



# Easy-to-use Instruments in Electronics Restoration

MAARC RadioActivity-2025

Ed Lyon

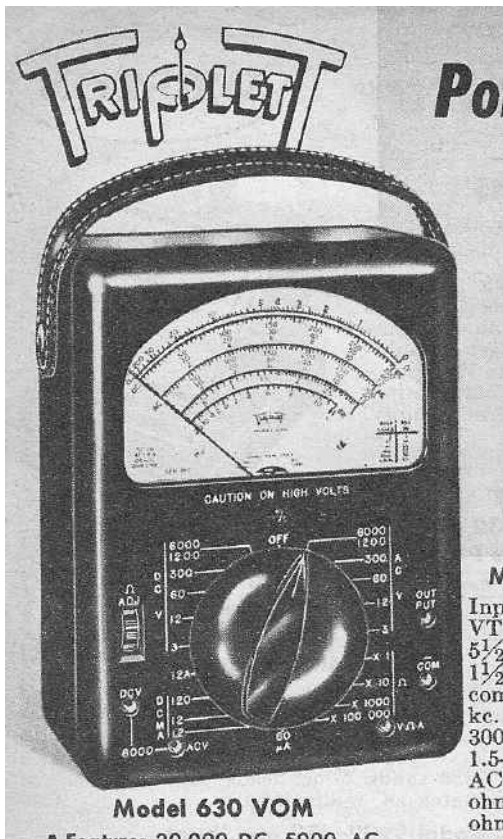


## Why does Electronics repair need test instruments?

- To **measure circuit values** (voltages, currents, resistances, signal characteristics, and component characteristics)
- To **supply test signals and voltages/currents** conveniently
- To **substitute sections of the circuit-under-test** by use of known and instrumented components/circuits.
- To **compare signals and circuit value changes** to read cause and effect relationships among components and circuits.

First of all, you'll have to be able to measure the basic electric parameters, **voltage**, **resistance**, and, rarely, **current**.

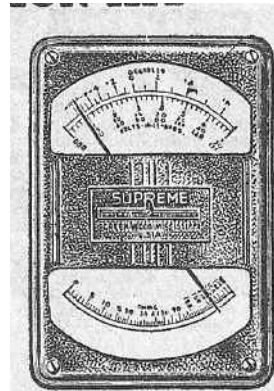
For this, a handy tool is the V-O-M (Volt-ohm-milliammeter).



Fluke 2083

Of Course, there are many brands and models of V-O-Ms

The ones shown on the last slide, Simpson 260, Triplet 630, and Fluke Digital, are probably the most trusted by electronics service people. Let's look at a few other brands, and get judgmental.



On the left is an EICO ad from an Allied catalog, 1966, a Supreme V-O-M from 1939, and a generic Oriental digital unit.

None would be a good first pick. Heath equipment is better than EICO, in general, and cheap digitals are not trustworthy or rugged enough.

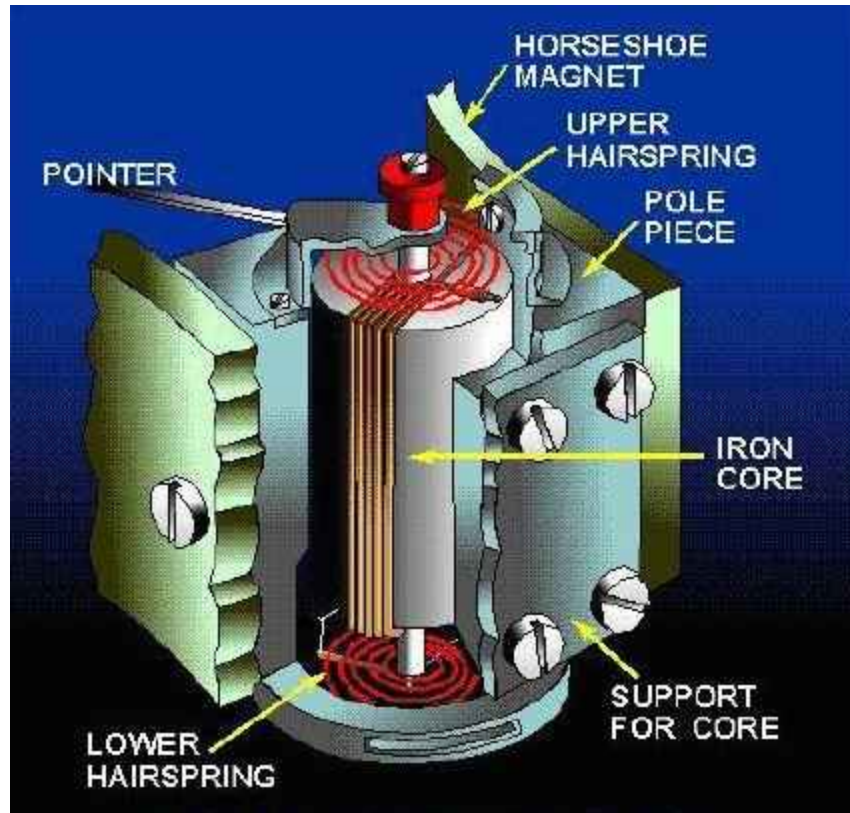
And...at the other end of the price scale, some meters have such refinements as anti-parallax mirror scales on them.



