Meters: The Gateway Test Instrument

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An affiliated club

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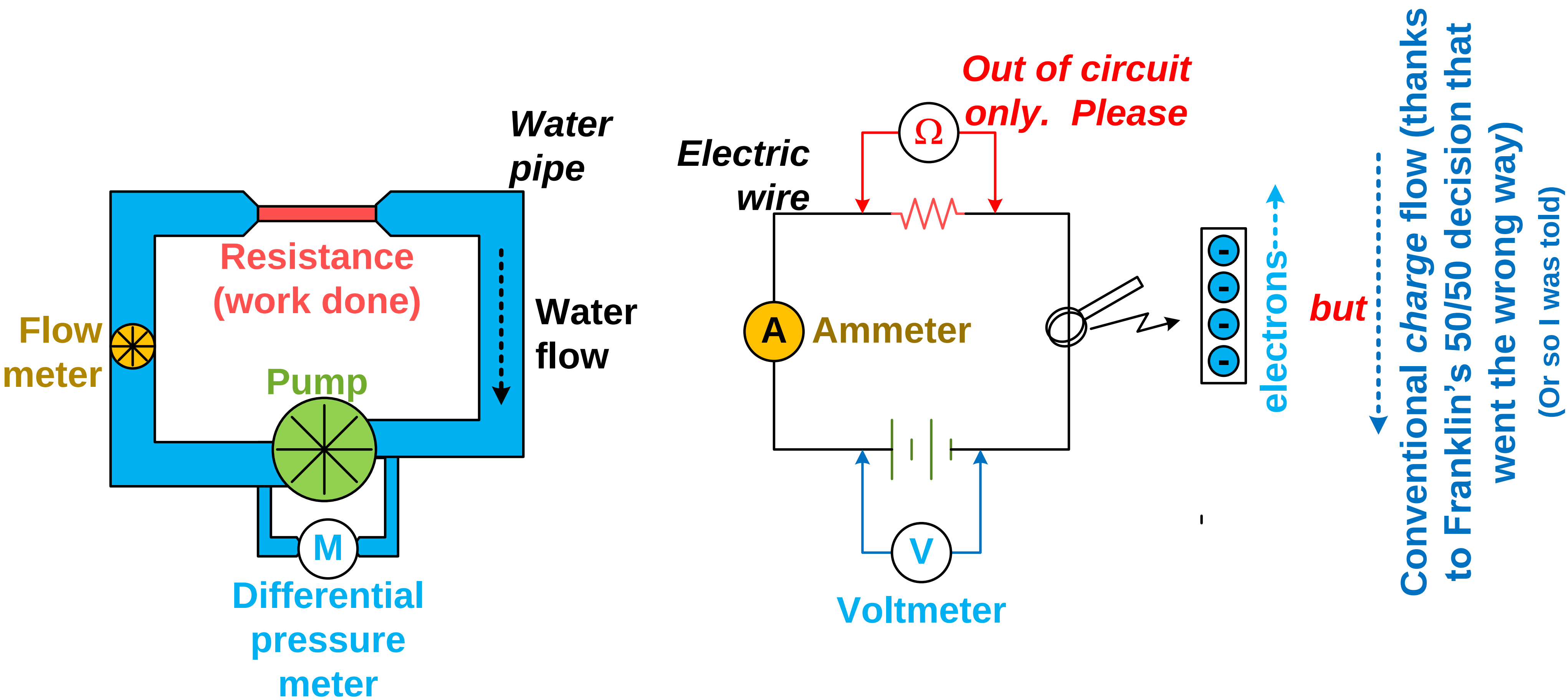
Humor me for a brief review



What we're going to talk about is measuring "stuff" going on in a circuit. You don't really know stuff about stuff until you can measure stuff about that stuff. So we'll investigate measuring the "stuff" of an electrical circuit: the charge flow, or current, measured with an ammeter (A), the amount of "push" on the charge flow, or voltage, measured with a voltmeter (V), and the resistance to that charge flow, measured with an Ohmmeter (Ω).

Analog Meters

Basic meter

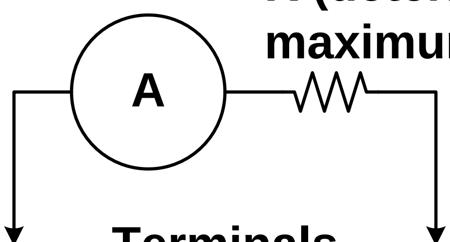
http://www.justscience.in/articles/types-and-usage-of-voltmeter/2017/05/25

Volt-ohm meter (VOM) – also measures current and sometimes more

Probes

https://www.delcity.net/store/5-Function-Analog-Tester/p_802130.h_802131.r_IF1003?mkwid=saHEnkkZp&crid=38094426869&mp_kw=&mp_mt=&gclid=EAIaIQobChMIs9zk_ci_5QIVEJSzCh1HnQ8MEAQYAyABEgKr-_D_BwE

