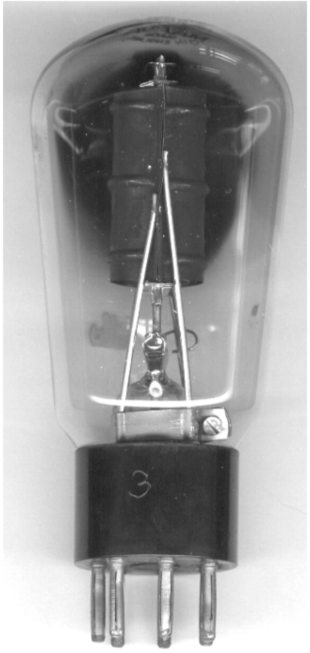
This material is adapted from the website 'vintage Radio World' www.vintageradioworld.co.uk and written by Tony Thompson

VALVES

It's quite possible that you've never encountered valve technology, especially if you were born at any time from the late 1960's on. It is, for sure, many years since valve radio manufacture ceased.



Left: a typical mid-thirties Mazda valve

NOTE for American readers: the terms 'valve' and 'tube' are interchangeable in this document. The latter name is used in the USA and is simply an alternative to valve. Similarly, 'plate' and 'anode' are alternate names for the same electrode.

Terminology has changed over the years, too. The letters 'HF' stood for 'High Frequency' which is now usually termed 'RF' - Radio Frequency. Therefore 'HF amplifier' and 'RF amplifier' are also interchangeable.

James Clerk Maxwell, a brilliant Scottish physicist, first developed a theory about electromagnetic waves in 1864. He based this on even earlier speculative work by other scientists. He believed that electromagnetic (i.e. radio) waves would behave like light. If light could travel through space, so could electromagnetic waves. This theorising was laboratory-proven in 1888 by Heinrich Hertz, another brilliant physicist, German by birth. Unfortunately he did not live to carry out advanced practical testing of his work as his lifespan was even shorter than Maxwells.

It was left to Marconi to first demonstrate a form of wireless telegraphy. It is often stated that Marconi invented radio. Though basically true, this is a simplification and the reality of radio's beginnings is much more complex. In fact, the British experimenter Hughes had demonstrated radio transmission some years before Marconi - but it seems the scientific community did not believe him!

Early radio could only use morse code. The transmission of speech and music required the development of the amplifying valve and continuous wave transmission system, where an oscillator generates a carrier wave of high frequency which is then modulated by another wave, an electric analogue of the original sound. At the receiver, the high frequency wave is removed and the speech or music analogue is amplified and fed to a loudspeaker to change it back into sound.

The valve, therefore, was crucial to the development of radio. The crystal set, which used a crystal 'signal detector' to detect (demodulate) the sound from the carrier, could not amplify. These devices could normally only be used by one person at a time, wearing headphones, and as they were powered by the strength of the received signal, were, for reliable results, limited to a distance of around fifty miles radius from the transmitters of the time. It is interesting to note that modern electronics is based upon solid-state, i.e., crystal, semiconductors!

The inventors.

John Ambrose Fleming, an English physicist and electrical engineer, invented the diode valve in 1904. This device contained a filament similar to that of a light bulb plus an 'anode', a metal plate carrying a high voltage charge. Fleming found that electric current would flow from the filament to the anode, but not from the anode to the filament, hence the name 'valve', from 'one-way valve'. This device could be used instead of a crystal, but amplification by the diode valve was only possible after Lee DeForest, an American physicist, added a third electrode in the form of a spiral of fine wire called a grid, fitted between the two electrodes. Small signal voltage changes at the grid could be made to result in large voltage changes at the anode. DeForest patented his triode (three-electrode) valve in 1906. The amplifying valve was born, and with it, radio for the masses.

Construction problems.

From the start the main difficulty was to seal the connections to the internal electrodes where they came through the glass envelope. Many variations were tried, using a plastics base to the valve, bonded to the glass and acting as a support for the lead out wires which were terminated in strong metal pins. The British 4, 5 and 7 pin series are examples. Bakelite bases fitted with side contacts were tried for a while. These and other later types that were all-glass with a 'pip' on one side 'snapped' into spring-tensioned valve-holders (sockets). It was widely thought that valves would work loose if they were not retained in some way. This may well have been true for WD and communications equipment, but for most domestic radios, especially those with standard horizontal chassis, the problem simply didn't exist. The later miniature valves -B7G and B9A - needed no such fixing as the holders gripped the pins quite firmly, though whenever they were used horizontally as in many TV sets, there would be a wire clip for security.

Screening.