While we call them **V-O-Ms**, the Brits have been calling them **AVO-meters**.

But “AVO meter” is a British trademark, and this is Model 8, in production for 58 years, 1951-2009. It has a mirror scale for eliminating errors in reading the meter caused by parallax.

Let us see what makes them tick

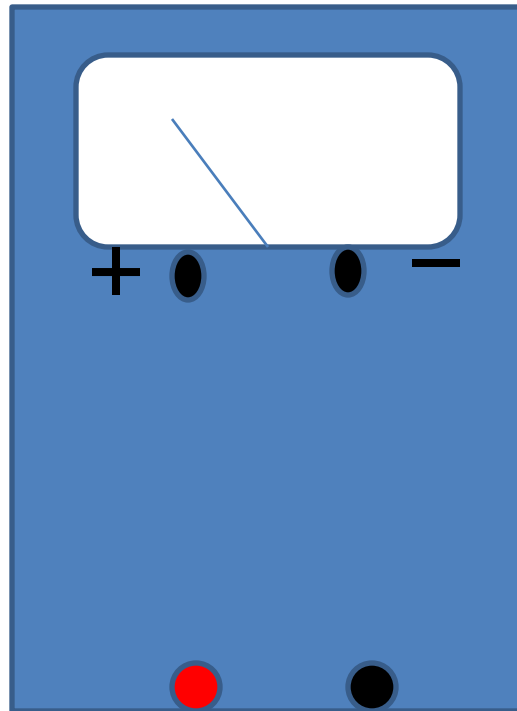


## D'Arsonval meter movement, cutaway view.

All analog meters operate on the same principle, excitation of a **CURRENT**-sensitive d'Arsonval meter. The higher the current through the meter's armature coil, the more the needle rotates to the right.

We start by building up an analog V-O-M.

Imagine this to be an empty V-O-M case with a pair of banana-jacks to fit the test leads and prods (red for positive and black for negative) and a d'Arsonval meter movement, which has + and - terminals.

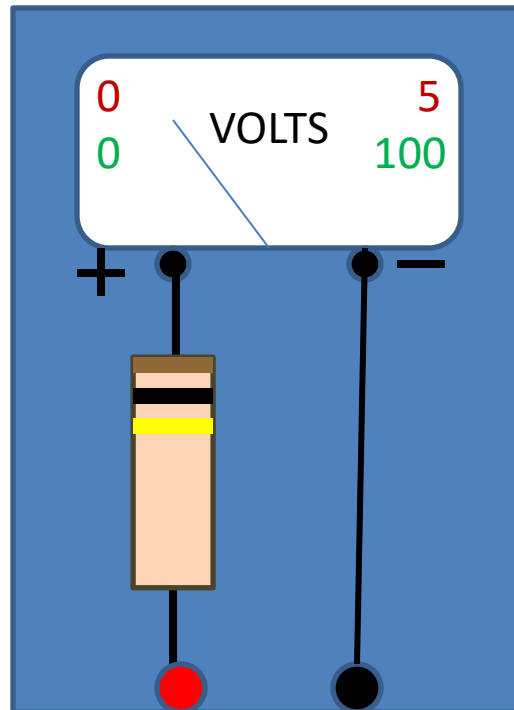


So, while it is CURRENT that deflects the meter's needle, it might be VOLTAGE or RESISTANCE that we need to measure with the meter.

It's the circuit AROUND the meter movement that makes it read voltages or resistance values, instead of just current.

Step 1: By adding a series resistor, it becomes a voltmeter.

Here we added 100K- $\Omega$  resistance. If today's calendar read "1936" the meter movement would be rated at "1000 ohms per volt" meaning it takes 1.0 mA to run the needle full-scale. So our Voltmeter now reads 100 times one volt, full scale, or 100V.

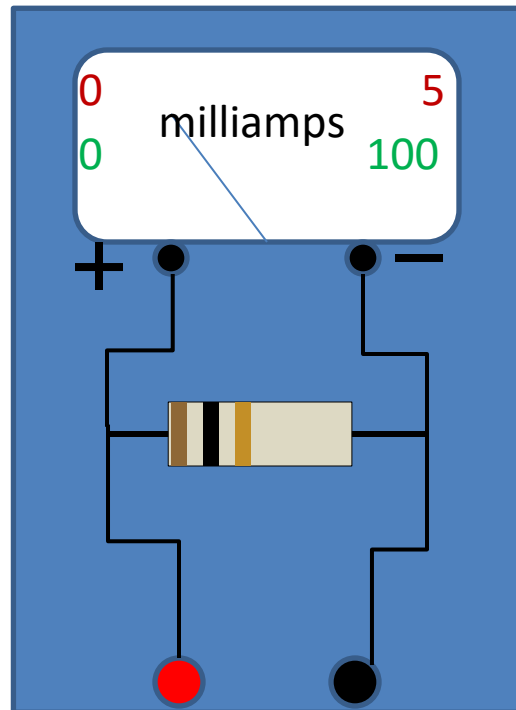


But since it isn't 1936, and we can get meter movements in V-O-Ms rated at 20,000 ohms per volt (0.05 mA F.S.), using the 100K resistor puts the V-O-M full-scale voltage reading at 5 Volts, not 100 Volts. Now the voltmeter robs only 0.05 mA from the circuit being measured.

