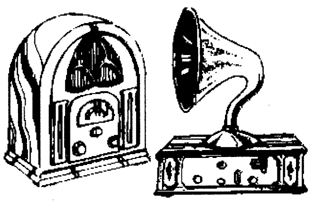
Vintage Radio



by ROGER JOHNSON

Early Radio Test Equipment — 1

Test equipment has been around for as long as radio itself, and was once just as rudimentary. Let's have a look at what was available to a radio mechanic in days gone by, to help track down faults.

The most ubiquitous of all early test instruments would have surely been the 'multimeter', used to measure volts, ohms and current. Like many of the radios of the 1920s and 1930s, a lot of these devices were home built. Most of the early meters had only DC voltage and current capability, but AC ranges followed in the later 1930s with the availability of copper/copper-oxide rectifiers.

Many of the early simple instruments comprised a 0-1mA moving-coil meter movement, with factory shunts to provide additional 0-10mA and either 0-50 or 0-100mA current ranges, and with suitable series 'multiplier' resistors to give usually four voltage ranges of typically 0-10V, 0-50V, 0-100V and either 0-500 or 0-1000V. These were considered adequate for most service work.

Construction

Most often these meters were built in a rather large case measuring approximately 10" x 8" x 2" (250 x 200 x 50mm) and sometimes used rows of banana sockets to give access to the various ranges. The test prods were simply plugged into the appropriately labelled sockets. At least one rotary switch was needed to switch between voltage and current, and sometimes between 'High' and 'Low' resistance ranges.

Sometimes, a two-pole 10 or 11 position switch was available for a fully switched instrument, to allow the use of a single pair of sockets for the test leads. But these switches were expensive, and not always very reliable. Quite often, the circuit diagrams of such meters were rather crudely drawn and very hard to follow.

Resistance ranges

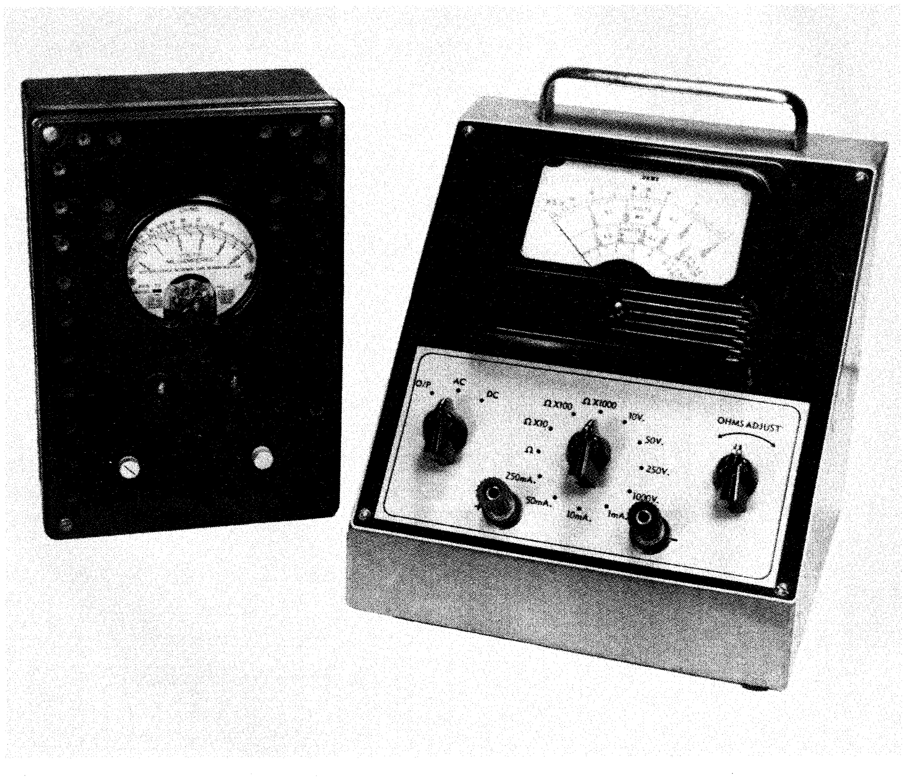
The tricky bit was the resistance ranges. Given a scale of 100 graduations for full scale deflection (FSD), the minimum practical reading of a 0-1mA meter is therefore 10uA, which when used with a 1.5-volt torch battery enabled a maximum resistance reading of merely 150,000 ohms. The high ohms range needed at least a 9V grid bias battery, which would have only extended the range to 900,000 ohms. A higher voltage battery (22.5 volts for instance) gave a corresponding higher ohms range — in theory.

