 21 and 22. The unusually high 24-bit resolution extends the ranges listed below significantly.

1. **Voltage:** (V terminal) DC & AC (sine) voltage ranges from 0.150/100 volts to 600/600 volts. Resolution 25 nV to 275 µv. Accuracy ±0.5% plus 20 counts.

2. **Current**: (A terminal) DC & AC (sine) ranges from 1.75/1.25 amperes to 10/9 amperes. Resolution 0.4 µA to 3.8 µA. Accuracy ±0.5% plus 50 counts.

3. **Resistance:** (Ω, active terminal) ranges from 2 KΩ to 9 MΩ. Resolution 250 µΩ to 1.5 Ω. Accuracy ±1% plus 50 counts.

4. **Low Voltage:** (Ω, or active terminal) DC & AC (sine) voltage ranges from 150/1000 millivolts to 100/700 millivolts. Accuracy ±0.5% plus 20 counts.

5. **Diode Voltage:** (Ω, or active terminal) DC voltage ranges from 200 mv to 2.2 v. Resolution 25 nV to 300 nV. Accuracy ±1% plus 50 counts.

The three measurement terminals have the following loading specifications:
V - >10M Ω, <200 pF. Surge protected to 6KV.
Ω - >100M Ω, <200 pF. Surge protected to 800V.
A - <20µV/mA. (20 mΩ) Surge protected to 10KA, 600V.

Case observations

The case of the Mooshimeter is well designed and mechanically sturdy. The clear polycarbonate case is ≈140 mils thick for the bottom half, and ≈ 90 mils thick for the top half. Two #0/1 Philips head, 4-48?[6] stainless steel screws, into metal threaded inserts hold the pieces together. There was no cost cutting mechanical shortcuts taken here. The circuit board plugs into the four test lead banana sockets molded into the top case. The sockets and the circuit board are gold plated for reliable low resistance contacts.

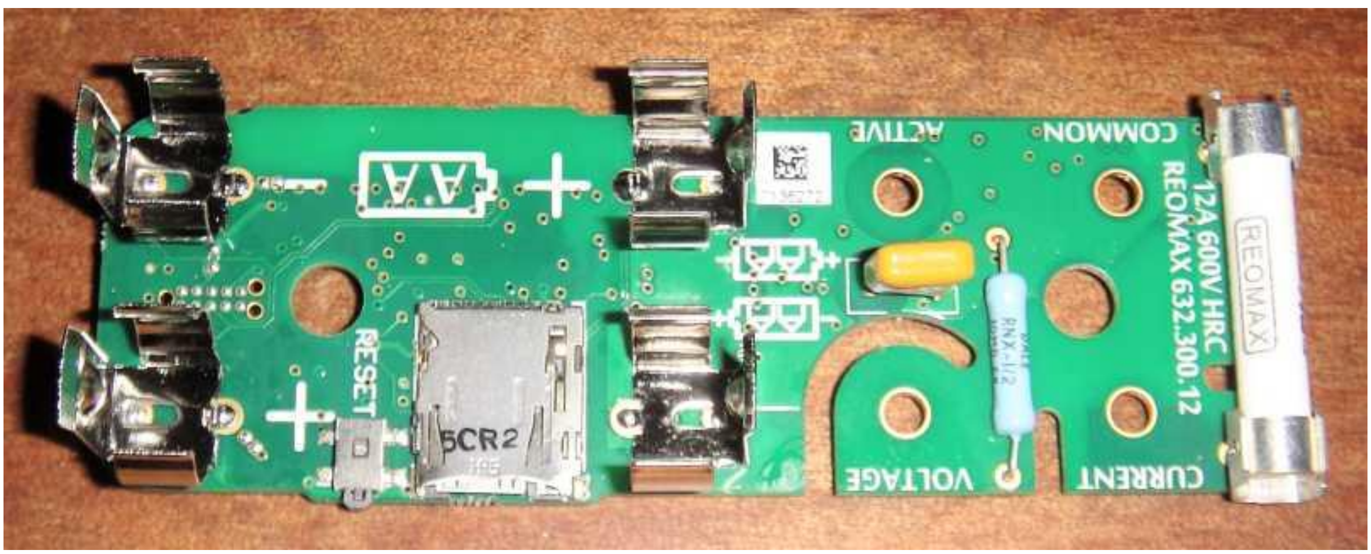


Fig. 6 - Circuit board sans AA cells. Large parts are on the top.

The circuit board is good quality, epoxy, double-sided, and 60 mils thick (rigid) for human field handling. All of the SMT (surface mount technology) parts on the bottom side with the larger parts; AA cell holders, reset switch, micro SD card holder, axial resistor, radial capacitor, and fuse holder on the top side. See Fig. 6. The well labeled circuit board uses clear simple text. Mine is REVl 04/2015.

Fig. 7 shows the right side view of the circuit board. Note how many hardware parts protrude above the board and above the SMT parts. This allows you to set the board down (on a non-conductive surface) with minimal mechanical stress on the parts. This facilitates handling the Mooshimeter with little possibility of damage. You will have to open your Mooshimeter to change batteries (or a fuse), press the rest switch, or insert a Micro SD memory card. Is all of this necessary?

The case is probably clear for geek appeal.

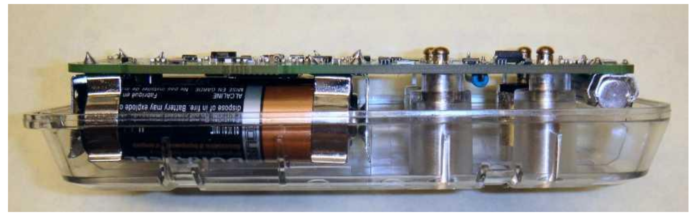


Fig. 7 – Right side view of the circuit board.

Missing case physical specifications

The Mooshimeter User's Guide has the general specifications on pdf page 20. Some of them have question marks for the values. These were probably unknown during development. This is Rev 1 dated August 2014. Table 1 shows the measurements of my Mooshimeter. Note that this is a sample of one and should not be construed as a "specification."

Table 1 – Physical Measurements

Parameter	Measurement
Size: height, width, depth (HWD)	11.6 cm x 4.6 cm x 5.2 cm (4-9/16" x 1-13/16" x 2-1/16")
Total weight	121 grams (4.27 oz.)
without AA cells	74 grams (2.61 oz.)
Case w/ screws	52.8 grams (1.86 oz.)
Circuit board	21.32 grams ((0.753 oz.)

Test leads

See Fig. 8 and Fig. 9 for the three test leads that come with the Mooshimeter.

Fig. 8a shows a stiff (semi-hard) carry case for the Mooshimeter. There is a little room "extras". A 3-1/4" x 5-3/4" User's Guide would probably fit nicely between the two halves.

Fig. 8a - Probes in case. Fig. 8b – High quality robust and sturdy CAT III probes. Fig. 8c - Safe probe plugs.

Fig. 8b shows the three probes that meet industry standards for high voltage safety. The long insulated banana CAT III plugs have a "high force" insertion and removal connection. See Fig. 8c.

Fig. 9a shows the pointed probe tip with a recess near the tip. This is for easier holding of the probe against another probe tip or wire. The point is not "pin sharp" for piercing wire insulation.

Fig. 9b shows highly insulated alligator clips that have a "socket" that the probe tip plugs into. Because of the insulation requirements, the plastic is thick, stiff, and requires "high force" to open the jaws. Fig. 9c shows a Pomona® MDP-02 3/4" spaced pair of banana plugs for general cable use. This makes it more convenient to make two banana plug connections at once. I connected a shorting wire (12 Ga. solid

Fig. 9a – Time tested probe tip design.

Fig. 9b - Probe tip alligator clips.

