The High Input Resistance Moving Coil 0-1000V & 0-10,000V DC Voltmeter.

Dr. H. Holden. Nov. 2026.



Applications:

This meter is intended for Tube Gear service work, in equipment with high resistance circuitry and high voltages. Such equipment includes Vintage TV's using Electrostatic CRT's such as the 7JP4. Typical sets which incorporated these were the Admiral 19A11 and the Motorola VT-71.

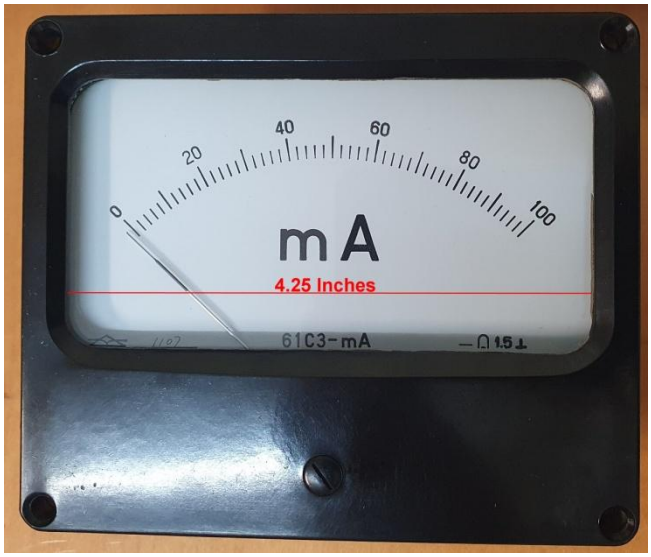
The 7JP4 CRT, and its final Anode, is normally supported by a 6kV output RF power supply which cannot support high current loads. Also, the support circuitry for the CRT has very high range resistance values and high voltages. This includes a voltage divider (EHT bleeder) chain which supports the deflection plate voltages, the focus voltage and they also often supply the high range voltages to the Vertical Deflection output stage.

To measure DC voltages which are in the Range of up to 6kV with minimal loading, it requires a meter (or probe arrangement) with a very high input resistance, at least 100 Meg Ohms.

This meter has many other applications where a high range input resistance is required, for example in Electrostatic CRT based Oscilloscopes where similar circuit conditions to the electrostatically deflected TV's apply. Many DMM's, which are capable of measuring up to 1000V tend to have a 10 Meg Ohm input resistance, this is too low for very high resistance circuitry. Although there are a range of High Voltage probe which can be used in conjunction with a DMM.

Meter Design:

The design of this meter was inspired by the idea of using up parts I already had in my workshop stock. Some years ago I had bought some large scale 0-100mA meters.



These are Chinese made a 61C3 type, very high quality with a Glass face and a Linear scale. All of the screw fittings in them have a threaded Brass bush and the casing is a dense resinous Bakelite material, not a Thermoplastic. The meter glass face is held in place internally by screws and small clips (not just glued as many cheaper meters are) The movement appears to be very high quality, and the whole assembly reminiscent of the way vintage moving coil meters were once made.

On opening the meter up I found it had a combination of a shunt and a series resistance, to serve its role as a mA Meter.

On removing the shunt, I found that the movement required around 6.6 mA to get to FSD. I then incorporated a 47 Ohm resistor in series inside the meter. This converted the meter itself into a unit which went to its FSD (full scale deflection) with around 0.32V applied to its rear terminals. There was a specific reason to do this. I wanted to apply back to back meter protection diodes, and this voltage is too low to result in any significant forward conduction. Other resistors would still be required outside the meter body, because the plan became to make the meter behave as a 5V FSD unit.

To convert the meter itself into a 5V FSD unit, with a very high input resistance, it then requires an OP amp to drive it, a calibration resistance, and a 5V reference voltage.

The OP amp chosen is the TLC272. One reason is that the input resistance of these OP amps is 10^{12} Ohms. And in this case the highest source resistance of the divided down input resistance, on the 0-1000V scale is around 500k Ohms. This source resistance being about one 2 millionth of the resistive load imposed by the OP amp's input. Also in the single supply operating mode, both the OP amp's output and input voltages extend to the negative supply rail. This OP amp also works to low voltages, such a 3V, however below a 5V power supply source, the meter calibration would fail because it is configured as a 5V FSD system.