Lots of early valves designed for use at RF were 'metallised' either with a grey or a gold conductive coating. The earlier grey in particular tended to flake off. As this screening was part of the structure of the valve, carried by a fine wire to earth (chassis) through a convenient pin, these valves can cause problems such as instability in operation. The later and physically smaller valves dispensed with screening and opted for external metal cans that had a simple bayonet fixing into sockets on the holders.

Filament and heater.

The early valves had direct filaments and were designed to run from DC supplies, which meant in practice batteries or accumulators. The development of the separate heater allowed sets to be designed for AC mains.

Battery valves.

Battery valve design, basically for portable or transportable sets, improved over the years. From the 2-volt filament types came the so-called 'all-dry' range of 1.4 volt filament valves. All-dry meant that no accumulator was needed for the filaments. The earliest of these were side-contact-based but these were quickly supplanted by octal style valves, usually in a tubular form with a plastic base and very elegant they were, too. I have a soft spot for them because it was this type of valve, specifically 1N5/DF33, 3Q5/DL35 among others I used when building my first radios, the 1952 Practical Wireless modern 1-valver, 2-valver etc. Because they used less current than the older 2 volt types they were used in both portables and small table models for those without mains supply, until supplanted by miniature B7G all-glass types, which retained the 1.4 volt filaments.

Basic types of valve

Diode: two active elements, anode and cathode (or filament in battery valves)

Triode: three active elements, anode, grid and cathode

Tetrode: four active elements

Pentode: five active elements

Some tetrodes and pentodes may be termed 'variable-mu'. This means that their gain can be controlled more easily by externally applied voltages, making them useful in automatic gain designs. They are found in RF amplifying stages.

There are also many variations of double valve, the common ones being triode-pentode, double triode, double diode triode, triode hexode, triode heptode. The latter two are used as frequency changers/local oscillators in superhet designs. Their name tells you they have even more elements!

Before going further, it should be noted that the presentation of circuitry is considerably different today from the way it was when valve radio was in it’s heyday. What we now call ‘schematics’ were then called ‘theoretical circuits’. Resistors were drawn as a zig-zag symbol, unlike the rectangle in European and British present-day use. Joined conductors simply met each other on the circuit diagram, no ‘solder blobs’ as today. Conductors crossing but not in electrical contact were drawn either with a break in one conductor at the passing point, or more commonly with an arc ‘jumper’ in the line of one conductor.

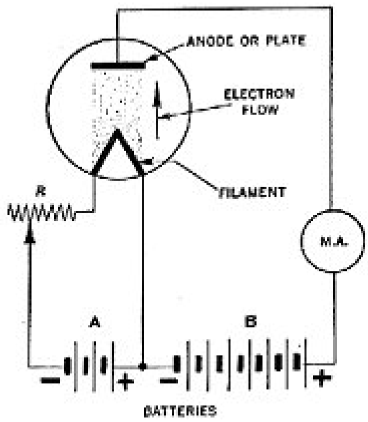
What we show as microfarads - the mu symbol – was usually designated m (or M). Therefore, a capacitor we would rate as 25µF (actually, we would use the preferred nearest of 22µF) would be identified as 25 Mfd, which would today might be falsely identified as being ‘millifarad’, i.e. one-thousandth of a farad, whereas (µF) is one-millionth of a farad – quite some error!

The terms ‘anode’ and ‘plate’ are interchangeable, as are ‘valve’ and ‘tube’, the latter in each case being mostly seen on American circuitry. Battery coding is described in the text that follows.

Another point to note is that the diagrams tend to be simplified - where 'filament' is used, it may also mean 'cathode' when referring to directly heated valves. It is important to remember that the earliest valves only worked from DC sources and it was the development of the electrically insulated heater instead of a plain filament that allowed AC capable valves.

The diagrams used here are taken from 'Audel's New Radioman's Guide', Theo. Audel and Co., New York, 1939

The DIODE

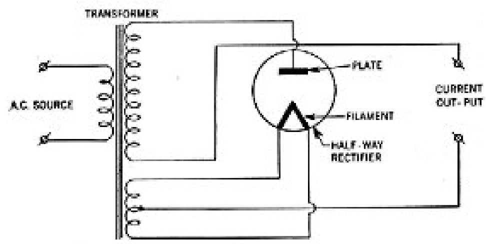


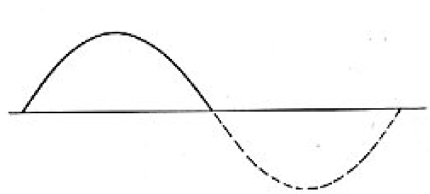
This is the simplest type of valve, having just two electrodes – anode and cathode (filament in the case of battery valves, as shown in the diagram).