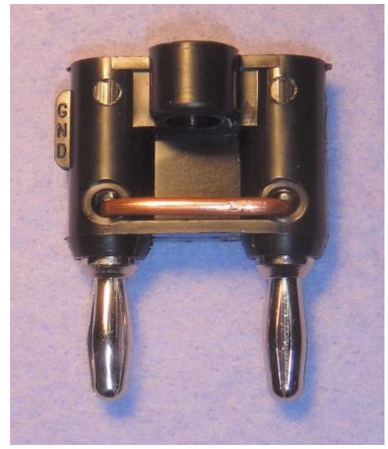


Fig. 9c - Wakeup shorting plug.

copper) across the terminals for waking up the Mooshimeter. This plug works with the sockets or on the terminal holes on the board if the PCB is out of the case. See the next section below. This "accessory" fits into the Mooshimeter case.

Suggested accessory ideas

After examining the Mooshimeter from a user perspective several changes and accessory ideas come to mind.

1. <u>Easier and faster waking up</u>. All too often – at least in my test environment – it is not convenient to disconnect the two test leads (probes) in order to wake up the instrument. The situation for me is that I will probably use the Mooshimeter more as a DMM than as a data logger, its intended application.

   I turn off battery-powered equipment when not being used by habit. My refrigerator can only hold so many batteries. The banana plug pair shown in Fig. 10a is a useful tool for this situation. I could just unplug the test leads from the Mooshimeter and then plug in the shorted plug to wake up the Mooshimeter, but I prefer one-handed operations. You cannot do this one handed. Fig. 10b shows a solution. This works with the circuit board out of its case as well.

   A switch as shown in Fig. 10a will fit into the cable strain relief of the Pomona dual banana plug. See Fig. 10b. The cable stress relief hole needs to be drilled to 1/4" and the switch threads are not quite long enough for a nut.

   Use a sharp X-Acto knife to trim the plastic on the bottom as required. Since the switch I had in the "junk box" was a SPDT center off type, I decided to include a 10 ohm[7], 1%, 1/4W metal film resistor as a "sanity" check. You could use a 1 K ohm or any other value[8]. I choose ten ohms because that was near the bottom of the most accurate range. Connect the switch leads by soldering a short wire to the two banana plug plugs. Solder the resistor – if you use one – to one of the outside switch terminals.

Fig. 10a – Plug and switch.

Fig. 10b – Switch fits plug.

I wanted to provide the test lead wire with some additional stress relief support so I drilled the two plug wire holes to 5/32". In addition to the probe lead wires and switch wires, I added a short length of rigid steel coat hanger wire. I removed the protective coating for good electrical contact. I used red and black heat shrink tubing, HST, to hold the probe wire and steel wire together. I used a second length of HST over the first length to further "round" the steel wire end to avoid splitting under stress.

Setscrews hold the wires in the plug. Do not lose them. I used a clear piece of HST to hold the two probe leads together a couple of inches from the plug. You can see the "stiff" probe wires in Fig. 11.

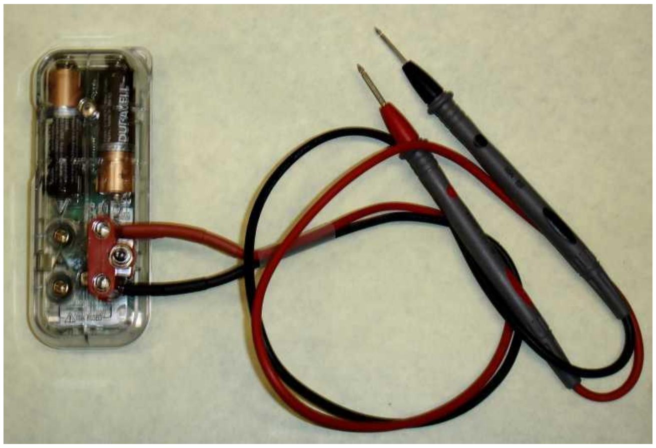


Fig. 11 - Probes connected to plug and shorting switch

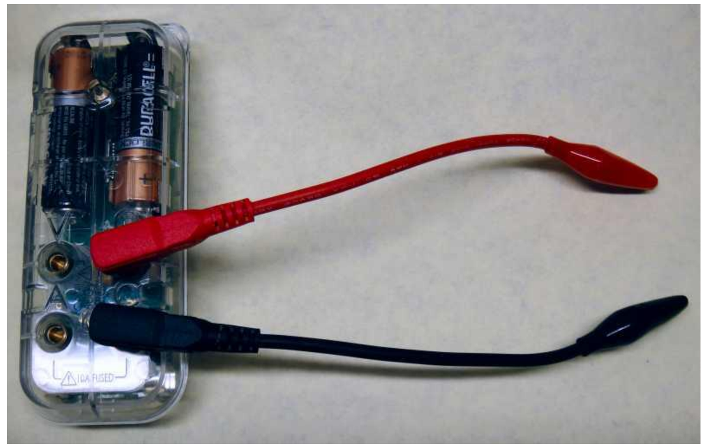


Fig. 12 – CAT III plugs with added alligator clips.

The two added test probes have their plugs cut off and connected to alligator clips for a 6-inch set of test leads. These are softer and easier to open. Another set of CAT III probes are readily available at most electronic suppliers[9]. Now you can wake up the Mooshimeter with one hand by flipping the switch.

The dual lead plug is also stackable so additional normal banana plugs may still be inserted.

2. Switch all three leads. The first idea worked so well it was expanded to implement a switch for all three inputs - Ω, V, & A. The idea is to be able to short the Mooshimeter input to remove the noise in plots without inputs.

Having a switch to do this is very nice to verify what the plot is showing. The switch also has the function to open (remove) the input. Both of these actions are a means of providing a time mark in the recorded or plotted data.

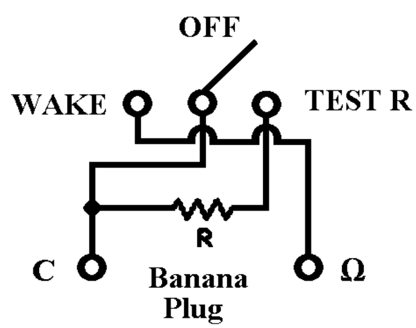


Fig. 13 – Fig. 11 Plug schematic.

The first modification of a banana-shorting plug was simple. I often demonstrate electronic principles and I build fixtures[10] to make measurements and data recording convenient, simple, and easy. I made a more elaborate fixture using a square piece of Plexiglas[11] slightly larger than the square formed by the Mooshimeter banana sockets - 2-1/4". I attached four plugs to this "base" with three switches mounted to short the common to the Ω, V, and A terminals. Fig. 14 shows how I wired each switch. This is especially useful when you are showing the plots and you want to avoid the noise values. Shorting the terminals with nothing connected instantly shows up on the plots making them more easily interpreted.

Fig. 15 and Fig 16 show the test fixture[12] with each switch wired as shown in Fig. 14. The fixture plugs into the Mooshimeter, uses test leads from other damaged (due to high voltage) low cost and FREE-with-coupon DMMs obtained over the years.

Each Mooshimeter input may be switched to [1] Input probe (forward), [2] Open (center), [3] Connected to common (back).

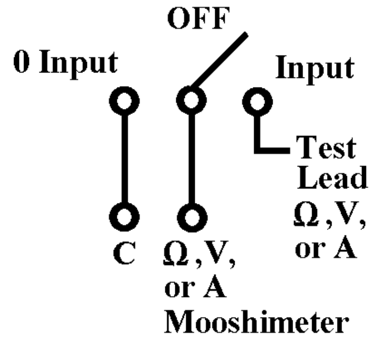


Fig. 14 - Typical switch connections.

