Vintage Radio

By MAURIE FINDLAY, MIEAust., VK2PW

All about thermionic valves (or vacuum tubes)

. . . as told by a veteran radio designer

Valves reigned supreme in the electronic world for more than 40 years, being the essential components of radio receivers, transmitters, early computers and many other devices. When television first came to Australia, it was black & white and the sets used valves. It has now been 50 years since the end of the valve era.

WITH AN EYE to preserving our history, there are many enthusiasts who restore early equipment, mostly radio receivers from the 1930s, 40s and 50s. Most popular sets used from four to six valves and many of them were well made and are well-worth keeping as representative of the technology of the era.

During the World War 2 (WW2), all radio communication depended on valves. It wasn't much use sending up a squadron of fighter planes if they couldn't talk to each other and coordinate the operation. Initially, valves were the least reliable parts in the equipment used until valve manufacturers in several countries made them much more rugged.

These military valves were produced using the latest technology available and in versions equivalent to ordinary valves. Most of them, if not abused, will meet their original specifications after 60 years.

Not all people restoring early radios will be trained technicians or engineers. They may be able to do a great job of polishing the cabinet, replacing the dial cord and even repairing the speaker cone. However, when switched on, the set just doesn't perform as well as it should. Maybe the maximum volume is limited or it will pull in only strong local stations. If so, does the set need realignment or does it have a faulty valve? Or could something else be wrong?

Valves are a common reason for poor performance in old radios and this article will answer some of the questions that are commonly raised by people restoring vintage sets.

But first a word of warning. Most enthusiasts will be aware of the basic safety issues for radios operating from the 230VAC power mains. If you are not confident about dealing with mains-operated equipment, then leave well alone. Even if you are capable and know what you are doing, be careful about doing repairs for acquaintances. There could be legal implications if something goes wrong.

We'll assume here that we are dealing only with sets that have a mains transformer. If you have such a set, it should be fitted with a good-quality 3-core power lead that's been properly anchored and has a good earth connection to chassis.

Unless you a very experienced and know exactly what you are do-

Taken in February 1954, this picture shows "Radio & Hobbies" staff members Raymond Howe, Neville Williams, John Moyle (Editor) and Maurice Findlay on the roof on "The Sun" newspaper building in Elizabeth St, Sydney (there to watch the Queen proceed down nearby Macquarie St during her 1954 visit to Australia). Both Raymond Howe & John Moyle served in the RAAF during WW2, specialising in signals and radar.

ing, don't touch transformerless (hot chassis) AC/DC sets that have one side of the mains (Active or Neutral) connected to chassis. They are absolute death traps for the unwary and should be avoided.

What sort of valves are there?

The simplest electronic valve type is the diode. It has two elements – the cathode and the plate (anode). When the plate is made positive with respect to the cathode, electrons are attracted to it and a current flows. Conversely, if the plate is negative with respect to the cathode, no current flows.

Diode valves are used to rectify alternating current. The larger diodes typically rectify the high-voltage AC secondary of the mains transformer, while the smaller diodes are used to recover the audio modulation from radio frequency (RF) signals. More often than not though, the latter will not be a single diode valve but will instead be incorporated into other valve types. In fact, there will usually be two diodes in the envelope – one to recover the audio and the other to derive the AGC (automatic gain control) signal.

The next valve on the list is the "triode". It has an element called a "grid" which is placed between the cathode and the plate. This grid usually consists of a fine helix of wire which surrounds the cathode.

In operation, the grid is usually made slightly negative with respect to the cathode and, depending on the voltage applied to it, controls the electron flow to the positive plate. In this way, it can be made to amplify.

As a result, triodes in radio receivers are usually used to amplify audio signals (ie, the audio is fed to grid of the triode stage). However, triodes have problems operating at radio frequencies (RF) because of the capacitance that exists between the plate and the grid (known as Miller Effect).

This problem can be overcome by placing another helix of wire around the control grid, to screen it from the plate. Valves with this feature are known as "tetrodes" and are used in simple circuits to amplify RF signals.

Another grid called the "suppressor" is often also placed around the screen grid. This improves the efficiency of the valve which is now called a "pentode". Like the screen grid, the suppressor grid also usually takes the form of a helix but the turns are more widely spaced.