The electrodes are enclosed within an evacuated envelope – bulb – usually of glass, the connections to the electrodes passing through this envelope via airtight seals.

The hot filament or cathode generates an invisible cloud of electrons in the space around it. A positive potential on the anode attracts these and a current flows from cathode to anode. A hard vacuum is created within the envelope in order to allow free movement of the electrons as they pass from cathode (filament) to anode and also to prevent destruction. Under no conditions can current flow from ANODE to CATHODE in any diode. The device is a ‘one-way VALVE’.

The DIODE as a RECTIFIER





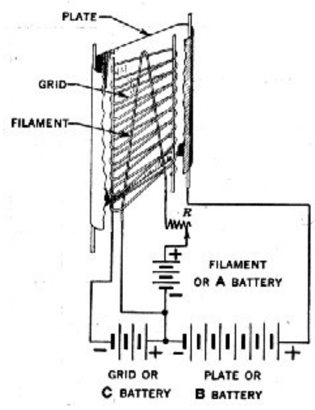
Increasing the positive potential will increase the flow of electrons from cathode to anode but if the anode is made negative, all current flow will cease. You can see from this that the positive-going (upper) section of the AC sine-wave will cause current flow, but the negative-going half (shown as a broken line) will stop all current flow. As current only flows in the one direction, the result is a pulsing but direct current output.

The addition of a reservoir capacitor across the output helps ‘fill in’ the gaps between the pulses by charging on the pulses and discharging in the gaps between them. This is improved further by either a choke or a resistor in series with an additional capacitor, called the ‘smoothing’ capacitor.

The choke/resistor-capacitor circuit forms a ’time-constant’ that filters even more of the residual AC ripple. Choke is more efficient, having a low resistance at DC, unlike the resistor which tends to waste power, but the resistor is often used because it is cheaper.

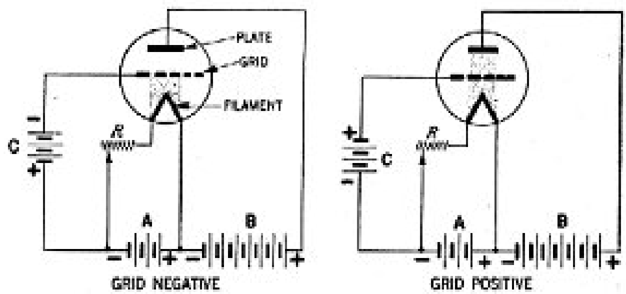
The TRIODE

The triode is a two electrode valve with a third electrode, called the grid, placed between the anode and cathode. The grid is usually a mesh or spiral of fine wire extending the full length of the cathode. The spaces between the wire spirals are quite large in order not to impair the passage of electrons from cathode to anode. The grid is used to control the flow of current through the valve. This action controls the anode current. By maintaining the grid at a negative potential, it will tend to repel electrons (like forces repel). The less negative, the less repulsion and the greater the flow of electrons. The more negative, the more repulsion and the smaller the flow of electrons. It is important to note that the grid is assumed to be always negative WITH RESPECT TO THE CATHODE. It cannot therefore collect electrons and small changes in potential at the grid can cause large changes in current flow through the valve.



This diagram shows the typical construction of a triode electrode assembly. Note that the filament in this illustration is directly supplying electrons, being heated by the 'A' battery, the grid has a negative potential supplied by the 'C' battery and the anode has an HT potential supplied by the 'B' battery.

These battery terms were commonly used in the USA. In GB the 'A' battery is called the LT (low tension) battery, the 'C' battery the grid-bias battery and the 'B' battery the HT (high tension) battery.

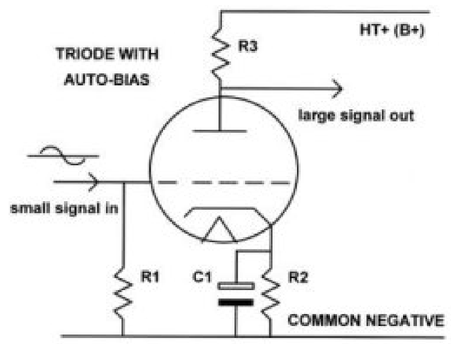


The variable LT resistor 'R' sets the operating voltage, therefore the temperature, of the filament. Although in early days such regulating rheostats were used, they were soon outmoded as advancements were made in valve manufacturing technology.

Inter-electrode capacity effects (Miller effect) limits the gain of the triode at higher frequencies.