Case "modification"

Even though the opened case (circuit board etc.) is rugged, I still prefer not to open it if not required. You cannot easily find replece-

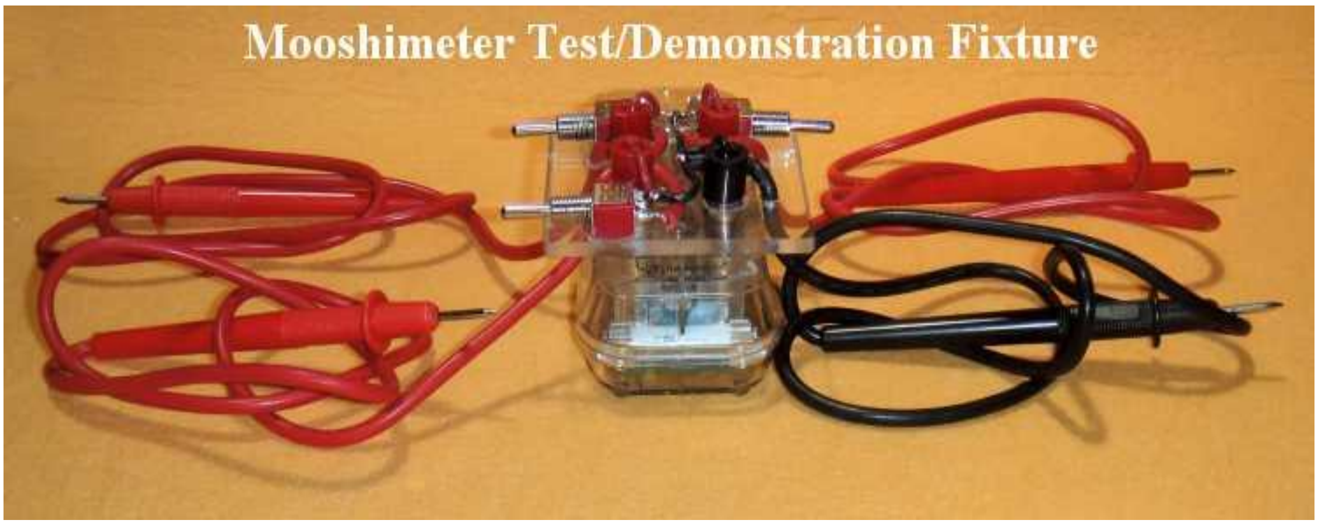


Fig. 15 – Plug-in test fixture for convenient test lead switching that is useful for time stamping signals.

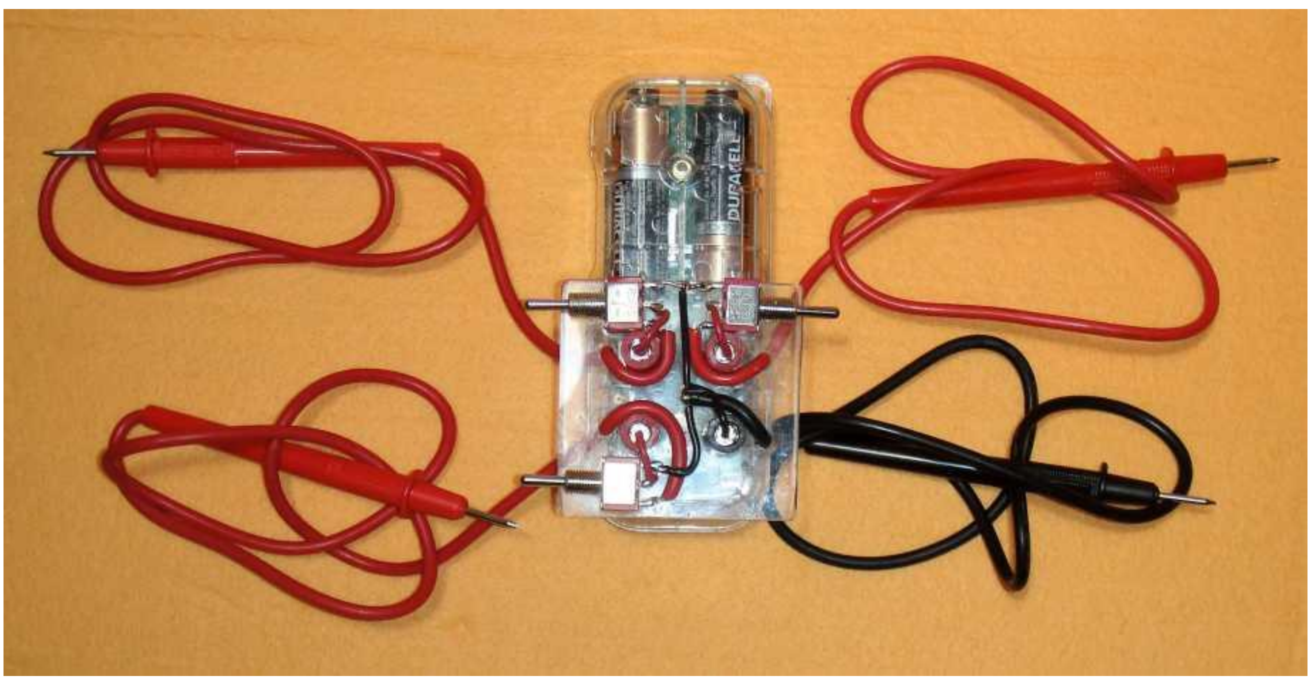


Fig. 16 – Test fixture top view. There is a three-position switch (also see Fig. 10a) for each test lead.

ment screws so you should not leave them out. For some unknown reason the holes for the reset switch and Micro SD card do not completely pass through both halves of the case.

Fig. 18 shows the part that is “incomplete.” I made it more visible by scratching it with a scribe using the complete half as a guide. Fig. 19 shows the two holes drilled and filed to allow access to the reset switch and the Micro SD cardholder. The spacing (excessive?) between the circuit board edge and the outside of the case may have been the reason to not have the case holes “open.” The spring loaded card eject pushes the card out far enough, but pushing it in would be a problem with large fingers and/or

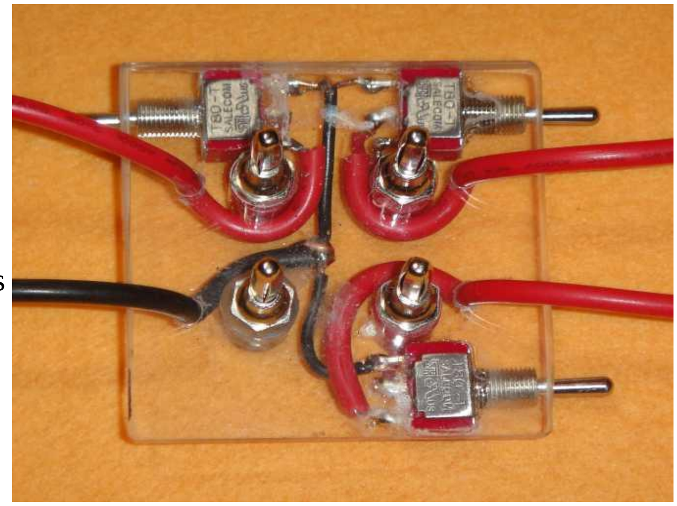
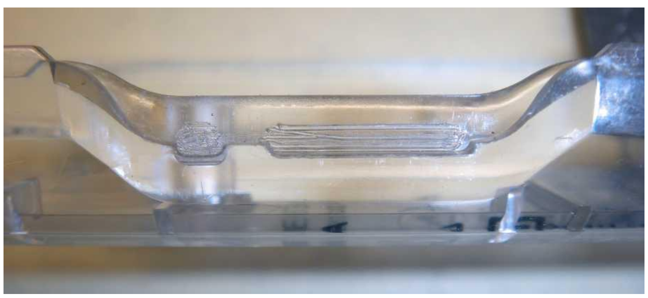


Fig. 17 - Banana plugs that plug into the Mooshimeter.