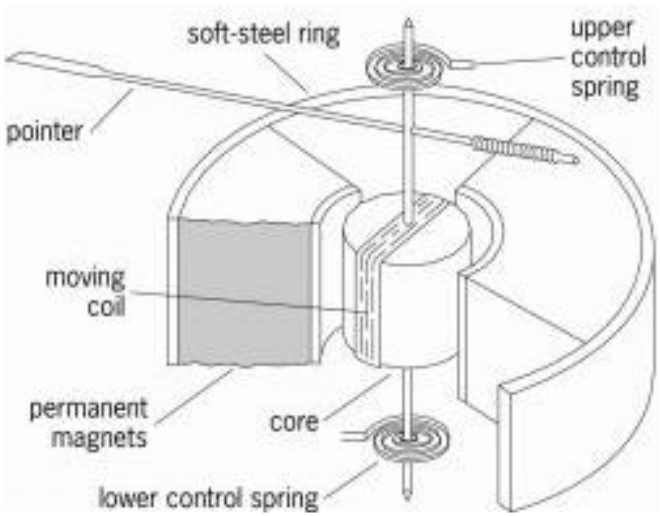
R (determines the maximum voltage read)



R=E/I
E = max V measured
I = current for max deflection

To make ac voltage and current measurements, use a diode in series with the meter and calibrate the meter appropriately.

Priniciple of the D’Arsonval Movement

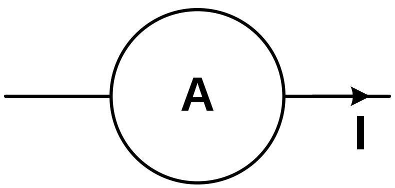


When an electric current is passed through a coil placed in a magnetic field, it experiences a force. This force causes a torque in the coil, which is fixed to a spindle. The spindle can rotate in fixed bearings.

The rotation of the spindle is proportional to the electric current passed through the coil. This torque that is produced is balanced after a movement against the restoring torques of control springs. This is called a *D’Arsonval Movement*, named for Jacques-Arsène d'Arsonval, a 19th century French physician and inventor.

Credit: https://instrumentationandcontrollers.blogspot.com/2012/06/darsonval-movement-electrical-analog.html, https://en.wikipedia.org/wiki/Jacques-Ars%C3%A8ne_d%27Arsonval

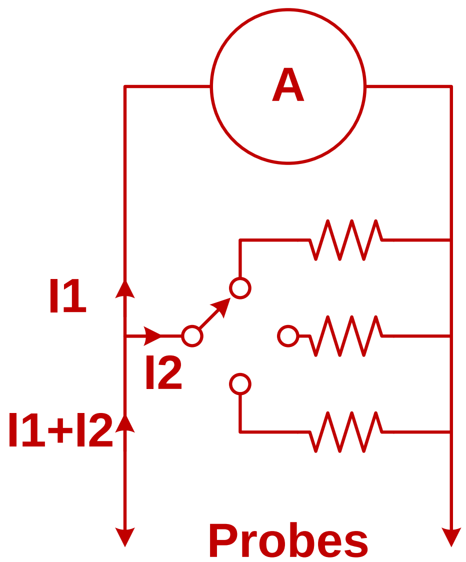
Block diagram:



The D’Arsonval meter movement, the basis of all analog meters, is a *current-operated* device. Ideally it has no electrical resistance, but not so in the real world. Depending on the sensitivity of the movement it needs a certain current for full deflection. For the purpose of making general-purpose meters, the less current required the better.

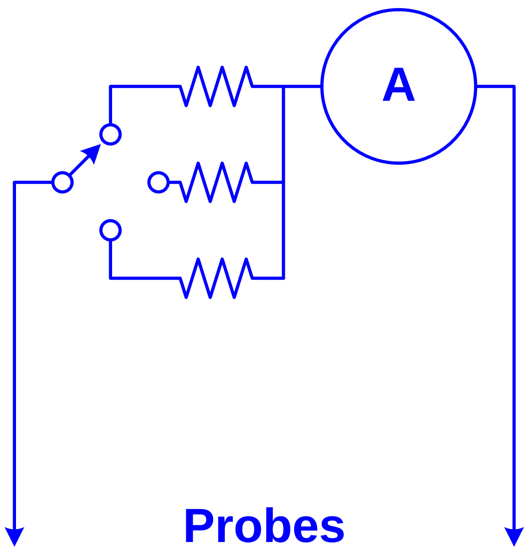
Making the basic D'Arsonval meter movement measure current, voltage, or resistance in different ranges

1. Current measurement (amps)



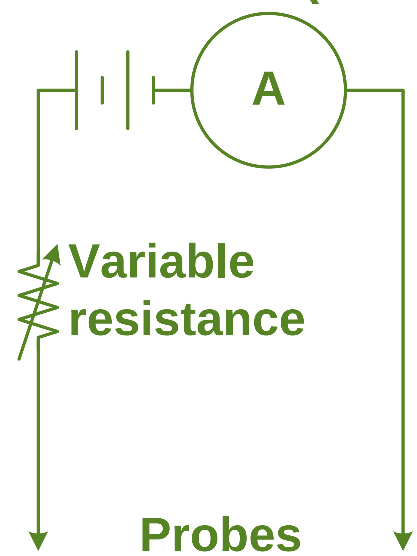
Switch selects the value of resistance that diverts just enough current from the meter movement to make the full-scale reading whatever is desired.