The trouble is, as anyone who has used an analog or 'old fashioned' multimeter knows, the resistance ranges are very cramped at the high resistance end of the scale. The reason is quite simple. For these ranges the meter is reading current, from a fixed voltage source through the unknown resistance. Mathematically, it is a reciprocal function (which incidentally has nothing to do with 'you scratch my back and I'll scratch yours!') and not a linear function as are the voltage and current ranges.

However, if the home constructor could fathom out the theory, a lower resistance range could be included by using an appropriate shunt to effectively turn the meter to a 0-10mA or 0-100mA. This allowed a correspondingly higher current to flow through the circuit with a corresponding lower resistance scale.

Voltage ranges

These are simply an application of



On the left is an early Weston multimeter of US manufacture, with range selection via many banana sockets. At right is a benchstyle 1000 ohm per volt multimeter described in Radio & Hobbies in the 1950s.

Ohms law once again. The meter this time is reading current from an unknown voltage source, but through a fixed and known resistance. On this occasion, the scale reading is linear.

A 0-1mA multimeter was said to be a '1000 ohms per volt' because that was the value of the total series resistance to read full scale from a voltage source of 1 volt. The series resistance is derived quite simply by dividing the required maximum range by the FSD of the meter. So a 0-10V range required a 10,000 ohm multiplier, and so on.

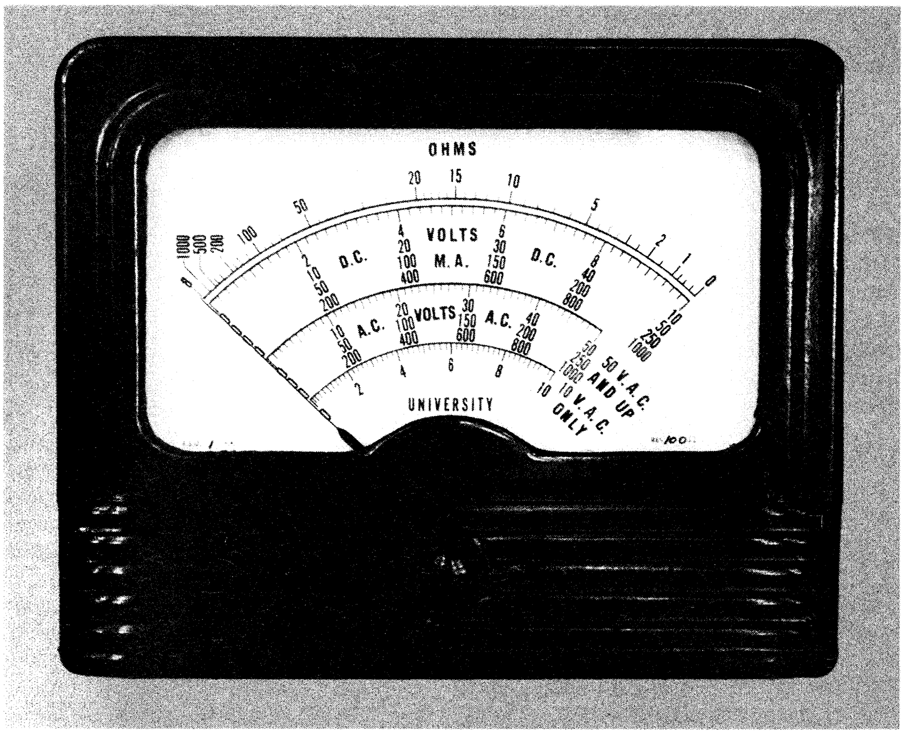
Strictly speaking, the internal resistance of the meter itself should be subtracted from this figure, but most 1mA meters had a resistance of only 100 ohms. So for ranges of 10V and above that represented less than 1% of the total resistance, and could safely be ignored.