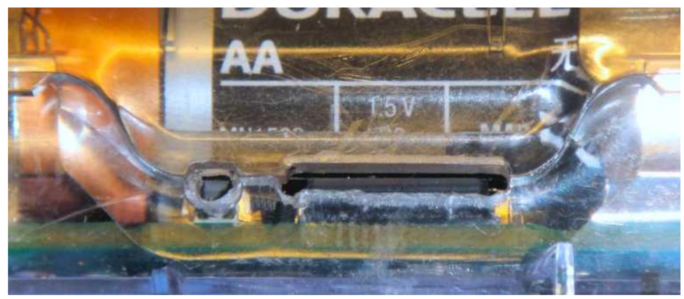


Fig. 18 – Scratched lower case shows incomplete holes. Fig. 19 – Drilled and filed reset hole and SD card slot

short fingernails. A toothpick or other nonconductive small stick solves the problem. You will need the toothpick to press the reset button. Do not use a metal object.

With this modification, you will only have to open the case to change the AA cells (or fuse).

I hesitate mounting the wake up switch between the Ω and C banana sockets because of the wire connects to the sockets. The space is a bit close but it fits. The leads could be brought to the board but then disassembly wouldn’t be “clean.” The issue is melting the plastic when soldering directly to the socket. Then there is the issue of getting solder into the expansive plug parts. A hole could be drilled on the side into the case plastic and a screw threaded into the plastic to make contact with the socket.

Making my first test measurements

Once I had the Mooshimeter working, I compared it against the standards that I use for checking my voltage, current, and resistance measuring instrumentation. See Fig. 7 on the next page.

These are relatively low cost, highly accurate, and stable standards suitable for DMM calibration with prices ranging from just under $50 (DMM Check) to just under $100 (DMM Check Plus & PentaRef).

Recent advances in IC technology has produced semiconductor reference devices that are low noise and temperature long term stable. The voltagestandard website is also a great reference with links to the sources and history of its designs.

The PentaRef is especially nice because you may specify five voltages from 0.100V to 10.000V to match your specific requirements. Tables 2and 3 shows the results.

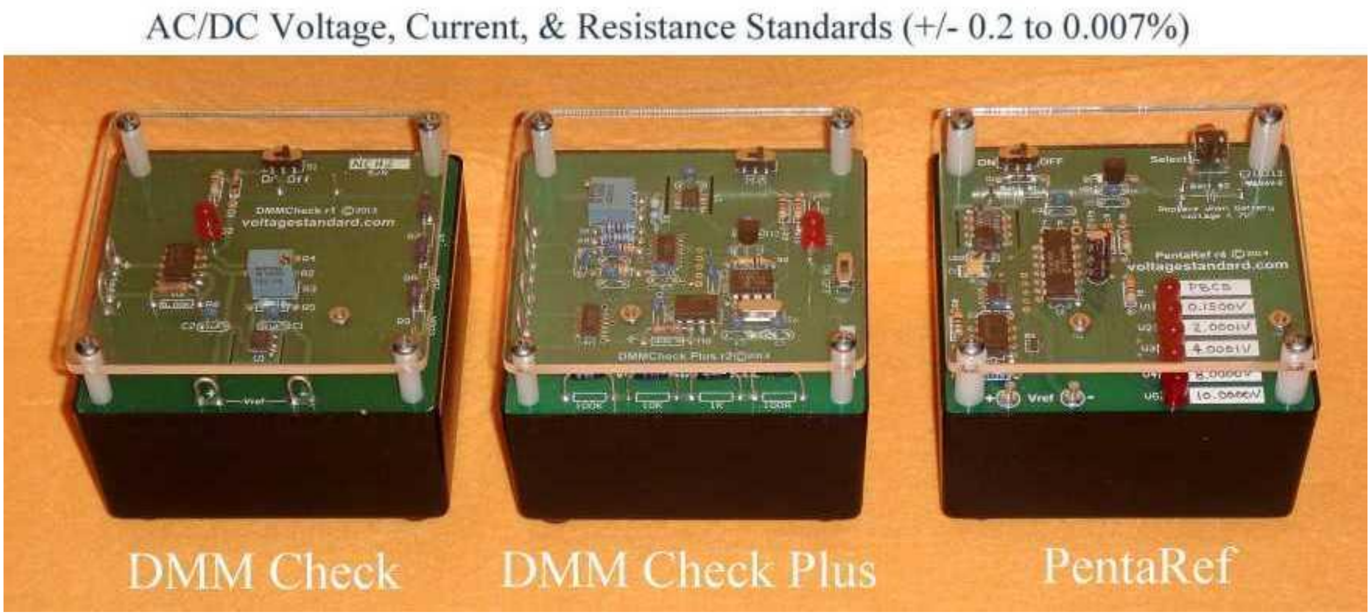


Fig. 7 – Voltage, current, and resistance standards from www.voltagestandard.com in Battle Ground WA.

Because of the Mooshimeter sin wave requirements the DMMCheck Plus square wave AC voltage and currents are not as conveniently suitable. 5.00 volts should read 5.55V per voltagestandard.

The notes below Table 3 also apply to Table 2

Table 2 – DC Voltage, Current, and Resistance Standard Measurements[a]

Resistance[b]	**MM[c]**	**Error**	**Comments**
100 ohms ± 0.1%, TC 10 ppm	100.879 Ω	+0.88 %	Note **g**
1 K ohms ± 0.1%, TC 10 ppm	1003.88 Ω	+0.39 %	Note ***g***
10 K ohms ± 0.1%, TC 10 ppm	10.0152 Ω	+0.15 %	Note **g**
100 K ohms ± 0.1%, TC 10 ppm	100.224 Ω	+0.22 %	Note **g**
DC Voltage			
5.000 volts[d]	5.0004 V	+0.008 %	Both DMM Check sources read the same [g].
0.1500 volts[e]	0.1501 V	+0.067 %	Note **g**
2.000 volts[e]	2.0002 V	+0.010 %	Note ***g***
4.000 volts[e]	4.0003 V	+0.0075 %	Note **g**
8.000 volts[e]	8.0005 V	+0.0063%	Note **g**
10.000 volts[e]	10.0007 V	+0.0070 %	Note **g**
DC Current 1.00 mA.[f]	0.0010 mA	agree	Note **g**

Table 3 – AC Voltage and Current Measurements[a]

AC voltage[d] 5.00 V	4.85 V	+7.6%	Correction 1.11V = 5.38 V
AC Current[d] 1.00 mA.	0.0007/8 A	-11%	Correction 1.11I = 0.00089 A

Notes: ***a*** *- The Mooshimeter showed 23.00 to 23.50° Celsius during the measurement taking period.*
b *– Using the DMM Check Plus.*
c *– The average of lowest and highest underlined fluxing digits over 15 seconds.*
d *– Using the DMM Check plus. AC is at 100 Hz. 50% square wave. Mooshimeter 8,000Hz, 256 smpl.*
e *– Using the PentaRef.*
f *– Using the DMM Check.*
g *– The Mooshimeter is within specifications based on my very limited testing.*

The conclusion of my measurements is that the Mooshimeter is within specifications. I do not have the AC standards suitable for the AC ranges. I could use an oscilloscope and use the well known DC voltages to calibrate the inputs and compare peak measurements, but that will have to wait for further exploration and is beyond a first look.

Mooshimeter program list on iPhone

Loading the Mooshimeter app was my first iPhone app experience. I have "reloaded" it twice and the experience has been a bit frustrating because of my ignorance and the time it takes to try and try again in order to figure out what is going on.