## Step 2 in making up a V-O-M:

Now that we have made a **Voltmeter** let's measure **current, in milliamperes**. We already know we can use the meter movement alone, which would allow measuring 1 mA full scale in 1936, or 0.05 mA full scale later, when 20,000 ohm-per-volt movements were more commonplace.

Let's say the basic meter movement exhibits 100 ohms resistance. We ignored this small resistance in the Voltmeter exercise, since we added 100K- $\Omega$  more, making the extra 100  $\Omega$  insignificant. In 1936, this 100-ohm meter movement needed 1 mA current for full-scale, thus requiring 0.1 volt applied to the meter to reach full scale.

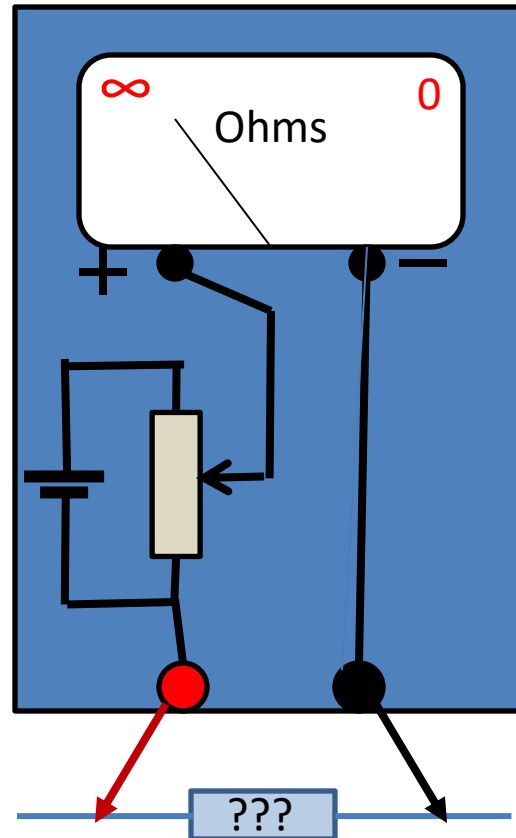


By SHUNTING the meter movement with a 1-ohm resistor, as shown, with the 0.1 volt applied to the V-O-M, this shunt resistor is carrying 100 mA. The entire V-O-M is now carrying 101 mA, but was likely labeled **0-100 mA**. For the modern movement (20,000  $\Omega/V$ ) that same shunt resistor would make it a **0 to 5 mA** range on the V-O-M.

## Finally, Step 3, making the meter measure resistance, becoming an Ohmmeter

This requires adding a battery or d-c power source, used to force a small current through the unknown resistance being measured.

Our meter then simply measures that current and the resistance value is read on a strangely **non-linear** and **inverted** scale. That's because zero current flows when the unknown resistance is **infinite**, and full-scale reading is reached when the current is either 1 mA if it's 1936, or 0.05 mA if the V-O-M is recent.



That's where the adjustability of the internal d-c source comes into play. If the internal source were perfectly constant, and the test leads were perfect, the source would never need adjustment. The pot is turned to "ZERO" the meter (full-scale current) when the test prods are shorted together.

In addition, most V-O-Ms or “multimeters” can also measure a-c voltages, which they do by rectifying the a-c voltage being measured . Vintage models used a copper-oxide rectifier, while newer units use silicon or germanium diodes. As a result they usually have a problem reading very low a-c voltages, say, below 1 volt, and they are not intended to be used to measure a-c at high frequencies, like signal frequencies in a radio.

Quite often the a-c scales are somewhat non-linear because of these effects, and are different from the d-c scales, adding complexity to the meter face.



Simpson  
260  
SERIES 7P

OVERLOAD PROTECTED  
VOLT-OHM-MILLIAMMETER  
20,000 Ω/V.D.C. 5,000 Ω/V.A.C.

ZERO DB POWER LEVEL  
-DBI WATT 600 OHMS

10 V RANGE: ADD 12 DB  
50 V RANGE: ADD 26 DB  
250 V RANGE: ADD 40 DB

TALY BAND  
DISPENSION

AC VOLTS  
DC VOLTS

187-107

Simpson

-10A +1V



## Important Notes:

Remember that analog meters are usually polarized, that is, the needle safely deflects upward (to the right) only; Measuring a reversed polarity voltage can damage the meter movement. The needle is limited in travel by “pegs” and banging the needle against either peg is a bad practice.

When seeking to measure resistance values, be sure you are connected only to the resistance whose value you want, and other “sneak” paths are not present.

When measuring resistance, be absolutely certain that voltages other than the battery built into the V-O-M are NOT present on the thing you are measuring.

Now, let's discuss digital meters. They're available at prices from \$5 to \$1200, so they must vary in quality or capability.

The best are made by John Fluke. Many others are less desirable, to varying degrees.



Left: Ideal 61-312; Middle: Radio Shack Auto-range; Right: Radio Shack booklet



 **RadioShack**  
www.radioshack.com™

## 29-Range Auto/Manual Digital Multimeter

OWNER'S MANUAL —  
Completely read this manual before using this meter.

22-813

Bar Graph Display – makes nulls, peaks, and trends more apparent.