Unconventional Use of a Part:

The meter circuit is powered by a 9V battery. In any battery powered machine, ideally there is an indication of the battery condition. One method is to use a comparator (or OP amp used as one) to measure the battery voltage and activate or deactivate or flash an LED when the battery has fallen below a fixed level. This alerts the user to the fact that the battery needs changing.

In this case I decided on a somewhat unconventional method, using the 7805 voltage regulator, the reason being I could get two functions from the one part.

On testing 7805's, their output voltage is unique to each specimen and can reside in the range of 4.9V to 5.1V, sometimes with more spread. I simply tested a few to find one where its output was very close to exactly 5V. These regulators keep a stable output voltage over many years, though when they have run hot for decades the output voltage will drop a little.

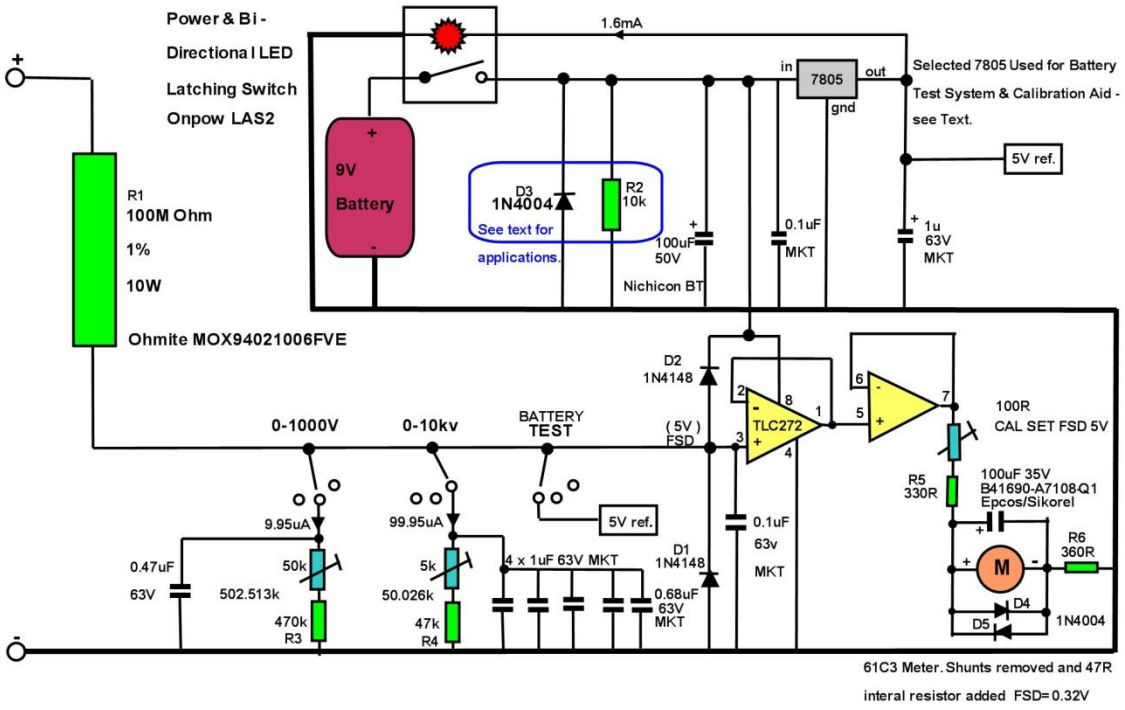
In this case the current asked from the 7805 regulator is insignificant, it is only about 1.6mA for the power LED that is integral with the power switch. That is all the voltage regulator powers in this case. It does not regulate the supply voltage to the OP amp or the meter. Imagine that, a 7805 voltage regulator to power nothing more than an LED, however, there is method in the madness:

This 5V reference voltage becomes a Calibration Aid. In that it is used to set the OP amp and meter to FSD (full scale deflection) with the 100R preset resistor & the range switch set to "Battery Test".

The interesting reason that this also forms a “Battery Test” circuit (in this case) is that the 7805, maintains its output voltage at 5V until is input voltage falls to the region of 6V to 6.2V, and below that the output voltage rapidly falls as the internal regulation in the 7805 fails. Therefore, with the 9V battery’s voltage above 6.2v, switching to Battery Test, the meter will read 100%.