Pressing the Mooshimeter icon the iPhone lists the program as follows:

Mooshimeter V.1
RSSI: -43 FW Build: 1447470000

As I now understand, RSSI is an indication of "Received Signal Strength Indicator". Each time I down loaded the app I was seeing different values. When I took the Mooshimeter further from my iPhone (two rooms away) approximately 35 feet and came back to the iPhone the program disappeared from the list. Would I have to go to a Wi-Fi spot and reload the program? Actually, the program didn't "disappear" it just didn't see the Mooshimeter. Turning the iPhone off and on again with the Mooshimeter close to the phone once again showed the program. This time I took the iPhone away from the Mooshimeter and watched the "Sig: -47 dB Bat: 100%" text at the top of the screen and I saw the –dB level dropping as I moved further from the Mooshimeter. At about -96dB the meter display disappeared and the program list appeared momentarily with an RSSI value of about the same value and then disappeared. Resetting the iPhone with it closer to the Mooshimeter and all was well again. The strongest signal I have seen is -24 dB (and RSSI as it appears is used by the Mooshimeter).

Mooshimeter Electronics heart

The Mooshimeter is based on two System-on-Chip, SoC, integrated circuits[(14)].

The first is a Texas instruments 32 pin Electrocardiogram, ECG, SoC. See "A" in Fig. 4a. Here is how TI describes the ADS1292.

"The ADS1192, ADS1292 and ADS1292R family of devices are two-channel, 16/24-bit, low-power, integrated analog front-end (AFE) designed for portable electrocardiogram (ECG) and respiration applications."

The second TI SoC implements the Bluetooth transceiver. Here is how TI describes the 40 pin CC2540

"The CC2540 combines an excellent RF transceiver with an industry-standard enhanced 8051 MCU, in-system programmable flash memory, 8-KB RAM, and many other powerful supporting features and peripherals."

Questions and issues

1. The Shipping (lowest?) power mode does not seem to be the same hibernation mode the iPhone app uses because my Mooshimeter hibernation mode flashed the status indicator every ten seconds initially and only every 2 seconds thereafter.

2., The two screws that hold the Mooshimeter together are non-standard. Why? You will not find replacements at your national hardware store. What are the specifications for these screws? They appear to be ≈ #4 in diameter and 50 pitch. At least the head is a Philips standard so most users will have a tool to unscrew them.

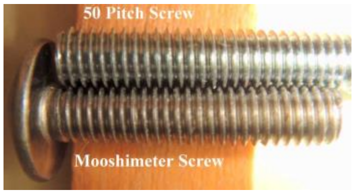


Fig. 20 – 50 pitch threads.

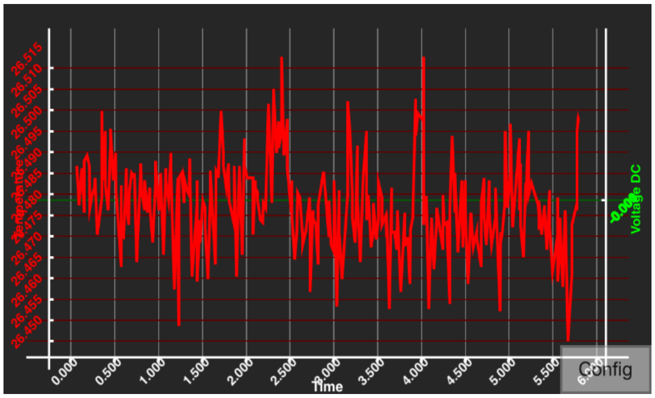
3., The 10 ampere shunt is a fuse. If the manufacturer doesn't publish suitable specifications this is a risky design decision. While it makes sense from an engineering perspective, the design may be in trouble when the fuse design changes or it becomes obsolete. I remember seeing a diode in an unfused lighted switch product. It was a Mil Spec approved product. When the diode manufacturer changed (improved) its design the dual use diode part was no longer suitable as a fuse. Ooops.

I suggest providing an extra fuse with the Mooshimeter.

4., When I start the iPhone Moosimeter app it frequently downloads an update – it takes about 75 seconds. Why? Three updates in 30 minutes? This may indicate iPhone ignorance on my part and it is an irritating time waster.

5., The data sampling is controlled by the parameters at the bottom of the screen (iOS). (1) Hz (Frequency) with ranges of 125, 250, 500, 1000, 2000, 4000, & 8,000 Hz. The number of samples taken is smpl (samples) with ranges of 1, 2, 4, 8, 16, 32, 64, 128, & 256. Suggested guidelines for various measurement situations would be very nice. The setting of these two parameters will control the number of digits displayed, but I haven't observed that they affect the digits displayed in the plots.

For example, if the F/S settings are 125/1 the display shows five decimal places. Increase the sample rate to 128 and the display shows six decimal places. The extra digits may seem impressive but are they needed or desired in most situations. The internal Temperature is a good example. Any digits beyond one decimal place are bogus. Why display them? See Fig. 9. Over a six-second period the temperature ranged from 26.45°C to 26. 55°C.



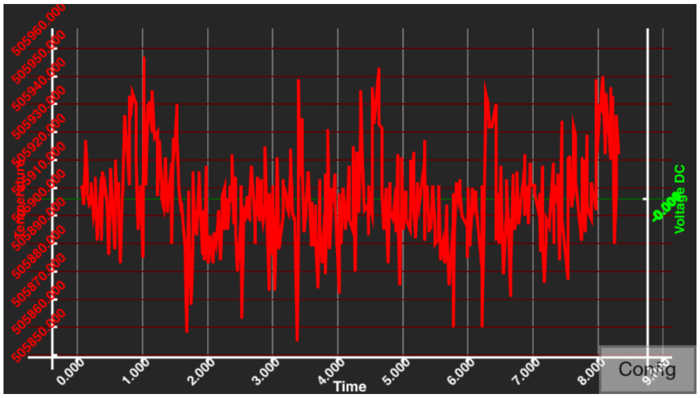


Fig. 21a - Int. temperature plot. Note 3 decimal places. Fig. 21b – Similar Fig. 21a plot using RAW data values.

User's Guide comments

As a technical writer, I have my own opinions on how to organize and format a User's Guide. This first look is not a review of the very brief User's Guide.

An engineer probably wrote the User's Guide. It has details often omitted in other DMM User's Guides. Thank you James.

<u>Old school vs. new school</u>.

A. You are expected to read the 23 page pdf file electronically. Your pdf reader will provide the page numbering. What if you print the User's Guide? **Number the pages**. We technical readers are used to the document page numbers not agreeing with the pdf file pages.

B. The section headings are top centered and kept one topic to page. While this professional style is nice, there is a lot of empty page space, probably 50% or more. The nice photos are a formatting constraint, but a more efficient format would cut the User's guide page count to below 12 to a **format that would fit into the carry case and would be a nice benefit.** Personally, I like the section headings left justified, especially for electronic reading because your focus is on the left column not the top center.

C. **All figures MUST have a figure number and caption.** How else may you reference the User's Guide? Missing captions are Power Factor, Opening (3 places), Replacing The SD Card, and Resetting the Mooshimeter.

D. **All technical documents need an Index.**

These comments are a bit fussy. The user will most often use the User's Guides in a reference or lookup mode. **Provide an Index**. I tested the idea of copying the User's Guide, removing the excess space, and simply reducing it to a size that would fit into the carry case. The text was too small without additional and time-consuming reformatting/typing. Taking on this project will depend on how much I use the Mooshimeter.

Ideas for the re-design

Most products that sell well are considered for a redesign to further reduce costs and implement improvements. Here are a couple quick ideas that come to mind during this first look.

1. Add a pushbutton wakeup switch.

2., Move the status LED to a position more easily seen – or flip the case lettering so the user will have the status LED facing him. This is the lowest cost solution. You can see the flash slightly reflected off the AA cell holder, but it is still not clearly visible.

3., Make the reset switch and Micro SD card accessible without having to open the case.

4., After about 8 days of use the black test lead socket letters; V, Ω, C, & A were no longer readable. The markings had worn off. The symbols are raised plastic so a chisel tipped black felt pen fixed this, but a future build should use a better, perhaps epoxy, paint.