A special case for power valves is the "beam tetrode". It employs a special construction technique that does away with the need for a suppressor. Pentodes are commonly used for both audio and RF amplification.

Special valves

To make things more complicated, there are a number of special valves that are frequently used in superheterodyne receivers to convert the tuned RF signal to the intermediate frequency (IF). One such valve is the "triode heptode"

In this type of valve, the triode element forms part of an oscillator and it injects the oscillator signal into a screened grid which is in the main electron stream to the plate. As a result, the intermediate (IF) signal appears at the plate and is then fed to the receiver's IF stages.

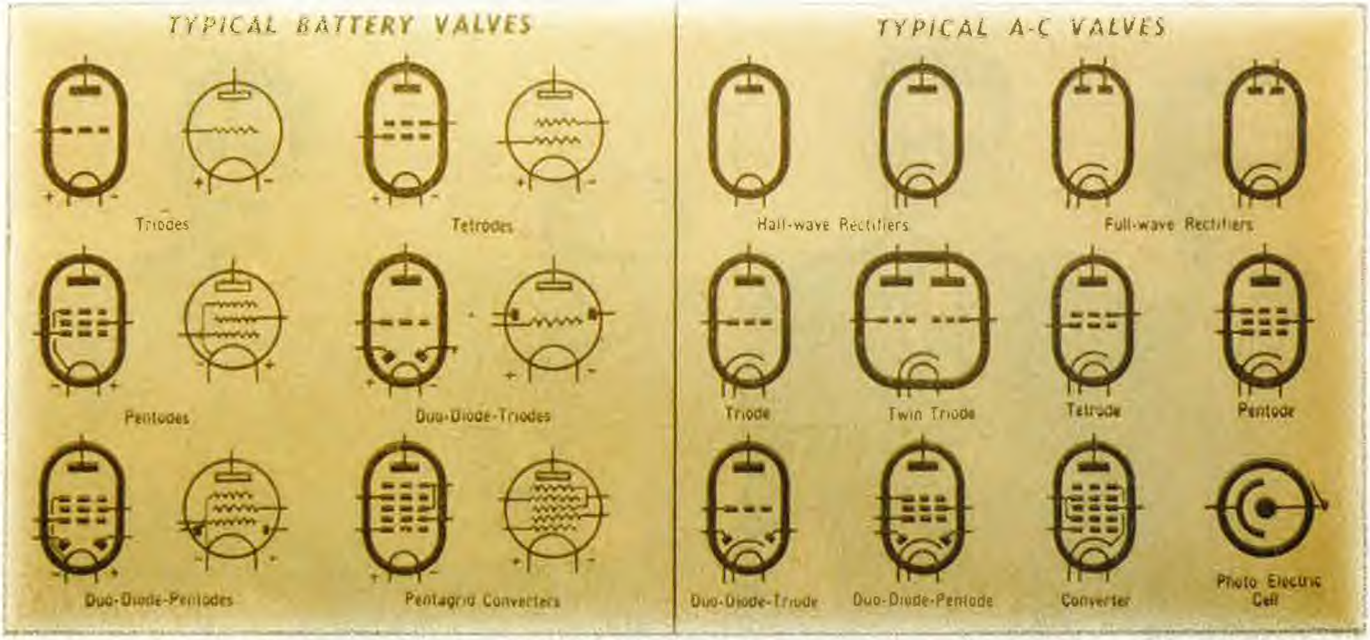


Fig.1: reproduced from the April 1949 issue of "Radio & Hobbies", this diagram shows the various valve types that were available. The valves designed for battery sets used directly-heated cathodes, while valves designed for use in mains-operated sets generally used indirectly-heated cathodes to eliminate hum problems.

Most valve superhet receivers use a triode-heptode for the input stage. However, more elaborate receivers may use a pentode RF amplifier stage before the frequency converter. This amplifies the tuned RF signal before it is fed to the converter and so provides better performance on weak signals.

Cathode construction

The cathodes for all the above valve types can take two different forms. For battery operation, strands of wire are used and valves with directly heated cathodes suitable for operation from both 1.5V and 2V were produced.

By contrast, most of the valves encountered by restorers in mains-operated sets use indirectly-heated cathodes. This type of cathode consists of a fine metal tube with the heater wire inside and insulated from it. A big advantage of indirectly-heated valve cathodes is that the heater can be operated from low-voltage AC without introducing hum.