2. Voltage measurement (volts)

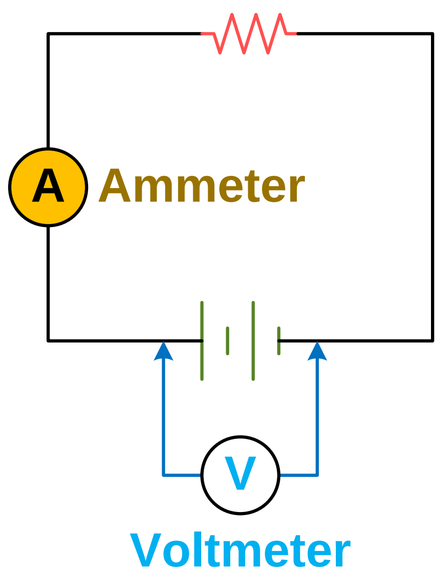


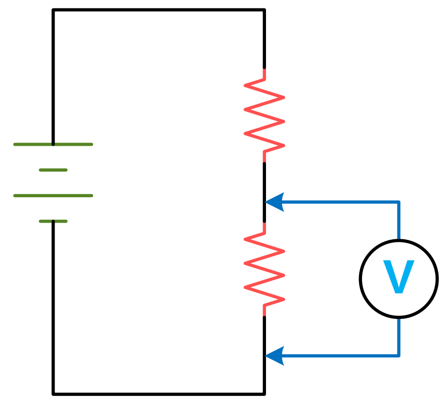
Switch selects the value of resistance that limits the maximum current to that which deflects the meter movement to full-scale at the desired maximum voltage reading

3. Resistance measurement (ohms)



Variable resistance sets maximum deflection ("0 Ohms") with probes shorted. Slightly more complex circuits can set different resistance ranges.

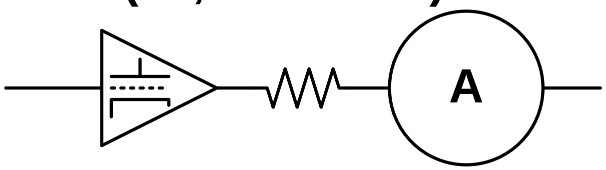




Ideally meters do their magic without changing the circuit in any way. This means that the ammeter has *0 resistance* so that it doesn't change the current when it is inserted. The voltmeter would have *infinite resistance* so that adding it doesn't draw any extra current. Obviously these conditions are a pipe dream. In the real world we need only get close enough that these are decent approximations.

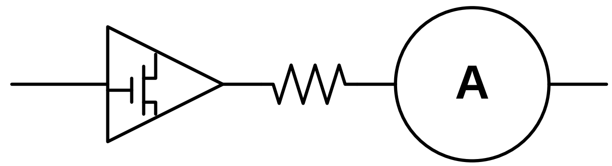
There Have Been Many Solutions to Overcome the Current Requirement of the D’Arsonval Meter Movement

The vacuum tube voltmeter, VTVM (ca, latter 60s)



High input resistance tube amplifiers

The transistorized voltmeter (ca, 70s)



High input resistance transistor amplifiers (usually FETs, first JFETs then MOSFETs)

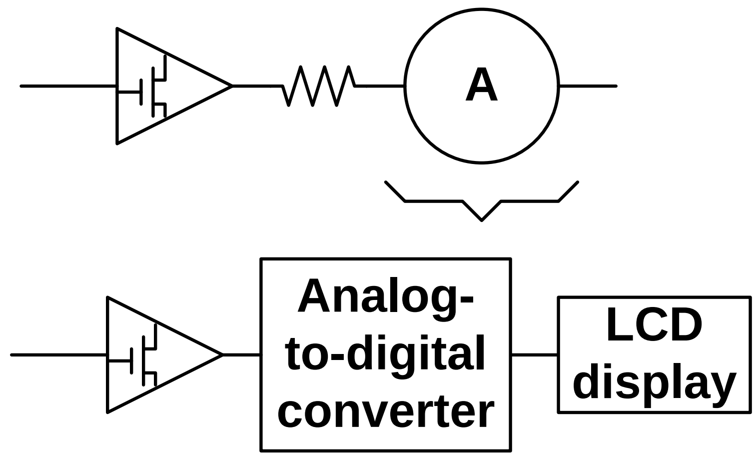
The amplifiers were voltage devices, so a resistor between the amplifier and the D’Arsonval meter movement converted the voltage output to a current. Input circuits were modified somewhat to accommodate the high input resistance.

Damaging a Meter by Overloading It's Input

It was quite possible to damage early voltmeters by applying excessive voltage or current to the meter. One could burn out the meter coil. You could also bend or even break the pointer (ask me how I know that – ask my dad if you really want an earful). You could cause the calibration to go bad by partially demagnetizing the permanent magnet, you could burn out the scaling resistors (but probably after you damaged the meter movement itself). And if all else failed, you could drop it.