Mooshimeter video references

There are many videos on the Internet related to the Mooshimeter. I have listed only a few. A later introduction overview that includes many of the examples of the others is #6 below. Check it out first.

0. Here is the official site: https://moosh.im/mooshimeter/ Most videos the provide the images are listed below.

1, Mooshimeter launch video: https://www.youtube.com/watch?v=TIJ8R2O1WJc shows early cream case.

2. Mooshim Engineering Videos. Most of these show the early model cream case and early versions of the software.
   A. Checking battery voltage and current of 2006 Honda Civic.
   B. Similar to the above with drive installation and better testing (brake lights, starting, blinker working etc.)
   C. Part 2 of "B" video. Continuing electrical measurements while driving.
   D. High Voltage testing of the Mooshimeter Rev E using a very large Tesla coil example.
   E. Mooshimeter as EKG measuring heart rate. James conducts the short video wherein two conductors measure the voltage from the hip to the throat to pick up the heartbeat.
   F. Quick Battery Discharge test. Simple voltage and current monitoring.
   G. Raw video: Car Electrical analysis with a Mooshimeter. Similar to "A" above, done by James.

3. Unboxing and Test: https://www.youtube.com/watch?v=tmDFOdqnrCQ Shows line voltage to tesla coil and power factor of a coffee grinder.

4. Mooshimeeter disassembly: https://www.youtube.com/watch?v=RzHyp5nkwmU Current clear case. The video states that the case must be opened to press the reset button and insert/remove the Micro SD card. You don't see his face, but it sounds like James is doing this video.

5. Measuring small resistances in live circuits; https://www.youtube.com/watch?v=aS8hlYUBxyE The text says: "In this demo, we measure a very small resistance (186µOhms) in a live circuit by using both channels of the Mooshimeter and a DC current clamp. James is doing this video.

6. Mooshimeter Introduction: https://www.youtube.com/watch?v=2VM9_mdSc24 This summary video starts with a variable transformer AC voltage measurement and flashes through many of the detailed applications listed above.

7, Solar Panel Demo: http://www.getlinkyoutube.com/watch?v=9T9UxeFDdWU Two channel of current and voltage being measured. James is doing this video. This uses the cream case Mooshimeter. This site allows you to download the video at various resolutions.

Mooshimeter document references

Several document (pdf) files are available at the following links. Most Internet sellers will have the document files on their websites. The general documentation link is at: https://moosh.im/documentation/ In addition to the three documents listed below there are links to the various blog entries. **The best one page "description" of the Mooshimeter is from the Mooshimeter Cheat Sheet.** See that page-space-compressed description reproduced in appendix B.

0. Here is the official site: https://moosh.im/mooshimeter/ You will find text and images describing the Mooshimeter and its features.

1. Specifications: https://moosh.im/mooshimeter/specs/ These are not in pdf format. You will have to copy them if you want to add the specifications to your library.

2. The Users Manual: https://moosh.im/s/manual/MooshimeterManualRev1.pdf This is Rev 1. Read this for the hardware measurement connections and specifications.

3. Mooshimeter Cheat Sheet: https://moosh.im/wp-content/uploads/2015/01/MooshimeterCheatSheet-V0.pdf This is V0. Read this for displays and what the software does.

Observations and conclusions

The Mooshimeter is a Kickstarter shirt pocket smart phone wireless two channel DMM with impressive specifications. Created by James Whong the accuracy specifications are better than the 1% usually reserved for expensive DMMs. Two DMMs would be required to make two simultaneous measurements. The additional ability to plot data and relate the two channels for more complex measurements such as power, and power factor sets the Mooshimeter above most portable low cost instruments.

The two AA cells will provide power to remotely gather data for six months (user specified buffer 1 to 256 samples) at up to 8,000 Hz. onto a micro SD Card.

The article provides a first look at the Mooshimeter itself. It attempts to fill in a few missing parameters and suggests user made probe lead accessories. Future articles will address such intriguing topics as making measurements and using the smartphone software application.

Comments, suggestions, ideas, questions, corrections and article copy (by title) requests are welcome at: rjnelsoncf@cox.net Richard J. Nelson is a very common name and the "cf" differentiation is for Calcfan.

Richard J. Nelson

V1 May 31, 2016

Notes for: The Mooshimeter – A First look

*(1) See my July 2012 article titled Measuring Calculator Current, 6 pages, 9 figures, 2 notes, and **350 KB as a pdf file**. This was published in HP's now inactive calculator newsletter, HP Solve, #28, page 31. See: http://h20331.www2.hp.com/hpsub/us/en/hp-solve-2012.html . Also, see a follow up October 2012 article titled Measuring Calculator Current – Nine Measurement Examples, 10 pages, 19 figures, 5 tables, 5 notes, and **1 MB as a pdf file**. You may find the article at the same link as above in Issue #29. The examples article measured the current drawn when **OFF**, **ON KEY**, **ON**, and **RUNNING**. The current ranged from <0.1µA (limit of DMM) to 19,900 µA (19.9 mA). This is a range of ≈ 200,000 to 1. The article describes the issues and measurement techniques of having the current meter "confuse" the calculator's operation.*

(2) An Internet electronics supplier, Circuit Specialists, is within driving range for me so I could get one immediately – unless they are sold out, which they were. They expected a new shipment so I kept calling until they arrived. https://www.circuitspecialists.com/mooshimeter_wireless_multimeter.html Also see their description and specifications in Appendix A.

(3) A good smartphone example is Flir, a manufacturer of infrared imaging instruments. They have lower cost models that are attractive to a wider range of users because they are used with a smartphone. This is a limitation because we heavily use our smartphones. In the case of the Mooshimeter the Blue tooth capability

of the smart phone is used to make the data collection wireless. This is a big step forward in measurement capability.

(4) See http://www.olin.edu/blog/career-and-graduate-stories/post/james-whong-09-develops-mooshimeter-judy-xu-18/

(5) Here is a quote from: http://www.pcworld.com/article/248142/email_vs_im_vs_sms_choosing_the_right_one.html

"Instant Messaging
Instant messaging, or IM, is fast – it has "instant" right in the name. It is a particularly good tool for communicating within an organization, but may not be the best choice for messaging third parties."
"Pros:
- It is instant. Assuming the intended target is online, the message will be received as soon as you send it.
- It is brief. Instant messaging tends to be confined to a single thought or sentence rather than a lengthy essay.
- It is conversational. Instant messaging has an immediate back and forth exchange that lets you collaborate in real-time.

Cons:
- It is intrusive. Instant messages pop up on the screen, announcing their presence with loud alert tones when you're in the middle of doing something else. Granted, you can configure the instant messaging software not to do that, but then you run the risk of missing the incoming message altogether which negates one of the "pros" of instant messaging.
- It is proprietary. Communicating via instant messaging requires that both parties have accounts with a given instant messaging service. There is some cross-communication, and there are instant messaging clients that are capable of simultaneously working with multiple instant messaging services, but basically if your target recipient is using AIM, you need to be logged in to AIM as well.
- You need to sign in. If you don't log in to your instant messaging service of choice, nobody can communicate with you.
- You lose the history. You can log your instant messaging communications, but each exchange is like an island unto itself. When you need to reflect back on a chain of communication a year from now, instant messaging logs will not be very helpful."