An exception in mains-operated sets may be the main (double diode) rectifier. This rectifies the high-voltage AC secondary of the transformer to provide the HT (high-tension) line and this valve is often directly heated.

Both directly and indirectly-heated cathodes employ special coating materials to ensure a good supply of electrons. In use, these materials gradually deteriorate, resulting in low emission and eventually making the valve unserviceable.

Other parts

Now for a brief look at other components. First, the electrolytic capacitors on the HT line in the power supply don't last for 50 years and if the originals are still there, they will need replacing. You can often tell from their appearance that they have failed, especially if they are leaking.

If there is any doubt, replace them with modern capacitors with a voltage rating of, say, more than 400V. The replacement values should be equal to or only slightly higher than the originals. In particular, note that substituting much larger value capacitors in the position immediately following the rectifier will invariably shorten the life of this valve, so don't do this.

Note also that the negative leads of these capacitors are sometimes connected to positions other than to the chassis. This means that you must check the lead connections carefully before removing the originals.

Low-value (non-electrolytic) capacitors and resistors are more reliable than electros. Most resistors can be checked in-circuit (with the power switched off) using a multimeter, while suspect capacitors can be removed and checked on a capacitance meter. One common problem in old sets is a noisy volume control. An aerosol contact cleaner may fix this problem but if the control is worn, replacement is the only answer.

Valve sockets and the pins of the valves themselves can also cause problems if the radio has been stored in damp conditions. Look carefully at the general condition of all metal parts – if they are corroded, this gives a good indication of valve socket problems

Power transformers are generally reliable, even after many years. The primary winding can be checked with a multimeter by measuring the resistance between the Active & Neutral pins on the power plug with the power off and the radio's on/off switch (if fitted) in the ON position. The primary winding will typically have a DC resistance of several hundred ohms.

If you have an insulation tester, check that the primary isn't breaking down to the transformer frame.

Valve testers

During the heyday of valve radios, valve testers were readily available. You simply removed the valve from its socket, set the controls of the tester according to a chart, plugged the valve into the tester and checked the reading on a meter. Although not totally foolproof, the results given by a valve tester were good enough for most purposes.

In fact, technicians who didn't know much about radio could often fix sets just by testing the valves.

Alternatively, they just replaced the valves in turn to determine which one (if any) was faulty. Such technicians were often derisively referred to as "valve jockeys".

Because they had to accommodate a wide variety of valves with different connection and power requirements, most valve testers were generally quite complicated. The most basic units tested the ability of the cathode element to emit electrons and checked for shorts between the elements. By contrast, the more sophisticated units also tested the valve's ability to amplify at varying power levels and usually required an experienced operator.

Making an instrument to test valves is impractical as a hobby project unless it is confined to simple tests on a particular series of valves. Instead, it is far easier to check valves in-situ by checking voltages (and sometimes current) while the radio in operation. In addition, an emission test on a valve tester can reject valves which may work perfectly well in low-power circuits.

The valves and other parts should also be checked visually (eg, are the valve heaters glowing?) but for other checks on the circuit, a multimeter is essential. Many basic digital multimeters (or DMMs) are available for $30 or less and these have a number of ranges to read current, AC and DC voltages and resistance. Nearly all DMMs have a high input resistance on the voltage ranges (typically 10MΩ) so that they don't disturb the circuit being measured.

If you don't have a DMM, buy one. You will probably pay less for it than you did for the radio!

The older-style moving-coil multimeters can be used for some measurements. However, their input impedance is much lower than for DMMs and this can lead to misleading results when making voltage measurements, particularly in high-impedance circuit. Even modern moving-coil multimeters have this problem.

Typical valve problems

OK, so what goes wrong with valves. Here are the most common problems and how to diagnose them:

(1) They lose emission – after a long period of use, the cathode (or filament) can no longer supply enough electrons to allow the valve to operate properly.

In practice, a valve's emission can

This photo illustrates the size difference between an octal (8-pin) valve and a later 9-pin "miniature" valve. The 9-pin (and 7-pin) types dispensed with the Bakelite base, the valve pins emerging directly through the glass envelope.

be checked in circuit by measuring the current at the cathode. A valve data book can be helpful here, to give an indication as to what to expect. If the valve has a resistor from cathode to earth, simply measure the voltage across it and then calculate the current through it using Ohm's Law.