With the addition of amplifiers you could design the amplifier to saturate before burning out the meter movement. This was a big improvement, though creative people continue to break meters. *"I keep making gear more idiot-proof, but they keep making better idiots!"*

The Next Improvement: the Digital Voltmeter (DVM)



Some have a marginally-useful pseudo-analog bar graph to help with relative measurements that are best displayed in the analog domain (e.g., peaking or dipping a circuit).

Going digital and technical progress has allowed other functions to be added to some meters:

1. *Auto-ranging* meters automatically set their range based on the voltage, current, or resistance presented.
2. Conventional meters are calibrated with the RMS voltage for sine wave measurements *only*. *True RMS* meters can calculate the RMS value of other waveforms.
3. The switch position with a diode symbol puts a set current through the leads and the meter displays the voltage drop. Silicon diodes have about 0.6 – 0.7 volts forward drop, PIN diodes have closer to 0.4 volts drop.
4. In a mode with a sound symbol, a tone sounds when the resistance between leads is very low. This is handy for identifying individual wires in a cable (sometimes called *ringing out* the cable).
5. A “Low Z” position adds a resistance between the leads, which can be handy in electrical circuit work, where “ghost voltages” can exist.
6. Specialized meters have a ferrite-loaded loop which allows non-contacting ac current measurements if you can get an isolated current-carrying lead. (A Hall Effect transducer, if used, can also measure dc.)
7. Some can indicate the existence of voltage when brought into proximity of a conductor with line voltage on it. This can be handy for electrical work.
8. Some (specialized) can output sequential voltage readings to a spreadsheet for subsequent analysis.
9. Some can make limited capacitance measurements by measuring the ac current in the part under test.

Good meter leads (Probes) are your friends

Blunt tip. Come with most meters, good for general-purpose measurements

Pin tip. Good for probing very small parts (e.g., surface mount) and for piercing insulation when needed.

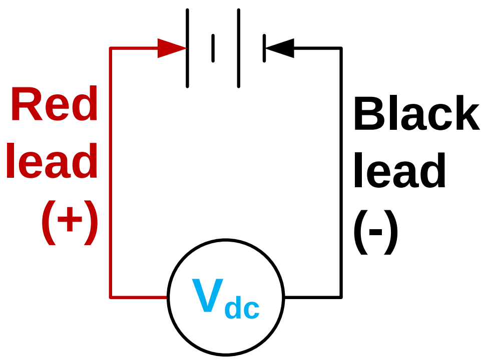
Aligator Clips. Indispensible for clipping onto wires and also for clipping to a chassis ground.

Mini grabber. Good for clipping onto a variety of components.

Search for "meter leads" at Amazon or at your favorite parts distributor. Of course you can use one type for +, another for -.

Practical Uses in the Ham Shack

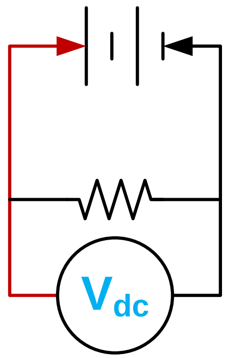
Test a Battery



High resistance voltmeter doesn't load the battery as does a real circuit

Check a battery: Set the meter for a voltage measurement and hold the leads against the battery terminals to get a semi-useful measurement of the battery condition. The measurement is semi useful because even an almost-dead battery may read close to new-battery voltage when under no load. If you can measure the battery while it is operating in the intended device, you'll get a decent measurement. Otherwise put a resistor across the battery that makes it produce the desired current. Wait about 10 minutes before drawing a conclusion. Special battery testers do this for you, sort of. The measure of battery voltage under load may give an indications of remaining power in the battery, but the details will depend on the battery chemistry.

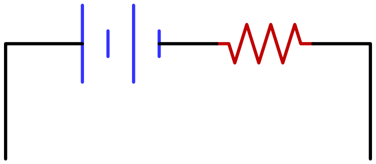
Test a Battery



Lower resistance battery tester approximates the real-world drain on the battery. Scale is usually calibrated *Replace* – *?* – *Good*, which is an *estimate* of battery condition based on measured voltage under load

Ideal battery: constant voltage (the voltage depends on the chemistry), infinite current capability

Internal resistance, which limits the current capability, and which increases as the battery runs down



Also causes the battery to get hot

Equivalent circuit of any battery

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Test a wall-wart

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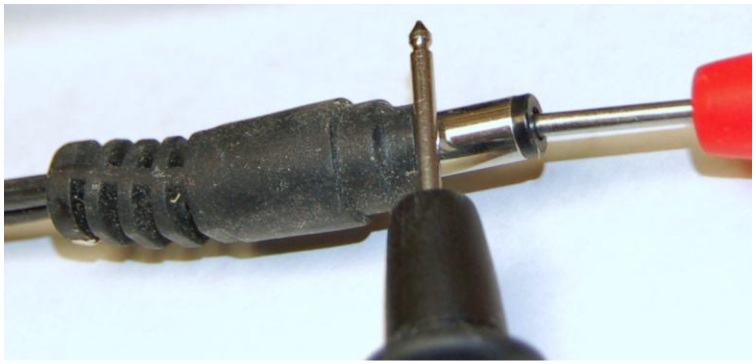
Test a wall-wart



All have an internal resistance as does a battery (and as does any other power supply for that matter), which can cause the voltage under load to be less that you measure under no load. Usually the only way to confirm loaded voltage is to penetrate the wires with sharp meter probes when the wall-wart is powering whatever.