As soon as the 9V battery gets below a terminal voltage or around 6 to 6.2V, the meter cannot reach 100% on the battery test position of the switch and it is clear that the battery requires replacing. Also the brightness of the LED powered by the 7805 also tends to drop fairly abruptly below the 6.2V mark presented to the regulator’s input.

The Schematic:



0 - 1000V and 0 - 10,000V DC Meter with 100 Meg Ohm input resistance.

The particular 613C meter movement is not particularly well damped mechanically. The type of 100uF electrolytic capacitor used in parallel with the meter, which helps damp the motion of the movement when the unit is not powered, is a high temperature very low leakage part EPCOS/SIKOREL type.

When the meter is running, the rate that the pointer moves is also slowed down by the filter capacitances associated with the two calibration resistors to make the movement of the needle more gradual but without too much delay. Also, if the meter is accidentally connected to a very high voltage AC source, due to stray capacitances the input voltage could climb very high and the filter capacitors help protect the IC from this issue too.

Also at switch off the 100uF filter capacitor on the 9V supply to the OP amp helps to slow down the collapse of the 9V supply rail. All of this is in the interest of being kind to the meter's movement and not having it slam to a stop at either end of its scale.

Other IC & Meter Protections:

There is the possibility that for a moment, none of the contacts in the rotary switch could be closed because it is a break before make switch. Therefore to ameliorate possible capacitive coupling effects from an accidental contact with a high voltage AC source, an additional 0.1uF capacitor is connected on the OP amp's input pin 3 and two protection diodes there too, to make sure the OP amp's input terminal on pin 3 never gets raised to an excessive voltage.

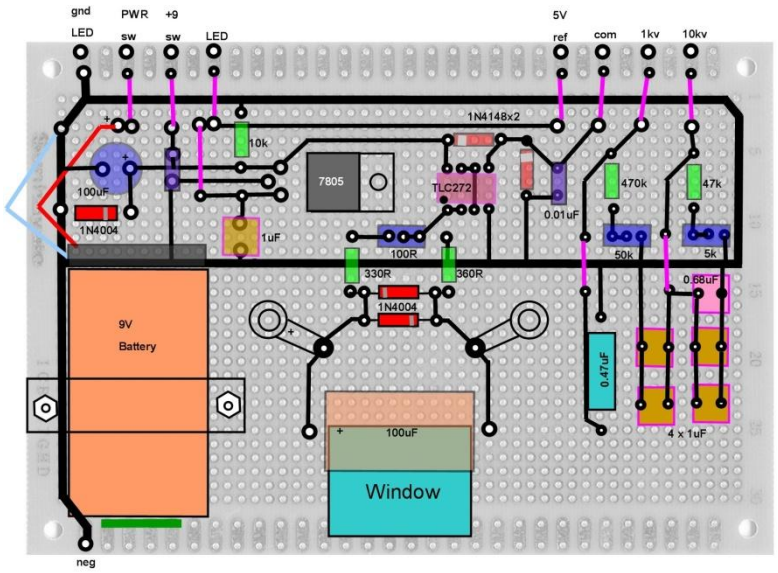
Fortunately the 1N4148 diodes have very minimal leakage currents, in the order of 25nA. These diodes prevent the input voltage under any circumstance going significantly above or below the battery's + and - terminal voltages.

However, there is the possibility that when the unit is switched off, and therefore the battery is not connected, that the OP amp's + supply terminal is not clamped to a specific voltage. In this case any conduction in D2 has the DC load of the 10k resistor R2 as well as the load of the 7805's input circuits. As these are substantially lower than the resistance of the 100M input resistor this helps hold the voltage down well below 5V for voltages of 20kV or more, even if the switch contacts on the rotary voltage range switch were all momentarily open.

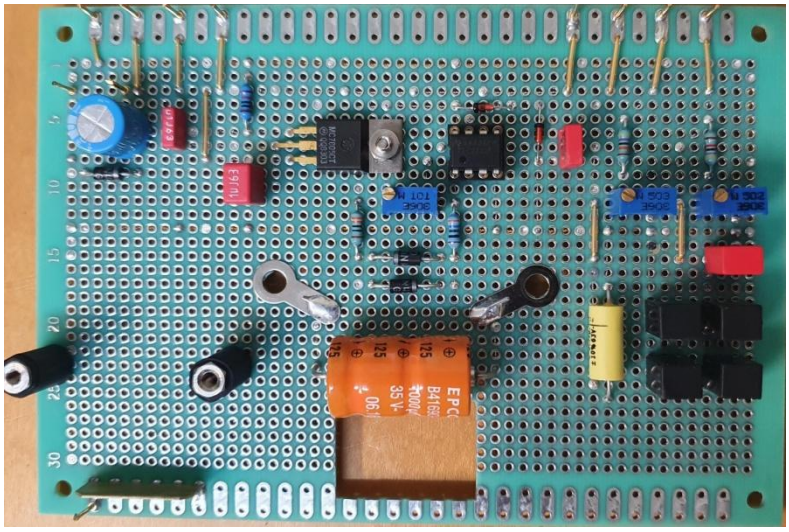
The diode D3 is present just in case an accidental momentary reverse touch of the battery clip occurred while the user was changing the battery and the power switch was on.