Auto-Ranging with Manual-Ranging Override – the meter automatically selects a range when you measure voltage, current, or resistance. You can also manually set the range when measuring values you know are within a certain range.

Function Dial

Latest IC and Display Technology – ensures reliability, accuracy, stability, and ease of operation.

Data Hold Function – The meter holds the displayed value, so you can see the reading even after you disconnect the test leads.



## Advantages of digital V-O-Ms

### DIGITALs:

- Very precise readings possible
- Auto-range models very handy to use
- Some measure frequency as well as voltages, milliamps and ohms.
- Some measure capacitance, too
- Can be very good at resistance measurement
- Input impedance very high (some are 11 Megohms)\*
- Almost like a VTVM, plus portable and isolated from all other circuits.
- Many have audible continuity check mode
- Some are quite inexpensive

\* But isolation of the probe is still needed in RF measurements.

## Disadvantages of Digital V-O-Ms

### DIGITALs:

- Accuracy depends on stability of what is being measured
- They sample, and the sample size, frequency, and processing is not published
- Cheap ones have probe and probe-jack contact problems
- Difficult to read or interpret if input is varying or noisy
- Capacitance readings good for mid-sized caps only, 500pF to 1  $\mu$ F; no warning that reading will be wrong.
- D-c with a-c signal overriding will confuse some meters.
- Most have upper limits on max voltage applied via the probes.

## V-O-M Overall Recommendation:

1. Get an analog meter of good quality (later-model Heath, Simpson, Triplett, Weston) of at least 20,000  $\Omega/V$
2. Keep an old classic around just for Show-'n'-Tell (Readrite, Superior, GR, Precision, Hickok, etc.)
3. Get a good digital meter for those times a VTVM is needed but would be unwieldy, recognizing its limits. (Auto-ranging is very handy unless the reading is varying, like when a radio is warming up, or the thing (voltage, resistance, etc.) being measured is fading or noisy.)
4. Get a cheaper digital that is compact, to keep in the car for checking tube and lamp filament continuity and the like, at flea markets. Check that its batteries are standard AA, AAA, etc.
5. With ALL V-O-M measurements, check that polarities are right and no voltages are present when doing resistance measurements. Observe maximum allowable applied voltages, currents, etc.
6. When measuring voltages on RF circuits, always isolate the test lead that goes to the "hot" RF point by means of a Lyon <sup>®</sup> Probe Isolator.



The term “VTVM” came up a moment ago. Of course it means Vacuum-Tube Voltmeter, and it is simply a specialized amplified V-O-M, with the emphasis on V and O.

A VTVM will generally exhibit a very high input impedance, somewhere between 10 Megohms and hundreds of Megohms, depending on the model and range selected. As a result VTVMs do not appreciably load the circuit they are measuring, and all come equipped with isolating probes that keep the test leads from disturbing the circuit under test. Controls are very much like those of a V-O-M.

Only serious limitation is that most are a-c powered from the power line, and most require that in voltage, current, and resistance measurements, the VTVM’s black (gnd) lead **MUST** be connected to a “ground-able” part of the circuit being measured, such as the chassis. This is VITAL.

Here are three easy-to-get VTVMs, two by Heathkit, and one H-P (410B)



And the d-c probe is the most important part you must look for when buying one at flea markets.

HP 410Bs, being far more accurate and reliable, need to have their A-C probe tube (yes, there is a VHF vacuum-tube diode inside the probe!) fitted with a switch to remove heater power when no a-c measurements are contemplated for long periods; otherwise the tube life is shortened, and the tube is scarce.



The D-C probe, which is much more ordinary, contains an isolating resistor of 12 Megohms, raising the total input resistance to about 112 Megs.



Heathkit VTVMs are very simple, yet quite reliable and sturdy, often left running on the bench all day every day.



Note here the military-surplus TS-505D/U, probably the finest VTVM ever made

These VTVMs can be used on a powered-up radio (**ac/dc radios NEED ISOLATION TRANSFORMER**) to run down the tube sockets checking each plate, grid, cathode, or screen terminal for voltage without affecting the circuits appreciably, meaning that the radio, if playing somewhat, will continue to do so as you check out the circuit.

**BUT THE PRECAUTION REMAINS: With VTVMs ALWAYS MEASURE VOLTAGES IN THE RADIO WITH RESPECT TO CHASSIS OR RF GROUND (often B-). Never try to measure a plate voltage with respect to B+, for example.**