Current ranges

A shunt resistor in parallel with the meter is required to achieve higher current ranges, and to work out the current value the internal resistance of the meter must in this case be known. The formula for a given shunt is the internal resistance divided by (n-1), where 'n' is the factor by which the original meter scale is to be multiplied.

Hence, the shunt for a 0-100mA range would be equal to the meter's internal resistance, often in the order of 100 ohms, divided by 99 — or a little over one ohm.

The higher current scales meant parallel shunts of a fraction of an ohm, and these were often purchased with the meter movement as supplied by the manufacturers.



A closeup of a 1mA meter movement manufactured in Australia by University Instruments, showing the various scales. Note the non-linear resistance scale at the top.

So there we have it! A typical circuit for a switched version is shown in Fig.2. Fig.1, originally in *Radio and Hobbies* for July 1939, illustrates the difficulty of following the diagram of the switching.

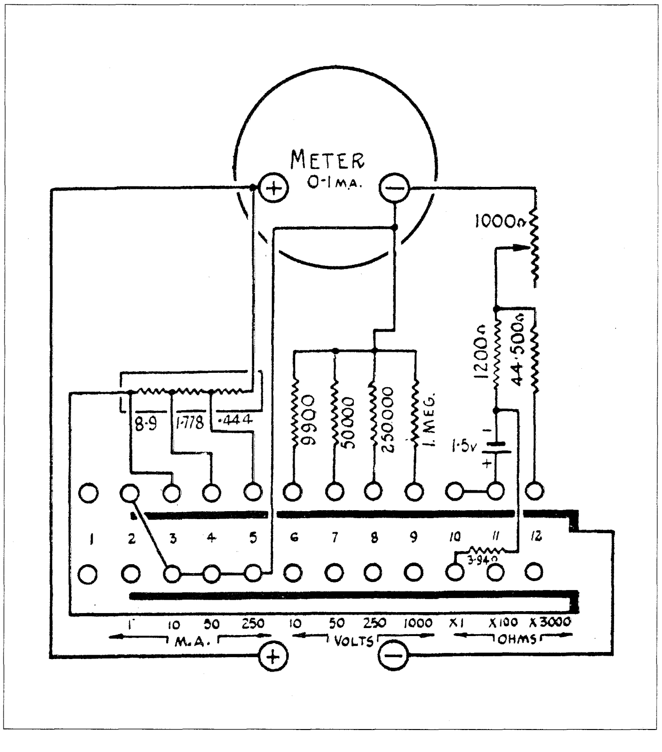


Fig.1: The circuit for a DC multimeter described in Radio and Hobbies for July 1939. Presumably the thick bars represent the moving contacts of the switch, although the wipers to the numbered contacts have not been shown.

AC ranges

For the home constructor AC ranges were added by the simple addition of a rectifier as described, an extra switch, and an additional dial scale that reflected the slight nonlinearity of the output from the Cu/CuO rectifier. These scales were once again provided by the manufacturer.

How accurate?

The limiting factor for the ohms range was the accuracy of the meter and the calibration of the scale. As long as the battery was not flat, and the meter was 'zeroed' in the usual manner, that part of the scale from about 1/5 of FSD upward could be sufficiently accurate for service work. The higher end of the scale may as well not have been there, and the higher ranges must be used, in much the same manner as an analog instrument of today. At the very highest end of the scale, a fraction of a division could easily be responsible for a 10 or 20% error!

The limiting factor for the current range was the value of the shunts, and once again, the accuracy of the dial scale. As both these items were often factory produced, they were regarded as quite accurate.