Power valves in mains-operated sets typically have cathode currents of 50mA, while other valves typically have values from 2-10mA. However, the cathode current will be lower for battery-operated sets.

(2) Vacuum is lost – when this happens, the cathode no longer emits electrons and so there will be no cathode current.

(3) Short-circuits between elements – this can be detected by checking the voltages around the valve. If elements are shorted, the voltages on them will be the same and will be incorrect.

(4) Open circuits – this particularly occurs with valves which have Bakelite bases, where wires from the elements are extended to the base pins. They can sometimes be repaired by re-soldering the base pins.

(5) Loose Bakelite bases and/or top caps – can be repaired by re-gluing.

8-pin octal valves

Untold millions of broadcast-band radios were manufactured in Australia between 1930 and 1960. AWA, Philips, Mullard, Astor and Kriesler are just a few of the brand names that come to mind. The early sets used valves with an 8-pin (octal) base and a glass envelope. Some valves also had the grid connection via a cap at the top.

The valve type was usually screen-printed on the glass. Basically, a valve with a particular type number complied with the standards set by agreement with a number of manufacturers. There were several sets of type-numbering standards, two of which were widely used in Australia – the American system and the European system.

For the American system, the starting number usually denotes the voltage for the heater or filament. Thus, a valve with a type number starting with "6" was designed for 6.3V while a type number starting with a 12 was designed 12.6V (this odd voltage comes from the fact that many radios were made for cars).

The last two letters denoted the type of envelope. "G" indicated a normal glass envelope, while "GT" denoted a smaller glass envelope. There were also valves produced with metal envelopes and for these the "G" or "GT" designation was simply left out. Metal