Most common: + center, - outer
Second: - center, + outer
Last: ac

Many sizes of connectors, no standards so far as I can learn.

Types of wall-warts with dc out:

1. Unregulated (linear, analog): big, bulky, unloaded voltage several volts above spec, not closely current-limited. RF quiet.
2. Switching regulating: smaller, lighter weight, efficient, current-limited. May be RF noisy.

Not likely you will find a wall-wart with an internal analog regulator due to power dissipation.

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Checking Antennas

You cannot completely test an antenna with a voltmeter, but you can often learn something about whether it is working right or not from the comfort of your operating position. Comes in mighty handy on cold rainy or snowy nights during the contest, which is obviously when an antenna is most likely to fail. A key is knowing in advance how your antenna should look to an ohmmeter. Learn this now, not when you have that terrible sinking feeling that your antenna has failed at the worst possible time (per Murphy's law).

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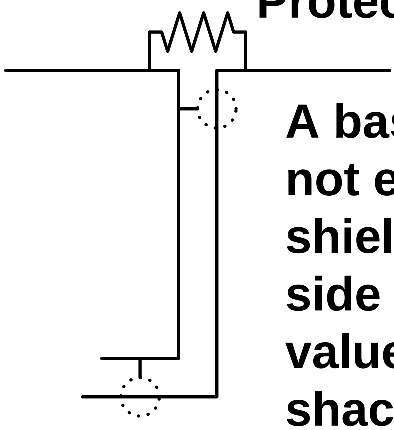
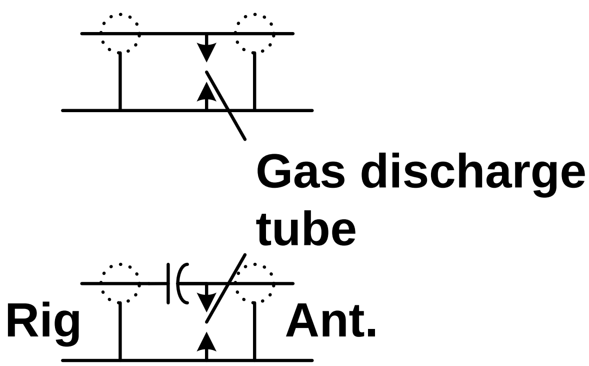
Checking Antennas

Solder a 100k – 1M resistor across the two sides of the antenna. Protect from weather and stress



A basic wire antenna, be it a dipole, OCF dipole, or end-fed, does not exhibit continuity between the coax center conductor and shield. An old trick is to solder a large value resistor from one side of the antenna to the other. You can measure the resistor value from your shack. If an ohmmeter measures a short in the shack, then the antenna or transmission line is shorted. If it measures an open then the transmission line is open.



Surge protectors (you DO use them, don't you?) come in dc-passing and dc-blocking configurations. The gas discharge tubes used usually fail shorted (test with your ohmmeter). Obviously if you have a dc-blocking surge protector the ohmmeter test will have to be performed in the antenna-side of the protector. But remember, the coax from your operating position to the surge protector may be shorted itself, so check it anyway.

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Checking Antennas - 2

Baluns may or may not add a short across the coax:

1. **So-called current baluns, probably do not**
2. **So-called voltage baluns probably do**
3. **Impedance transformers probably do**

Other types of antennas may or may not have a dc short between the center conductor and the shield.

The solution is to measure across the transmission line when you know the antenna is working properly.

One way or the other, you can learn something about your antenna/feed line from using an ohmmeter and comparing readings with what you obtained when you knew your antenna was working.

When you take an antenna down to service it, you can always check the continuity of the feed line and usually determine if you have a problem with the feed line or not. If necessary. Use an extra extension cord(s) to measure continuity of the feed line from one end to the other if necessary.

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Fox Hunting

In order to accurately fox hunt, you will likely need to get a fix on the fox by peaking (or much better, nulling) the fox by rotating your antenna. You can look at your radio's S-meter reading to see the null, but it is likely more accurate to bring out the AGC voltage from the radio and monitor it with a voltmeter. An analog display is much easier to interpret than is a digital display.

Practical Uses in the Ham Shack

Trouble-shoot equipment

First task is to make sure equipment is getting power

1. **If wall-wart powered, measure at connector inside equipment if possible**
2. **If ac powered, *carefully* measure the output(s) of power supply regulator(s) and/or raw power supply**
   Observe polarity of voltage (usually but not always negative ground)
   Observe voltage range
3. **Modern equipment may use multiple voltages, which may come from different regulators or may come from dc/dc converters.**

Next begin measuring individual circuits, based on an understanding of how the circuits work. On rare occasions you may get lucky and have a schematic with voltage measurements, or a table of voltage measurements.