The voltage range, however, is a different kettle of fish. The accuracy here is purely determined by the accuracy of

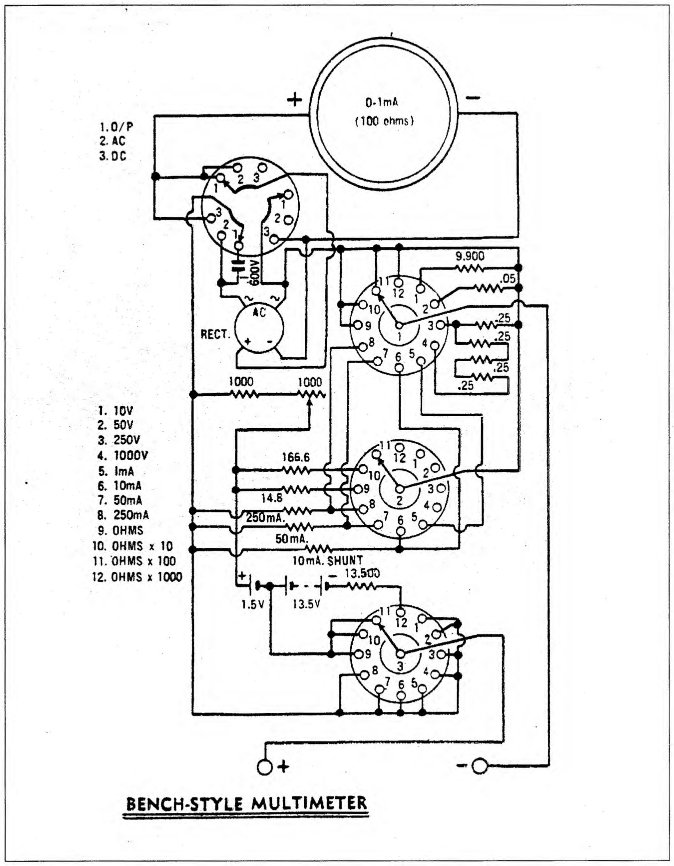


Fig.2: This somewhat clearer circuit drawing of a more sophisticated instrument appeared in Radio & Hobbies for January 1958.

the series multipliers. Resistors of 20% tolerance were regarded as satisfactory for ordinary home construction projects. 10% types were available, at extra cost, but 1% and 2% types were definitely stretching the friendship. Once again, the series shunts were sometimes supplied by the manufacturers, but at a price. Basically, you got what you paid for.

Loading effect

In certain applications the 1000 ohms per volt multimeter was notorious for its poor accuracy on the voltage ranges, but not because it used wide tolerance multiplier resistors. It all had to do with the shunting effect of the meter upon the voltage being measured. The following explanation might help.

Consider trying to measure the screen voltage of a normal pentode wired as a voltage amplifier. Typically, the value of the screen dropping resistor was 1.0 megohm, resulting in a screen voltage of about 50 volts when the screen current was 0.2mA. If the meter's 100V scale is used to measure the voltage, this effectively connects a 100kΩ resistor from the screen to earth, forming a voltage divider with the existing 1MΩ screen resistor. If the HT voltage is 250 volts, this means that 0.27mA will flow through the chain, and the screen voltage might well be so low that it may not draw any current at all. The meter will therefore now read about 27 volts!

If say, the meter's 0-1000V range is used, then 1MΩ is placed in series with the 1MΩ screen resistor — resulting in 0.125mA flowing down the chain. If the screen still draws 0.2mA, the additional 0.125mA means that 0.375mA would flow through the 1MΩ screen resistor, resulting in a voltage drop of 375 volts from a 250 volt source. This is of course is an absurdity. The screen will draw some current, a voltage drop will occur across the screen resistor, and the voltage reading will be somewhere between 27 and 50 volts — but closer to 50.

Of course trying to read 50 volts on a 0-1000 volt scale has its own scale accuracy problems!

When reading battery, normal HT or cathode voltages, and screen voltages on RF, mixer, and oscillator plate stages, such inaccuracies were markedly reduced because the higher value meter shunts were placed across much lower impedance (resistance) sources. A cathode resistor, or the internal impedance of the voltage source, such as batteries, or even a normal 250 volt power supply, are much much lower than the impedance (resistance) of the multimeter being placed across it.