Board Layout:

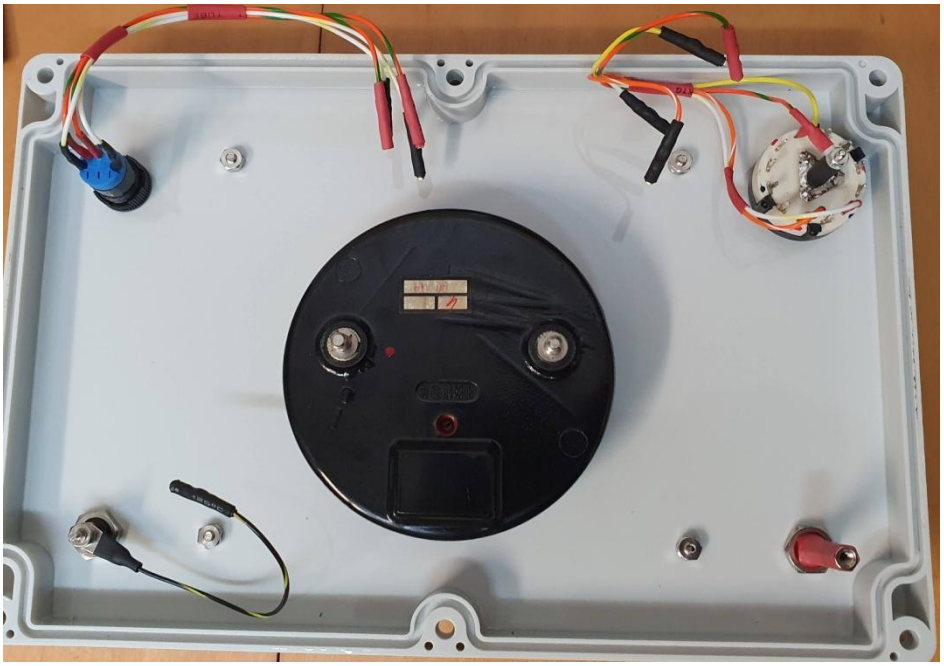
This was done on 2.54mm x 2.54mm plated through hole spot board. There was plenty of room. The PCB mounts on the two 4mm studs on the rear of the meter. A widow (rectangular hole) in the pcb was required to clear a rectangular projection on the rear of the meter body:



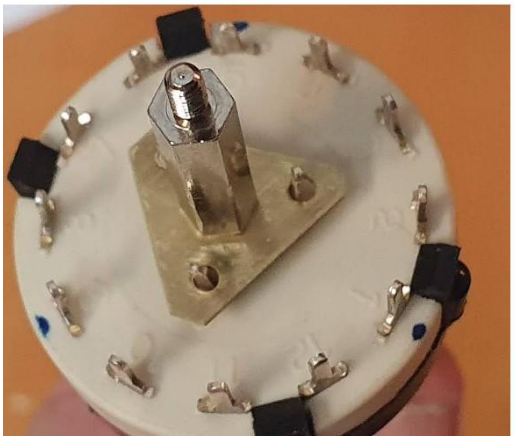
Construction of the Board:



The board connects to the peripheral devices by Jaycar 0.9mm single pin Gold connectors. And as noted the board is mounted to the 4mm Studs on the Meter body. These 0.9mm pin/socket connectors are very handy, because it means that the board can be removed and or re-fitted without having to solder or de-solder anything. The photo below shows the situation prior to fitting the prototype board:

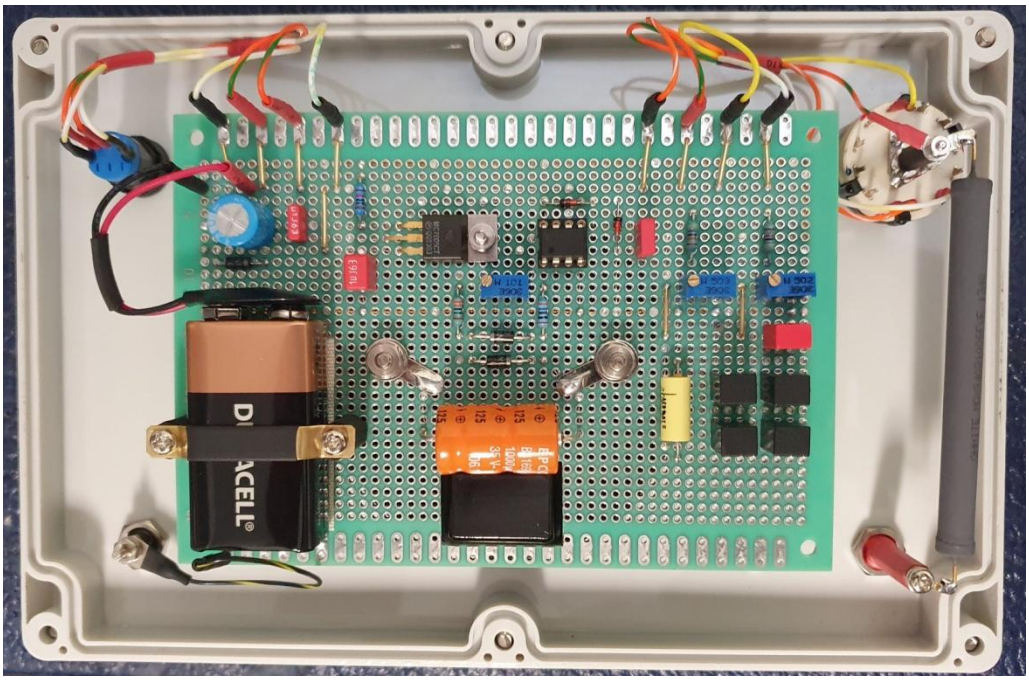


To be able to mount the 100 Meg Ohm resistor, in a manner where it could also be removed if required, it was mounted on two posts. One 3mm hex Brass threaded extension post was applied to the Banana connector for the Positive meter terminal. Since the other side of the resistor was connected to three connections of the 3 position rotary switch which are common, a small Brass triangular shaped plate was made with 4 holes in it. One 2mm central hole was used to fit a 2mm threaded extension post and three 1.5mm holes to fit over the three central pins on the rotary switch prior to soldering:





Fitting the board and adding the 100M Resistor:



The plastic housing was mounted on two custom tilt feet, made from 10mm thick black Nylon.

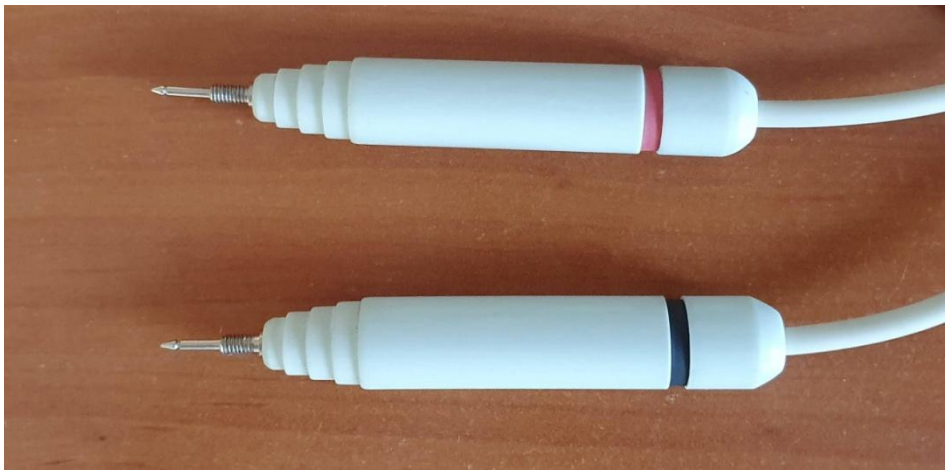
The photo below shows other views:





Meter Leads:

I machined some 16mm diameter (about 0.63”) Fibreglass Rod and used some flexible 20kV rated White Silicone rubber covered wire. The fibreglass is a little off white and almost has the appearance of Ivory:

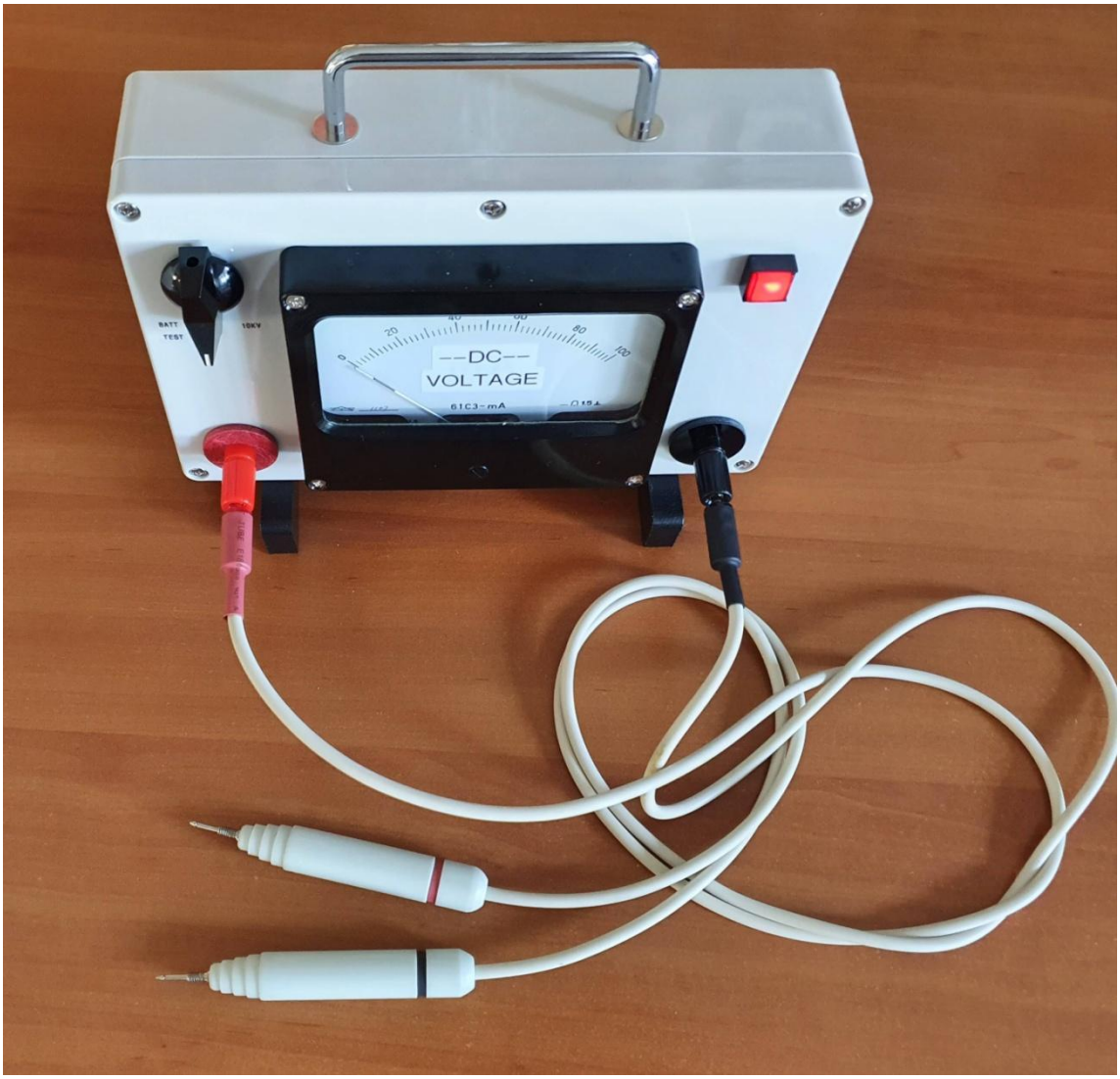


I had cut grooves in for color coding and initially intended top paint those with Red & Black Enamel paint, but I decided it was easier just to to use some short sections of Heat-Shrink sleeving to acquire the colors that way.

The threaded probe tips were taken from some modern probes. These also accommodate screw on accessory Alligator clips if required:



The photo below shows the finished unit with its leads:



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