Caution! If you are working on high voltage equipment, remember safety: best to keep one hand in your pocket (a shock can be fatal)

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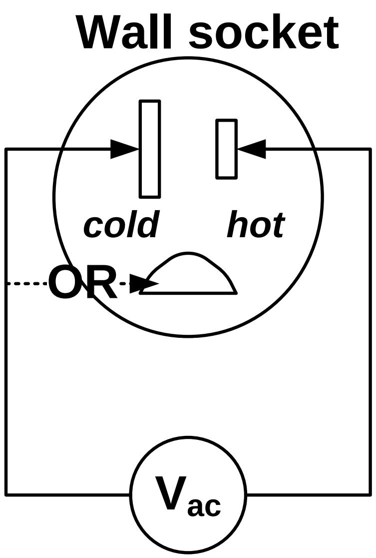
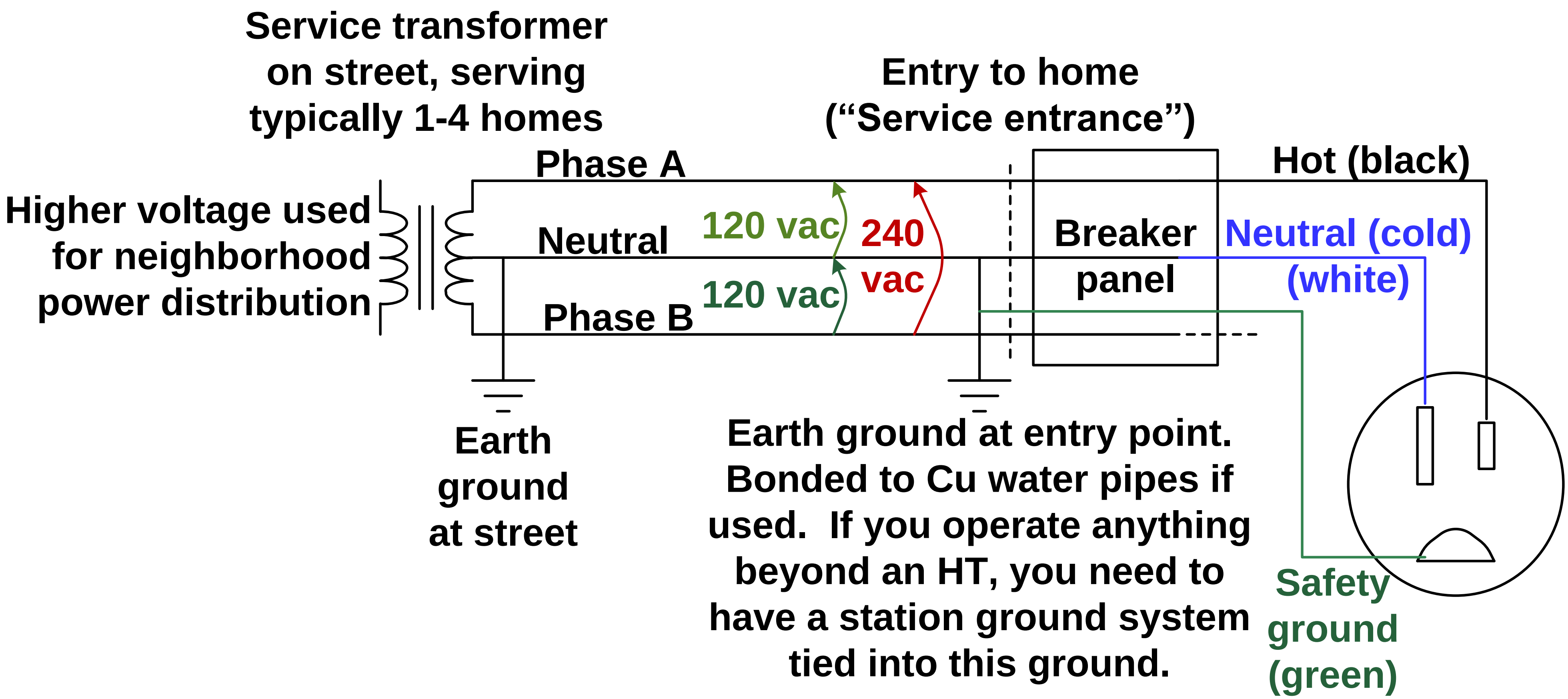
Measure ac Voltage



Set the meter for ac volts and the correct range. C*arefully, very carefully* insert the leads in a wall outlet to measure line voltage. Be careful: there is potentially lethal power exposed on the leads. In North America, the voltage should be between about 115 vac and 130 vac (double for high-power, "220 volt," circuits).