## Other radio circuit parameters that need to be measured from time to time:

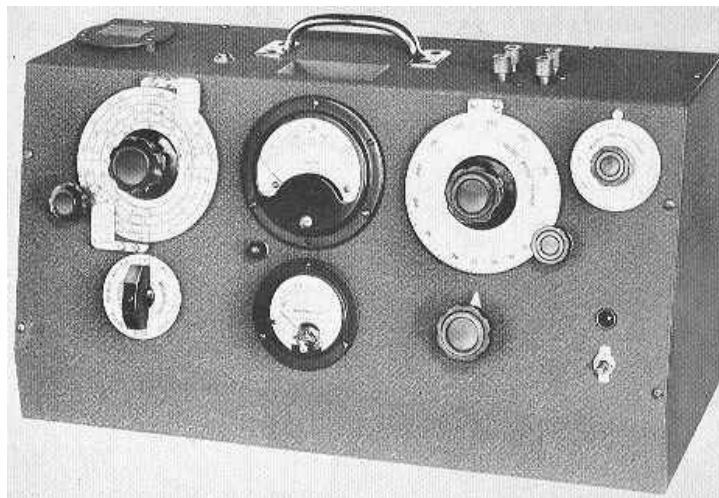
- **Capacitance?** Rarely, but sometimes a strange type capacitor shows up, like a molded lozenge-shaped thing, a strange color-code type, or a ceramic with no capacitance markings. High-end audio circuits that shape the spectral response benefit from capacitor Q-value tests.
- **Inductance?** Rarely, but often you must resonate a capacitor-inductor combination. And often you need to know a way to find shorted windings on transformers or coils.
- **Frequency of a signal?** Yes, fairly often it is helpful to know the frequency at which an oscillator seems to be making a signal.
- **The details of a signal waveform?** Yes, and the more you use this method the more you learn from viewing the actual signal behavior.

For capacitance measurements, the digital V-O-M noted earlier (mine is an “**Ideal**” brand) reads capacity directly, but has limitations. There are capacitance testers and bridges, as well. (Heathkit and ZM-11/U shown)



Get one with a capability to apply voltage to the capacitor. Be careful removing the capacitor, as it may remain charged after the test.

Inductors can also be measured. Two tester types are available, a digital type, for audio/power-line only, and bridge-type for either RF or audio components.

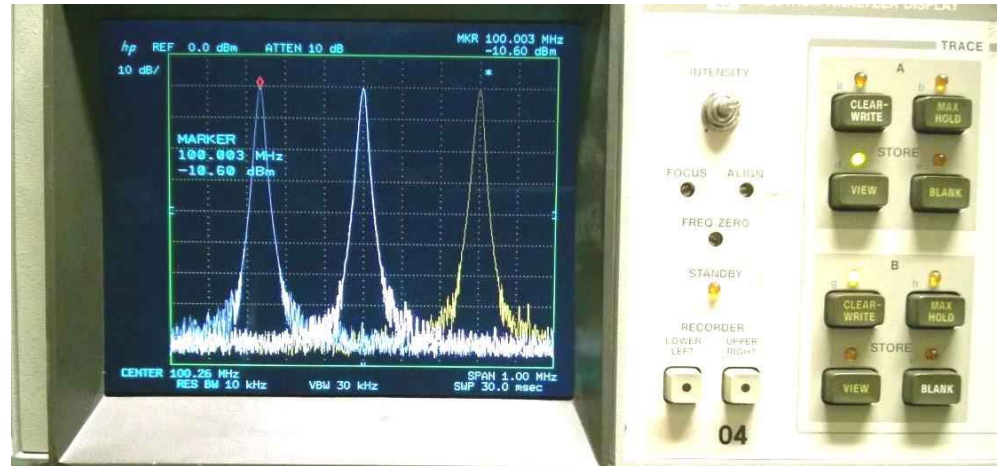


**Left:** Digital audio (<100 kHz) L-C-R meter, actually computes inductance, if not too lossy; usually used by industrial and motor/relay/transformer service.  
**Above:** Boonton (sort of like GenRad) Q-meter, for measuring inductance, capacitance, and Q **at RF**. Heath made a copy of this instrument. The ZM-11/U shown previously, is a similar bridge, running **at 1 kHz**. These bridges can identify coils, chokes, and transformers that have shorted turns, and can measure capacitor dissipation factors, important in some circuits.

## Frequency Measurements: There are several ways of measuring the frequency of a signal.

- The most elaborate way is to use a spectrum analyzer, which can show exactly where in a spectrum a signal is located, and what other signals surround it or interfere with it. These are expensive instruments. (I picked up a non-functioning HP 3585A for \$100; it sold in 1983 for \$22,000.)
- Frequency counters are often used for this purpose, but can yield wild results if the signal is not at a single frequency or has serious distortion. These instruments count zero-crossings and display on a numerical readout (like Nixies or LED/LCD, etc.) display.
- Using a hand-held all-wave radio with a tiny pickup coil instead of the usual antenna is a cheap and handy way of detecting the signal and audibly diagnosing what might be going on in the generation of the signal. A radio with a BFO (for Morse listening) is best.

Hewlett Packard, and others, make high quality spectrum analyzers, able to examine any practical span of the overall spectrum, to show where signals fall into place, how “clean” the signals are, and how stable they are.



But this small all-wave radio can scan frequencies in a band and can be fed by a short co-ax and pickup coil instead of the built-in whip antenna.

Now we come to the most elaborate of radio test gear, those radio Stage-Substitution-Sets, first popularized by John Rider, with his Rider Chanalyst, later commercialized and copied by others.



The Rider Chanalyst (and Meissner Analyst) are complete TRF radios, built in sections so that you can use the front-end of the Chanalyst to feed the middle part or back end of the radio being repaired, or do any other stage substitution you might need to do to best diagnose the problems with the radio before you.

This one is the Meissner Analyst, refined (over the Chanalyst) by the addition of a meter to read voltages. You probably don't need one desperately, but they do combine a number of instruments in one package.