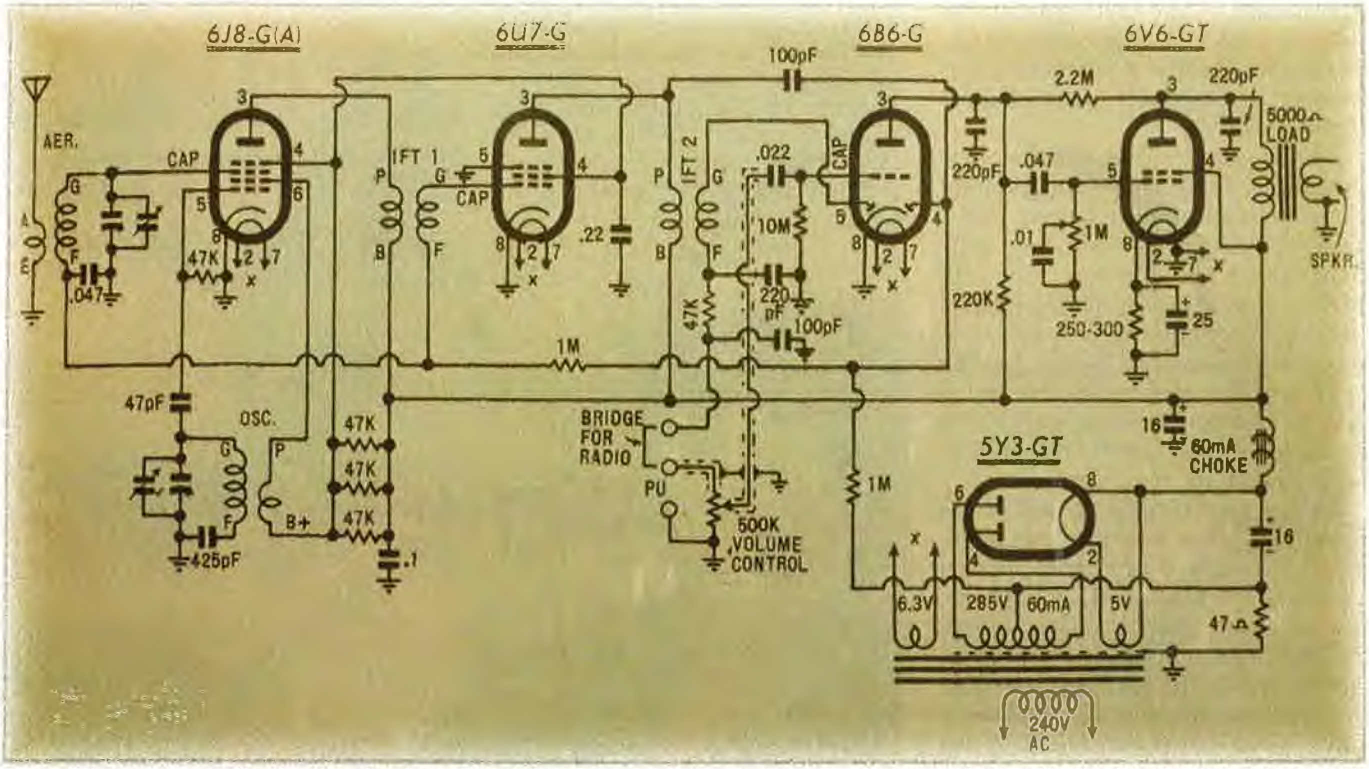


Fig.2: this was virtually the standard configuration for a mains-operated 5-valve superhet radio during the late 1940s and 1950s, although this particular circuit was actually published as the "ABC Five" in the August 1966 issue of "Electronics Australia". The "ABC" stood for "all bits collected".

valves were produced in relatively small quantities.

By contrast, European type numbers often started with letters to indicate the elements within the valve. An "A" usually indicated a diode, a "B" a triode and so on.

If your object is simply to restore historical radios, it isn't really necessary to become an expert on the thousands of valve type numbers. However, you should try to get a circuit diagram of the radio with the voltages marked and the base pin numbers indicated. A valve data book could also be useful or you could check the data on the internet.

Directly-heated valves

Inexpensive battery-operated radios from the 1950s typically used the following valve types: 1R5 (frequency changer); 1T4 (pentode IF amplifier); 1S5 (diode and pentode detector plus audio amplifier); and 3V4 (audio power amplifier – used to drive a small loudspeaker). These valves are of all-glass construction, have 7-pin miniature bases and had directly-heated cathodes.

A 1.5V battery is used to power the filaments, while a 90V battery (2 x 45V) is used for the high tension (HT) supply. By modern standards, the performance is not outstanding and a common problem with these valves is that the filaments tended to be unreliable.

A more rugged series of valves designed for battery-operated receivers was produced by AWV in Australia. These came in larger glass envelopes, with octal plastic bases and 2V filaments. Their power consumption was higher than the 1T4 series but they were more reliable and gave better performance. A number of military sets used the 2V series.

Indirectly-heated valves

Indirectly-heated valves were manufactured with a number of heater voltages: 2.5V, 4.0V, 6.3V and 12.6V, plus some with even higher voltages. However, the majority required 6.3V.

A simple mains-operated radio of the 1950s typically used the following valves: 6J8-G (triode heptode – frequency changer); 6U7-G (pentode – IF amplifier); 6B6-G (double-diode & triode – detector, AGC & audio amplifier); 6V6-G, (beam tetrode – audio amplifier); 5Y3-G (double diode – power rectifier). These are all 6.3V indirectly heated types except for the 5Y3-G which has a 5V heater/cathode and is operated from a separate 5V winding on the power transformer.

Combined with well-designed tuning coils and IF transformers, the performance of a radio with this valve line-up on local stations is more than adequate. In fact, the audio gain of the standard 5-valve mains-operated set has some reserve and the audio amplifier following the detector can be left out if very high volume is not required. This was the basis of the 4-valve "Little General" radio made popular in the 1940s by John Moyle who was the Editor of "Radio & Hobbies" (later to become "Electronics Australia").

It now more than 60 years since the original "Little General" was described in "Radio & Hobbies". Since then, transistors, ICs and large capacity memory chips have made mobile phones and digital radios both reliable and inexpensive. None of these consumer items are now manufactured in Australia.

Modern day marvels

John Moyle died in 1960. What would he have made of a little radio on sale in popular stores in the year 2010 for about $40 – an hour's working time for a skilled tradesman?

The type of set I'm thinking of typi-

Maurie Findlay – An Interesting Career

Maurie Findlay began his electronics career by making valve radios while still at school in the 1940s. He subsequently did a course to become a marine operator in his late teens and qualified for an amateur radio license at about the same time.