The smaller rectangle in the upper right, is the hot lead, and you are measuring against the cold (grounded) lead in the longer upper left rectangle. You should read the same voltage between the hot terminal and the semicircular safety ground below the other two. If not, you have a *serious* safety problem with the outlet and should not use it until the fault is repaired. So what the heck is going on here?

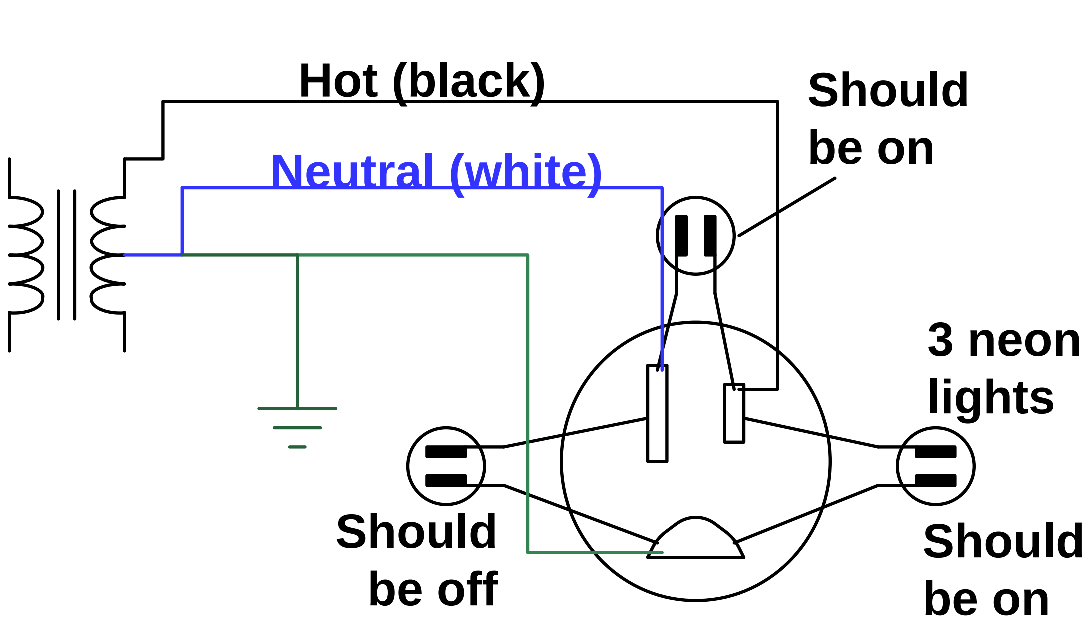
So What the Heck is Going On with ac Line Measurements?



All equipment takes power between the hot and neutral, never intentionally passing current through the safety ground, which is connected to all exposed conductors. This is an extremely important safety feature.

Half the outlets come from phase A, the other half from phase B. 240 volt circuits come from the two hot wires.

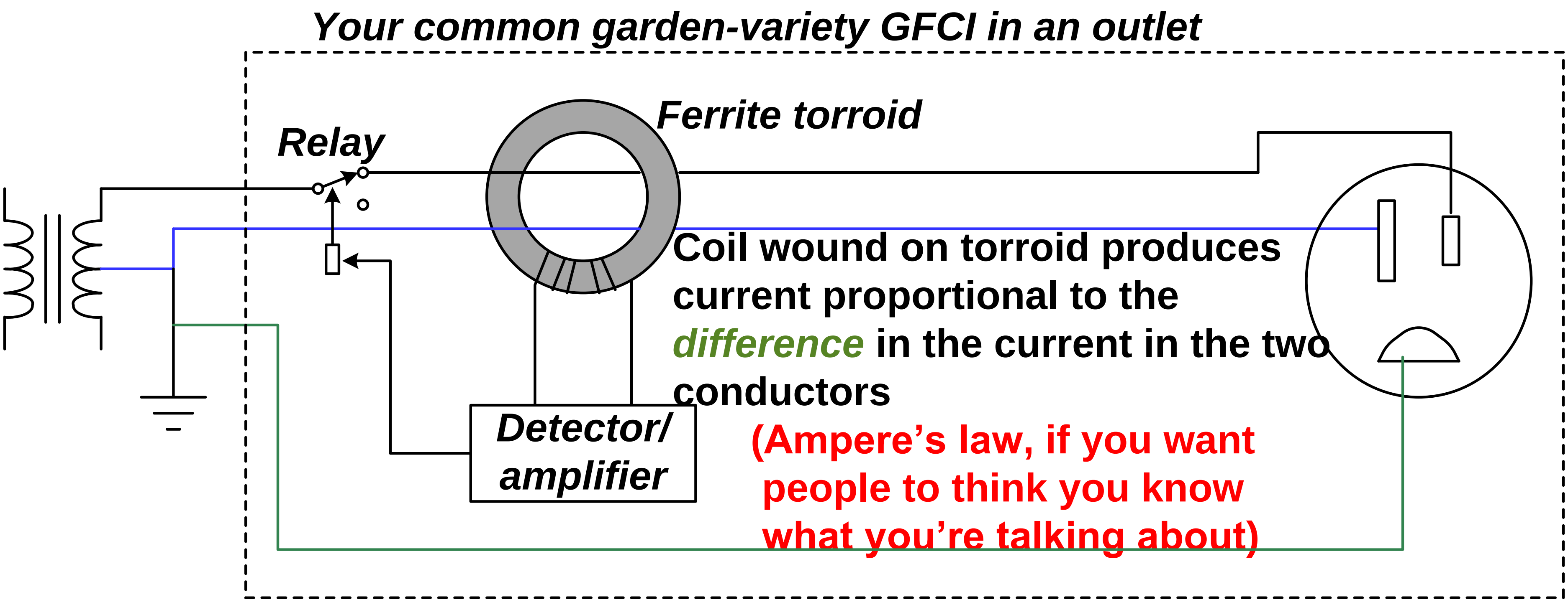
An extremely handy and low-cost outlet tester