## Now, Tube Testers:

Of course the only kind to have, or at least the best to have, especially if you sell a tube from time to time, is a “mutual conductance” tester. Essentially all such tube testers derive from the original Hickok design that found its way into most Hickoks, most military testers (like this TV-7D), and most newer (B&K, Sencore, etc.) types of testers



And the military surplus TV-10, which also tests some transmitting tubes and has a convenient roll-chart of the tubes, rather than a booklet.



On left is a Hickok 539C, one of the best; On the right is a Hickok 6000, successor to the 600 series, made small enough for servicemen to take along to customers' homes, but limited to less-antiquated electronics.



We arrive at the most versatile of test instruments, the Oscilloscope. You either love them or fear them, depending on your experience with them. Once you find a good one, and learn to use it, you will likely shove most of the rest of your instruments to the back of the bench, and flip on the 'scope as soon as you sit down to service an amplifier, radio, or instrument.

And you will discover that the 'scope is just the thing for measuring frequencies –accurately!

That is why you should opt for a 'scope that has actual time-base for the horizontal-axis sweep generator.

It will read directly in milliseconds or microseconds per horizontal scale division.

So, how does one read frequencies directly?

1. Use a 'scope that has an actual TIME base for its X axis sweep deflection.
2. Using the 'scope's isolating probe, touch it to the suspect circuit and adjust the scope for a handy number of waves across the screen.
3. Read the time between the peaks or zero-crossings of any two adjacent waveshapes, in microseconds, milliseconds, or seconds, whichever is convenient.

Using fourth-grade math, compute the reciprocal of the time you found.

If time is in microsec, then reciprocal is MHz;

If it is in millisec, freq is in KHz

If it is in seconds, freq is in Hz.

## Selecting the right 'scope for your needs:

1. Look for a Tektronix (or other Tek-wannabe\* brand) of a physical size you can manage;
2. Then, from all the ones of the right physical size, screen size, weight, and condition, pick one from the few that meet your electrical needs:
  - At least two (Y-axis, or vertical-deflection) channels
  - Bandwidth adequate, but not excessive
  - Screen trace sharp, bright, and clean, at all needed sweep speeds
  - Y-axis channels (maybe via plug-in preamps) have adequate gain, sensitivity, stability, and cleanliness; d-c balance is good.
  - Trace positioning smooth and complete, over entire screen; screen has no burns.
  - X-axis (horizontal channel) has all the sweep speeds needed, has noise-free trigger control, sync works in all modes, trace position and size fully adjustable; if sweep expansion/delay is present (and wanted), does it work well?
  - Check the probes for bandwidth adjustment, gain, completeness.

\* Tek-wannabes: certain Heathkits, Fairchilds, Hewlett-Packards, BKs, and a few Sencores.

## Selecting a 'scope, continued:

3. Look inside; be sure it is clean, all repairs were done professionally, the high-voltage area is free of soot or oily residue, and there are no signs of overheating or damage. Check it out thoroughly, or know/trust the seller.
4. Some decent Tektronix models:
  - Tube-type (very large and HEAVY) – with plug-in preamps:
    - Model 531 or 535 w/ 53/54C plug-in, for up to 10 MHz
    - Model 541 or 545 w/ 53/54C plug-in, for up to 25 MHz
    - Model 317 single-channel, 3-inch screen.
  - Solid State, dual trace types:
    - Model 465B - dual channel up to 100 MHz
    - Model 2235 – dual channel up to 150 MHz
    - Model 2247A -4-channel, up to 100 MHz
    - Model 2225 – dual channel, up to 50 MHz
5. Some other models:
  - BK-Precision 2160 dual trace 60 MHz, solid state
  - Fluke/Philips PM3240 series, 100 MHz, 2 trace
  - Elenco S-1325, 30 MHz, 2-trace
  - H-P-made Military USM-281

## Types to avoid:

1. Any (especially HP/Agilent) that uses “soft-buttons” (software-defined control buttons)
2. Any “storage” oscilloscope using a special storage CRT
3. Most oriental ‘scopes, but some Leader (Korea) and Hitachi (Japan) models are decent.
4. Any older Dumont, Heath, Eico, or RCA models that have the horizontal-axis controls labeled in frequency units, not time units.\*
5. Any sold on the internet that are described as: “...powers up but since I am not an engineer, I can’t get nothing on the screen; Sold as-is with no returns...”
6. Any that cannot tolerate inadvertent contact of the input probe tip to the radio’s B+. (most new ‘scopes were made for solid-state work)

\* In a good ‘scope, the horizontal axis should be a TIME axis. Therefore the control of the trace on this axis should be in terms of units of time per graticule division (usually centimeter), and not in terms of “horizontal frequency, in kilocycles.(or the like)”.

Some of the most reliable 'scopes are very large **and heavy**; these include the Tektronix 531/535 and the 541/545 which dominated the electronics manufacturing and servicing world for about 25 years.



Model 535 with 53/54B plug-in



Model 541 with 53/54C plug-in

Two generic types to avoid: The “cheap” pre-Tektronix era scopes (Left), and the “storage CRT” types (Right) that evolved in the 1970s. On the left is a Heathkit; the other is Hewlett-Packard.