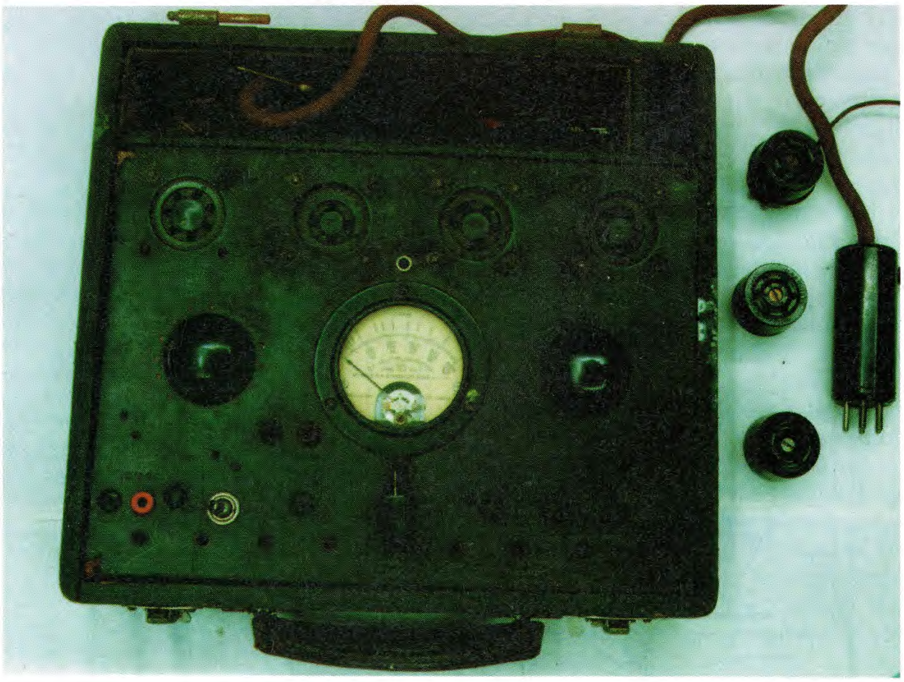


Fig.3: One of the set analysers referred to in the text. Unfortunately it is beyond restoration, but is an interesting static museum item.