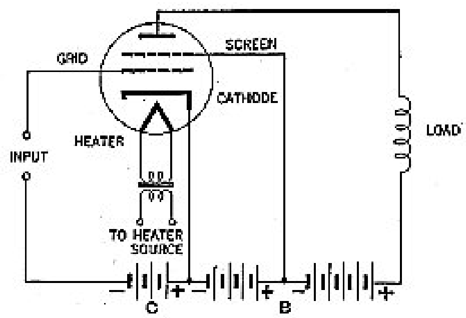
Automatic biasing

Grid-bias batteries were inconvenient even in battery receivers and unsuitable for use in mains powered ones. Automatic biasing was developed to get around this problem. In the triode, the cathode will be slightly positive due to the current flow through the resistor R2. The capacitor C1 keeps the potential steady. The grid is therefore negative with respect to the cathode. The value of the resistor R2 needs to be chosen with care if the valve is to be correctly biased. Resistor R1 removes any charge caused by the supply signal positive-going swings causing the grid to act as a second anode, creating grid current. Resistor R3 is the load resistor across which the signal is developed that mirrors the input signal as an inverted signal with much greater voltage swings.



The TETRODE

Internal capacitance limits the range of frequencies that the **triode** can amplify. Simply put, the higher the frequency, the less the gain of the valve. This is due to the internal capacitance of the electrode structure. The **tetrode** has an additional grid called the screen. This reduces internal capacitance and improves frequency response compared to the triode. The grid usually has a bypass capacitor (not shown on the diagram) which further reduces inter-electrode capacitance and allows still greater amplification and a wider frequency range.



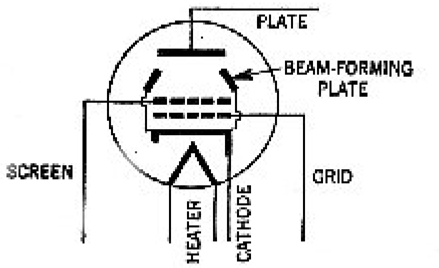
The PENTODE

The **pentode** has a further electrode, called the suppressor grid, placed between the screen grid and the anode. This grid is connected to the cathode and is therefore at cathode potential. In all valves but especially the tetrode, due to its higher gain, secondary emission takes place when electrons bombarding the anode dislodge other electrons. These ‘wandering’ electrons cause no trouble in diodes and triodes as there is no positively charged screen nearby to attract them and they return to the anode. In the tetrode the collection of these electrons lowers the current and therefore the gain of the valve, limiting the valve performance. The suppressor grid repels these relatively low-speed electrons back to the anode without obstructing the normal flow of electrons. The pentode, therefore, can provide considerably higher gain than the tetrode.

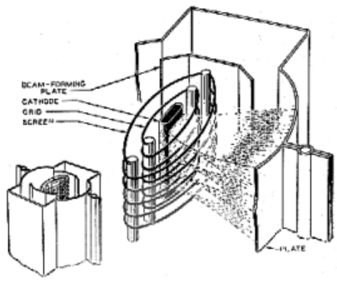
Many pentode valves are duplexed, i.e. the functions of more than one valve are enclosed within the same envelope. One typical combination valve is a double-diode pentode. The diodes are commonly used for signal detection and AGC (automatic gain control) and the pentode for power output or AF amplification. Superhet designs using this type of power output triode are sometimes called 'short' superhets, as effectively, one separate stage of valve amplification is saved. This made the sets less expensive to make - and perhaps to purchase (but not always, as manufacturers sometimes put more money into the overall quality). Sets using the duplex valve as an AF amplifying stage feeding the output valve stage are classed as 'long' superhets and often (but again, not always) formed the designs at the mid-to-higher-priced end of the market.

NOTES ON BEAM TETRODES

The action of the beam tetrode output valve is similar to the pentode but instead of a suppressor grid, beam-forming plates concentrate the electron flow and increase the total power output.



The diagrams on the right show the construction of a beam tetrode output valve and the action of the beam plates in focusing the electron beam onto the anode (plate).



Valve Types

The main purposes for which valves are used in domestic broadcast receivers may be classified roughly as: voltage amplifiers (RF, IF and AF); frequency changers; demodulators; AF power amplifiers; power rectifiers; and tuning indicators. Within these groups further subdivision is possible between those with variable-mu or straight-line characteristics, directly and indirectly heated types, etc.

In practice, however, valve assemblies are additionally classified according to the number of electrodes they contain, the heater of an indirectly heated valve being omitted from that number.

Number of Electrodes	*Classification*
2	diode
3	triode
4	tetrode
5	pentode
6	hexode
7	heptode
8	octode

A single, double or multiple valve assembly may be contained within one envelope, for example a double diode triode, a triode pentode, a double triode etc.

End of section