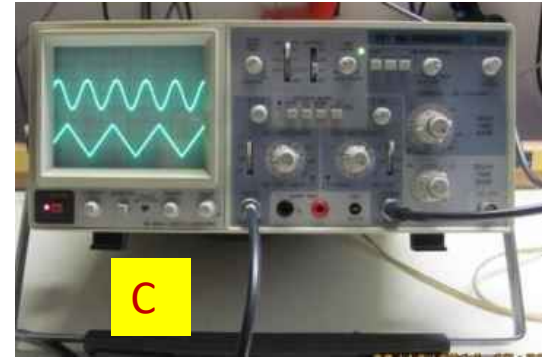




A



B



C

- A. Tek. 465
- B. Tek. 2235
- C. BK 2160
- D. Heathkit 1-chan



D

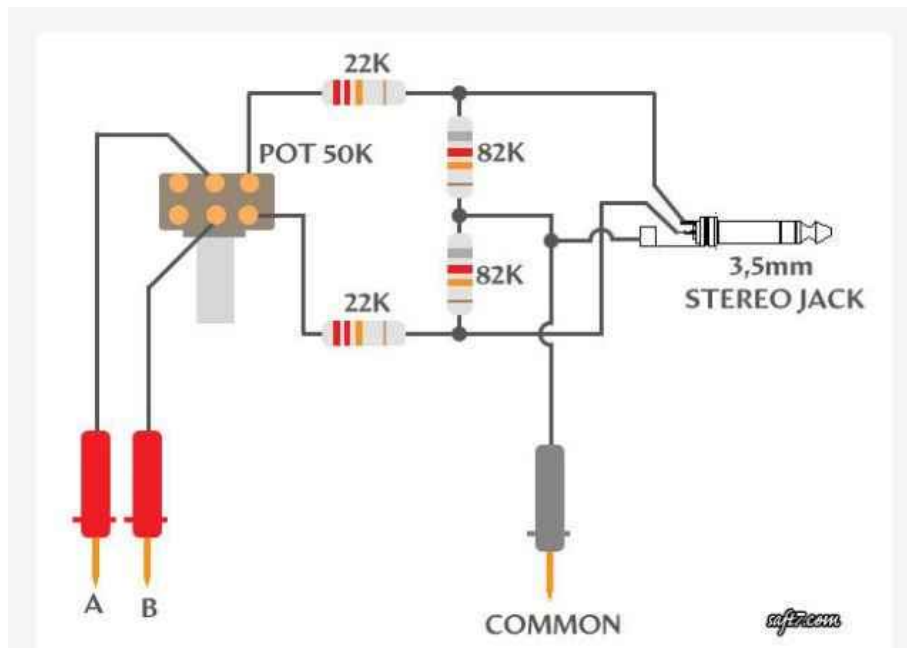


**Four decent “modern” ‘scopes and the very important PROBE!  
One probe needed for each vertical-deflection channel.**

Somewhere, someone is asking: “How about those DIY oscilloscope kits for my laptop or i-phone?”

OR

How about those newer DIGITAL oscilloscopes?



Schematic

These kits use the computer sound card as an analog-to-digital converter.



The OWON SDS1202 digital SCOPE

Be aware of the limitations of these cheap or DIY oscilloscope adapters for computers:

- They usually load the circuit they are measuring
- Their probes are usually non-isolated, and detune any RF circuit they touch
- **They cannot abide high voltages, like radio B+ levels**
- Most work only for audio and power-line frequencies.



E-Panorama brand USB-connected 'scope adapter for laptop.

## Digital Oscilloscopes

There are those considerably more expensive 'scopes that combine a relatively standard good-quality solid-state 'scope like a Tek 465, BK 2160, or H-P USM-281 (ex-military test set), with a built-in digital computer, which does a number of things for the operator automatically. These might include:

- (a) setting the vertical axis gain control automatically so the waveform displayed takes up perhaps 60% to 80% of the screen height,
- (b) Taking an FFT of the incoming signal to tell you its frequency content

But there are also digital scopes in the \$150-\$200 range, like the OWON SDS1202

I've found they can show waveforms that repeat, and can probably capture lone waveshapes, like you need to capture if you have an intermittent problem with a piece of electronics. But they do not scale the display so you can tell how long the disturbed waveform lasts, how many microseconds it persists, or the like. They do sync easily, but the scale is hard to fathom.