(6) I counted the threads per inch at 50 and 48 is the closest standard size. Could this be a metric size? 50 threads per inch is 19.7 threads per centimeter. Do not lose them. The length is 0.62". See Fig. N1

(7) I wanted to have a resistor that would measure as 10.00 ohms and I bought a batch to select one. See my May 2016 article titled Sorting 10 Ohm 1% Resistors, 4 pages, 3 figures, 1 table, 5 notes, and ***600 KB as a pdf file****. The value distribution is not what was hoped for; it was biased entirely on the low side.*

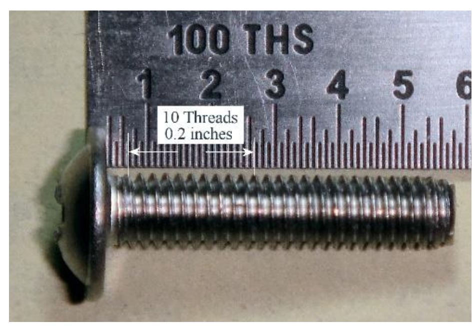


Fig. N1 – Case screw.

(8) The intent is to select a value that will fall in an often used range. Ten ohms is in the lowest range. A 1 KΩ value is on the border between the 1 KΩ and 2.5 KΩ ranges. The exact value is less important than its stability – you simply record it. It will serve as a reference value that should not change with time. A metal film resistor typically has a 50 ppm per degree Celsius temperature coefficient. This will work.

(9) Circuit Specialists sells the same test leads as their number T3008, for $5.95. See them at:

https://www.circuitspecialists.com/t3008.html


←Fig. N2 – $6 CAT III CS probe set.

*(10) See my July 2012 article titled <u>Home Brew Test Fixtures</u>, 8 pages, 15 figures, 1 table, 7 notes, 1 Appendix, and **1.2 MB as a pdf file.** The current revision is V4. Five fixtures are described. The component test fixture uses a special "must have" Grayhill Test Clip as detailed in Appendix A.*

(11) Either Lexan or Plexiglas may be used but Lexan is harder and stronger. 1/8" or 1/4" are the most common thicknesses available in hardware stores. I used 1/8".

(12) The switches are bonded to the Plexiglas using The last Glue. I roughened the Plexiglas using a battery powered scribing tool normally used for marking items. I also roughened the switch with course Emory paper. I self-threaded the banana plugs into the Plexiglas by drilling a hole just under the thread diameter by trial and error using a tapered reamer. I used the plastic plug insulator as a nut to further secure the four plugs. I cut these insulators on each end to maximize the thread area and reduce the height. The colors also aid in orienting the fixture when plugging it in.

In the spirit of the Mooshimeter, I also made a set of alligator clip accessories for the probes. I only had red so I colored one with black felt pent. The heat shrink tubing also identifies the lead. Black is the common.

Fig. N3 – Alligator clips & Pin sockets.

Fig. N4 – Probe alligator clip accessories.

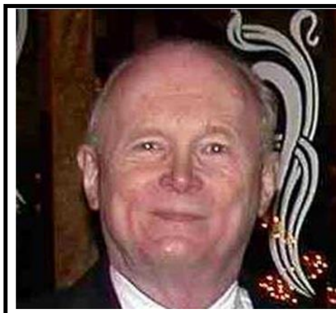
(13) The US National chains are Home Depot, Lowes, Ace, and True Value. Personally, in Mesa AZ, I have found true value to have the greatest selection of nuts, bolts, and screws. Unfortunately, they are the furthest from me. The upper screw in Fig. 8 is from True Value. Screw pitch is traditionally/formally defined as the spacing from thread to thread, but it is common practice to define it as threads per inch.

(14) Here are links to the TI data sheets.

Input processing. **http://www.ti.com/lit/ds/symlink/ads1292.pdf**

Bluetooth communication. **http://www.ti.com/lit/ds/symlink/cc2540.pdf**

About the Author



Richard J. Nelson

Richard J. Nelson is a Mesa AZ retired EE who spends much of his time recreational writing on electronic, physics, USB microscope, and DIY related projects. Richards first electronics experience was building projects with the CK722 and 2N107 transistors in the mid 50;s. An amateur radio project was to convert a WWII SCR-522 aircraft VHF radio for 2M use. Richards's diverse career interests included doing failure analysis on Sky Lab door timers, and transmitting a radio signal around the earth from a Philippine amateur radio station he built which continues to operate today. Richard was a junior engineering team member that developed quartz tuning fork crystals. Tuning forks revolutionized the quartz watch industry. He measured the temperature rise of a biomedical implant using classical methods when others working for years failed using exotic and expensive methods. His five US and three foreign patents are for biomedical implant inventions.

In terms of published articles, Richard has written extensively on HP calculators and calculator development since June 1974. He has edited and published five newsletters related to HP calculators and is the founder of PPC. He proposed, managed, and published the one man-century effort PPC ROM. His most recent calculator newsletter articles were for HPs calculator newsletter, ***HP Solve*****,** as author and editor. Richard started an international annual conference dedicated to calculators called the Hewlett-Packard Handheld Conference, HHC, in September 1979, which continues to this day. HHC 2015 was held in Nashville TN. See hhuc.us for details and a list of these conferences.

Because Richard was an active HP User Group organizer from the very beginning of the advanced Calculator era, he has assembled the world's largest collection of HP calculator literature, brochures, books, articles, and manuals.

Richard enjoys all aspects of a DIY project from an idea to design, construction, measurement, testing, photographing, and its complete technical documentation. You will find his articles on HP's website, the website of the Microscopy Society of California, and the HHC website.

Appendix A – CS Mooshimeter Description & Specifications - Page 1 of 3

Bluetooth/Wireless Data Logging Digital Multimeter
That Uses Your Smartphone as the Display

ALL MOOSHIMETERS FROM CIRCUIT SPECIALISTS WILL INCLUDE AN 8GB MICRO SD CARD AND ADAPTER https://www.circuitspecialists.com/mooshimeter_wireless_multimeter.html

The worlds first smartphone multimeter and data logger!

- Wirelessly Connects to Android or iOS
- Measures current, voltage, resistance, temperature
- Measures 2 channels at once
- Data Logs to SD card (not included) for up to 6 months
- 24 bit precision gives you sensitivity to see small changes
- Includes accessory kit

The world's first smart multimeter that uses your iOS or Android device to capture and log multichannel measurements.

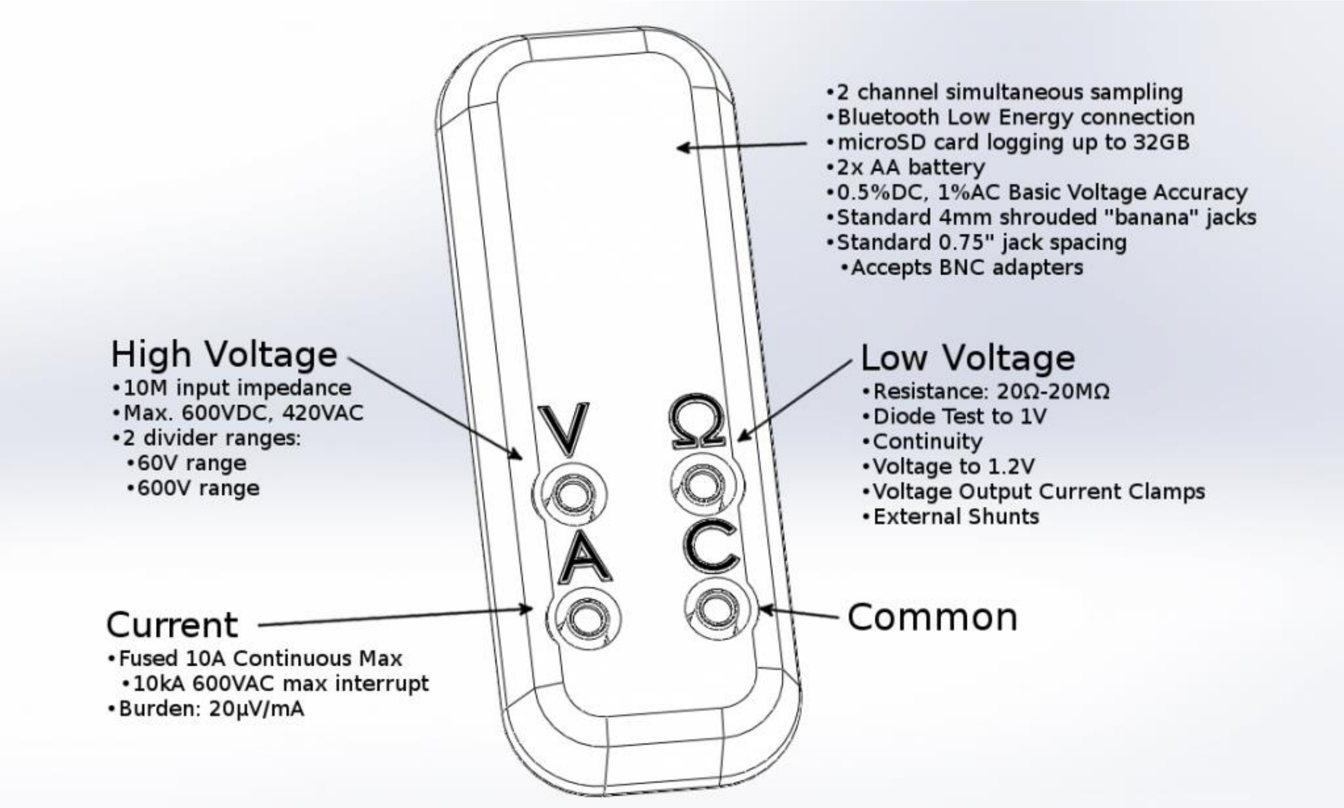
The Mooshimeter is a multi-channel circuit-testing meter that uses your smartphone or tablet, through Bluetooth 4.0, as a wireless, high-resolution graphical display. Safely measure 600V and 10A with 24-bit resolution from up to 150 feet away while logging results for up to 6 months.