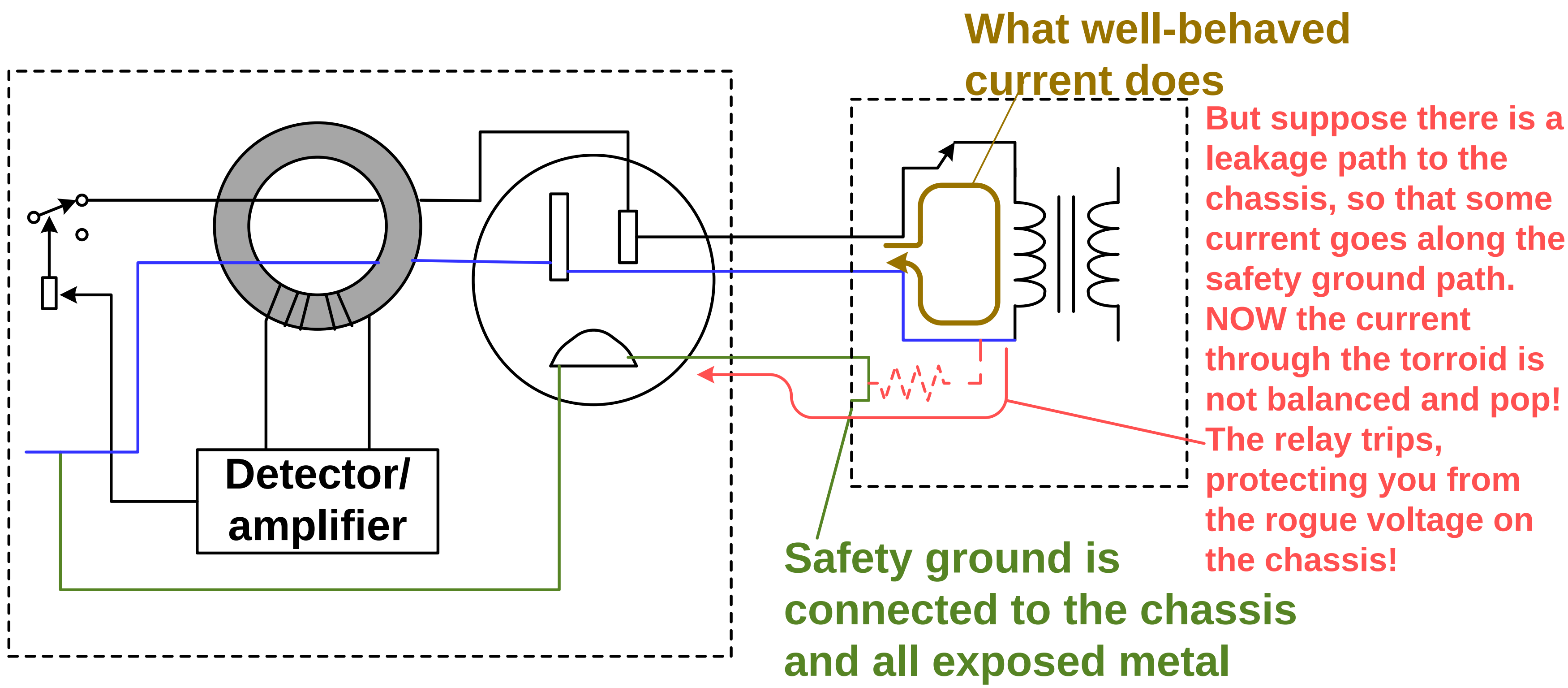
Source: https://www.homedepot.com/p/Commercial-Electric-Outlet-Tester-with-GFCI-OTG-102R/206029151

Ground Fault Circuit Interrupters:

an important safety feature



So long as the current in the neutral and hot leads is identical but in the opposite direction, nothing happens. But as soon as there is any imbalance in currents, the coil produces current, which the detector detects and trips the relay.


What well-behaved current does
But suppose there is a leakage path to the chassis, so that some current goes along the safety ground path. NOW the current through the torroid is not balanced and pop! The relay trips, protecting you from the rogue voltage on the chassis!
Detector/ amplifier
Safety ground is connected to the chassis and all exposed metal


That's all Folks!
kalilak