Being an avid reader of "Radio & Hobbies", he jumped at the chance when offered a job with the magazine in 1947. He subsequently left in 1953 to spend a year with Mullard-Australia as a sales engineer, just three years before the introduction of TV into Australia. His responsibilities included advising manufacturers on the best valve types to use in early TV receivers. During this time, he made a number of trips to Mullard's plant at Hendon in South Australia to study the manufacture and testing of valves.

Maurie then rejoined "Radio & Hobbies" for another five years. During his 10 years total with the magazine, he completed a cadetship as a journalist and studied part-time to become a professional engineer.

As well as being involved in the production of the magazine, Maurie also designed and described valve and later solid-state radio receivers, as well as amateur transmitters and test equipment. He hand-made the mobile radio equipment used by "The Sun" newspaper in the early 1950s and was generally involved in designing and testing the system. A major accomplishment at the time was his ability to eliminate receiver hash, due to the crude "vibrator" power supplies that were used!

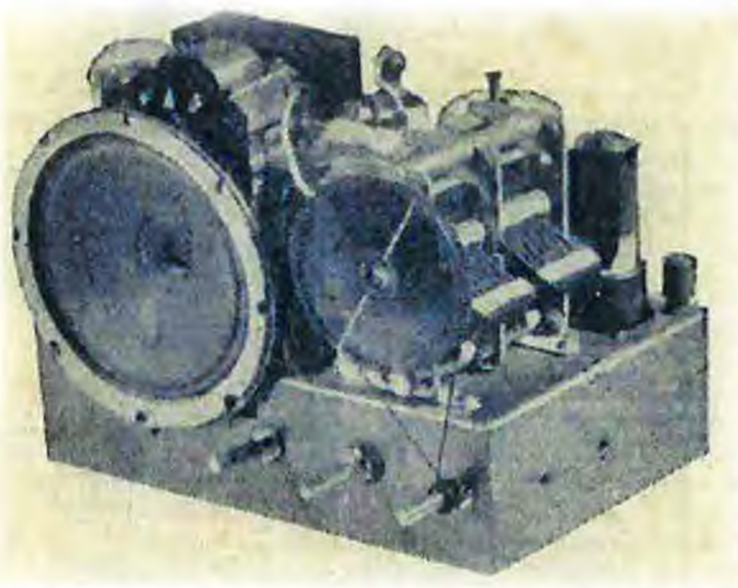
Maurie left "Radio & Hobbies" at the end of 1959 and joined the de Havilland Company as a trials engineer working on the "Black Knight" research rocket. This British-designed rocket was used to study the physics of re-entry into the Earth's atmosphere at very high speed. The aim, almost reached at that time, was 20,000 miles/hour (32,000km/h).

Maurie's responsibility on the Black Knight project involved the special tape recorder used in the re-entry head. He then returned to the company's plant at Stevenage in the UK to study the larger "Blue Streak" rocket.

Family responsibilities had priority over career and he subsequently returned to Australia to take up a position as Chief Engineer with Weston Electronics. Among other things, this company was involved in the manufacture of VHF transceivers and outback radio systems.

In 1962, Maurie formed Findlay Communications Pty Ltd which was to produce SSB marine equipment and mobile sets for use in the Royal Flying Doctor Service over a period of nearly 25 years. During this time, Findlay Communications also designed and supplied receivers and solid-state 1kW transmitters for the Australian Civil Aviation Authority.

Now retired, Maurie is a Member of the Institution of Engineers Australia and is still an active radio amateur with the call-sign VK2PW.



There were lots of "Little General" 4-valve sets described in "Radio & Hobbies" over the years. This one was described in January 1946 by Neville Williams and is closely based on the design originally published in the April 1940 issue by John Moyle. The valve line-up was as follows: 6J8-G, EBF2-G, 6V6-G and 5Y5-G.

cally measures no more than about 100 x 60 x 30mm and is powered by two AA cells which last for about a month with typical usage. It features not only an AM broadcast band but shortwave, stereo FM and an inbuilt digital clock with alarm features as well. And of course, digital tuning and a preset station memory are all part of the deal.

John Moyle was an imaginative and resourceful man. He would almost certainly have come up with some new angle. I knew him well. **SC**