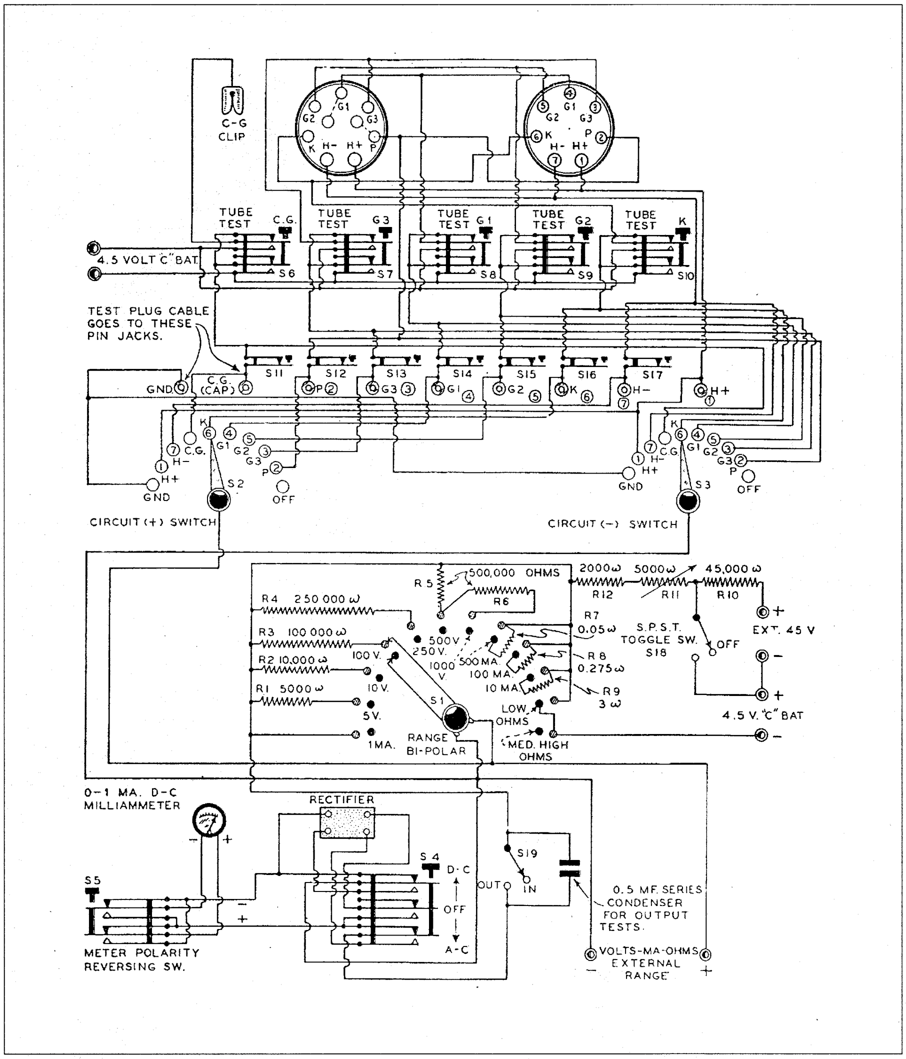


Fig.4: A circuit of a typical 'set analyser' of the 1930s, designed for home construction. Anyone game?

Work arounds

So how did the servicemen cope, back in the vintage radio days? There were one or two tricks that manufacturers adopted, which helped. Firstly, they specified the voltage to be measured on a specified range of the multimeter, thereby allowing the serviceman to compare apples with apples.

A second way they helped was by using a 'voltage divider', a large resistor with adjustable taps and a total resistance of between 15,000 and 25,000Ω, connected between HT and earth and used to derive the various intermediate voltages. This meant that there was a constant current drain across the HT of between 17 and 10mA, in addition to what was being drawn by the oscillator plate or RF screen or whatever.

If, say, the audio amp screen was to be set at 50 volts, a meter resistance of 100kΩ across that portion of the voltage divider (say 3 - 4kΩ) is going to introduced fairly insignificant loading.

Another trick was to set the mixer screen and IF amplifier screen voltages at the same level, and derive that voltage from a single screen dropping resistor. Quite often the value of this resistor was in the vicinity of 20 or 30kΩ, which again means that the shunting effect was minimal when using the higher scale of the instrument.

The 'Circuit Tester'

An extension of the multimeter was a curious device, popular in the USA in the early 30's and called a 'circuit tester' or a 'set analyser'. This device, it seems, was designed to measure voltages and currents without having to remove the chassis from the cabinet.

The idea was that a valve was removed from its socket and plugged into the appropriate socket of the set analyser. A cable with one or another adaptor was then plugged into the vacant socket on the chassis.

By judicious manipulation of a series of pushbuttons for current ranges, and switches for voltage ranges, and either more complicated switching or a series of 'wander plugs' to connect to the respective base pins, the entire operating conditions of the valve under test could be measured.

Not only that, there was often an external source of grid bias. This feature was incorporated to vary grid voltage and measure the anode current variation, thereby enabling the mutual conductance of the valve to be measured.

This method of testing valves was by far and away more superior and reliable than the equally ubiquitous and unreliable 'emission tester'.

The emission types of valve tester were standard fare for vintage servicemen in Australia, whereas the set analysers were not. Perhaps being imported and designed for the comparatively few valve types used by US radio manufacturers of the early 30's limited their appeal somewhat in this country, where European valves were as common as the US types.

The set analyser became obsolete by the late 1930's, due in no small measure to the introduction of more and more valve types. One survivor is illustrated in Fig.3. Unfortunately, the maker's plate is missing, and examination underneath shows that it has been tampered with and modified, so that restoration is nigh impossible. It does, however, give a good idea of what one looked like. A typical circuit for such a device is shown in Fig.4.

In future articles we'll look at valve testers, audio and RF oscillators and other test gear. ❖