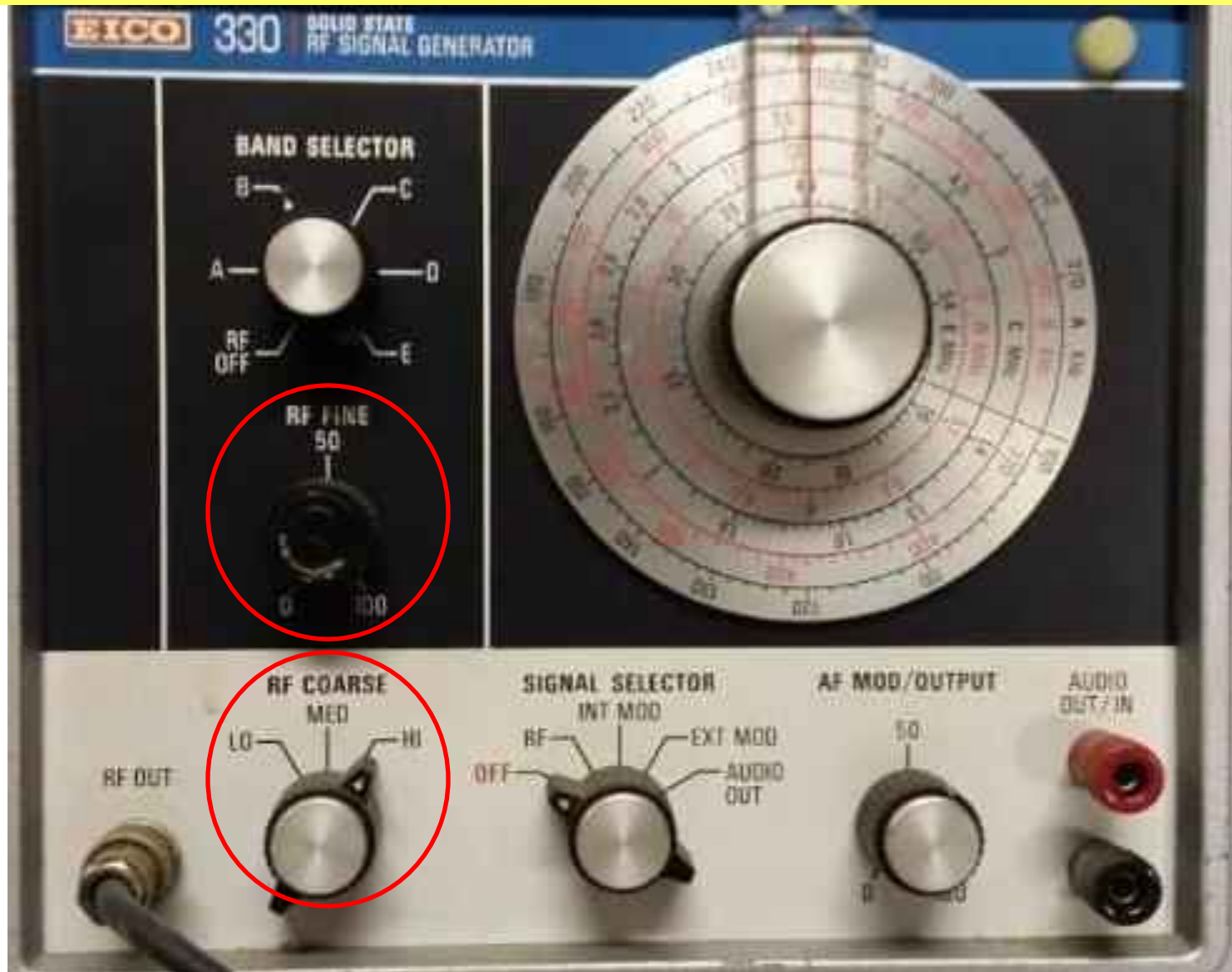
We have finished talking about **measuring** radio voltages, currents, resistances, capacitances, signal characteristics, and the lot, and find that sometimes a radio is SILENT, and we need to **GENERATE** trial signals to send to the radio circuit.

We looked at this technique back when discussing the CHANALYST and ANALYST instruments, but what we really need here is a simple generator of signals for the RF end of the radio, and separately for the Audio end of the radio or amplifier.



Two good examples of RF signal generators: a B&K and an Elenco.

This inexpensive EICO 330 has 2 level controls, sort of like volume controls, coarse and fine, to vary the output level of RF being delivered to the circuit under test.



The H-P 606 RF generator, on the other hand, has a true step-adjusted attenuator delivering the output.



These two Hewlett-Packard RF signal generators are quite good and reliable; the one on the left is the 608D (for signals at 10 MHz and above) and on the right is the 606B (for signals from a few hundred kHz to about 40 MHz. Both produce very pure sine-wave signals, very low in distortion and noise. These are for the high-roller who does not worry about hernias, or gets a brother-in-law to move them.



Below are two vacuum-tube models by Heathkit, very popular (cheap) but limited in signal purity, as any oscilloscope will demonstrate to the user.



In fact, many affordable RF signal generators have problems producing pure single-frequency-at-a-time signals; most produce horrendous harmonics. If you use these, always start with the generator at a higher-than needed frequency and work your way downward – not the other way 'round.



Hickok  
EICO



Jackson  
RCA



And in the audio universe, there are very costly generators like Bruel & Kjaer, but you seldom need that kind of purity, so go with the one that started the audio oscillator work as we know it, the H-P 200 series (left, below).

Some inexpensive models that are adequate, if not sophisticated, are the EICO (center) and Heathkit (bottom right). **BUT. Be sure to check them for waveform purity, especially for audio restoration work.**



So much for signals we needed to generate. How about raw power we might have to supply to the sick radio, to see, in a safe way, if it is fit to operate on its own power system? Let's look at some handy ways to do this.

MODEL PS-3



The Heathkit PS-3 was a way to go back in the 60s.



For lower-voltage applications, like transistor radio repair or solid-state audio gear there are several Heathkit bench power supplies making adjustable voltage pairs, like +/- 0-30V.



This has been a review of affordable and capable test gear for the electronics restorer. There exist better models of such equipment, and there are more expensive examples as well, and some are easier to use. But these we covered today are generally available, and are good enough for most restorations.

So, as Bob and Ray would say, at sign-off:

“Write if you get work” and “hang by your thumbs.”