Includes:
- Mooshimeter
- 2x AA batteries
- 3x 10A 600V CAT III Test Leads
- 3x Slide on Alligator Clips
- Tool Case

Technical Specifications:
- Voltage
  - Up to 600V, DC or peak AC
  - Up to 420VAC RMS sinusoidal
  - Better than 0.5% accuracy DC
  - Better than 1.0% accuracy AC for harmonic content below 1 kHz
  - >10 Megohm input impedance
- High Precision Voltage
  - Up to 100mV with <15nV per count resolution
  - Up to 1.2V with <200nV per count resolution
  - >10 Megohm input impedance
- Current, Internal
  - Up to 10 Amps
  - 20 µV / mA burden voltage (using factory fuse)
  - Less than 5 µA per count in 10 Amp scale

Better than 1% accuracy
- Resistance
  Better than 1% accuracy over 20 Ohms – 20 Megohms
- Frequency
  Better than 1% accuracy up to 1kHz
- Diodes
  Up to 1V @ 100nA
- Sampling
  8kHz dual simultaneous sampling
  4kHz analog bandwidth for most measurements
  24-bit resolution max
  >18 Effective bits at 125 samples per second
- On Board Storage – SD Card
  MicroSD Card Up to 32GB (More than a week of constant logging two channels at 8kHz)
  SD or SDHC (not SDXC)
- Radio:
  Protocol: Bluetooth Low Energy
  GATT Profile: To be released in 2014
- Wireless Range
  The wireless range has been tested empirically through the following media to an iPhone 5.
  50m air, line of sight
  5cm of refrigerator, door closed
  1m of 2006 Honda Civic – Engine compartment to the passenger seat
  10m air + safety shield of a Tesla Coil rock-bands testing facility

Applications:
- Power
  Simultaneous high-speed sampling of voltage and current gives the following power measurements:
  True Power
  Reactive, Complex, Apparent Power
  Power Factor
  Total Harmonic Distortion
  Phase Lead or Lag
- Impedance
  Measure the supply sag under load to estimate:
  Supply or Battery equivalent resistance
  Battery State of Health
- Current Measurement, External Shunt
  - Measure thousands of amps with sub-milliohm shunts
  - Measure precision currents with large shunts
  - Use the existing wiring for “quick’n’dirty” measurements
  - Use 1′ of 10AWG for 12µA per count resolution, up to several times the wires ampacity.
- Temperature
  - External Thermistors
    - Steinhart-Hart or Beta parameterized
  - External Thermocouples
  - Internal ambient temperature sensor
  - Internal temperature sensor for temperature drift compensation



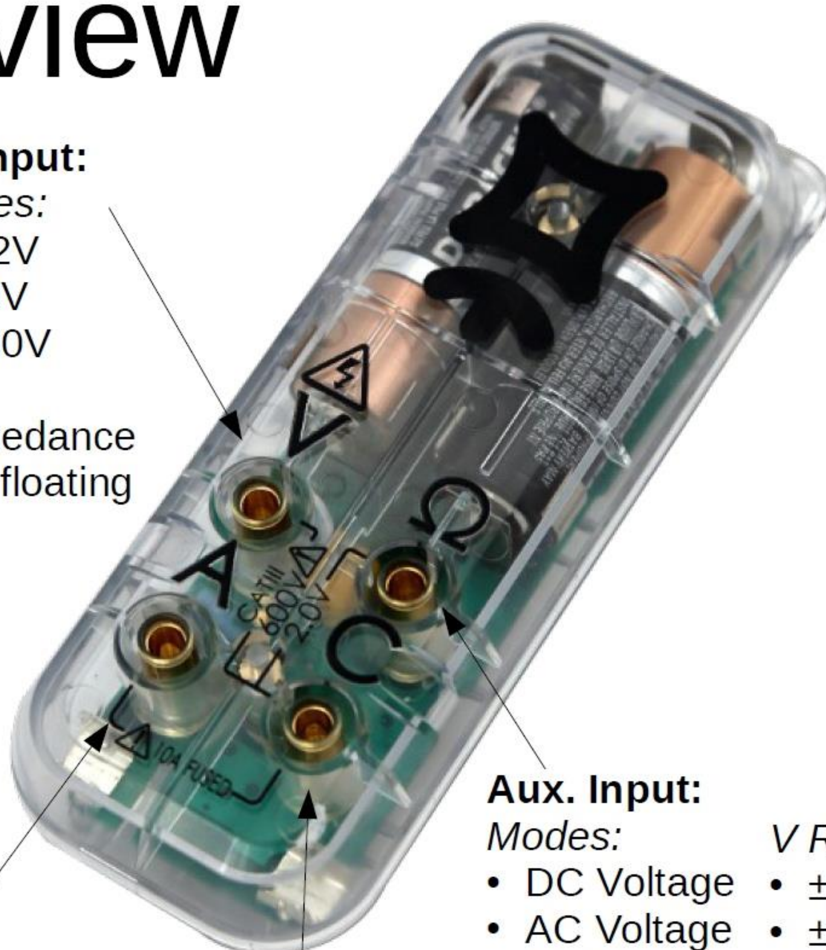
Users Manual

Related Products

8GB Micro SD memory card from Sandisk $7.99

Appendix B – Brief Mooshimeter Description & Features

Measurement Overview



High Voltage Input:

Modes:
- DC
- AC

Ranges:
- ±1.2V
- ±60V
- ±600V

10MΩ input impedance
± 1.2V range is floating

Current Input:

Modes:
- DC
- AC

Ranges:
- ±1A
- ±2.5A
- ±10A

Connected to C (Common) input by current sense resistor and fuse.

Common Input:
All other measurements are relative to this terminal

Aux. Input:

Modes:
- DC Voltage
- AC Voltage
- Resistance
- Diode Drop

V Ranges:
- ±100mV
- ±250mV
- ±1.2V

Ω Ranges:
- 1kΩ
- 2.5kΩ
- 10kΩ
- 1MΩ
- 2.5MΩ
- 10MΩ