Valves (Tubes)

By G8MNY (Updated Sep 16)
(8 Bit ASCII graphics use code page 437 or 850, Terminal Font)

Although Valves are considered old hat nowadays, they are still used in big Tx, RF heating systems, microwave ovens, & of course in lots of old kit.

Here is some valve information for anyone who wants to brush up on the basics.

HT VOLTAGES

Most valves use quite high voltages, the High Tension e.g. 90, 120, 200, 250, 350, 1k5V 2kV, 3kV etc. Only a few special Rx valves use voltage as low as +12V HT.

So care must be taken if you don't want a nasty HT nip or even DEATH!

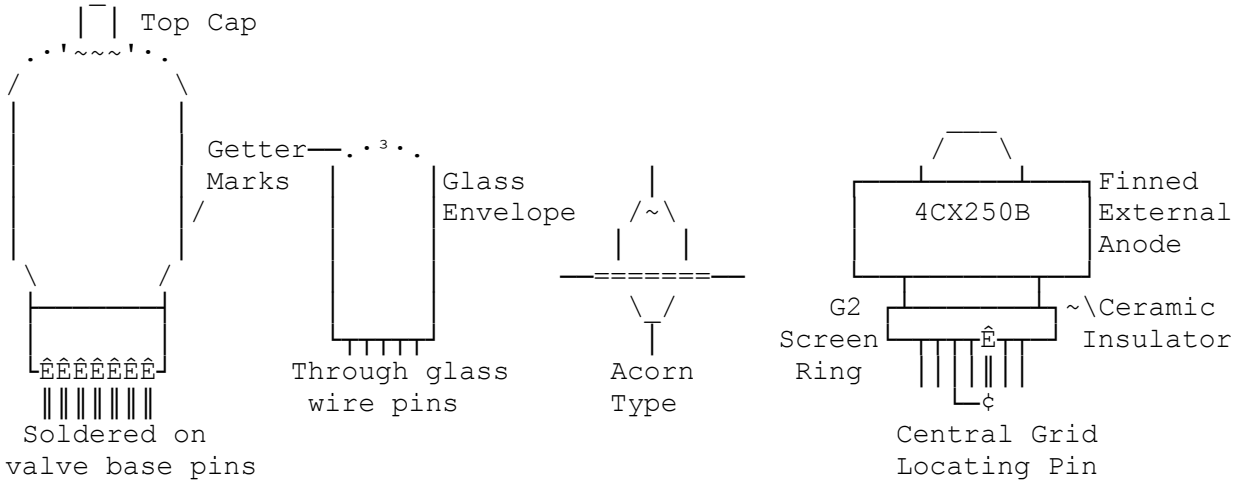
HEATERS VOLTAGES

Only special cold cathode & gas filled valves need no heaters. The heater power can be quite large compared to the total power. For battery radio valves heater voltages of 1.4V or 3V are normal. The most common voltage is 6.3V & for mains heater chains where all the heater in a set are in series, either 0.3 Amp or 0.1 Amp are the 2 common standards with a dropper resistor, AC capacitor, or diode to make up the mains supply voltage. Negative temperature thermistors were commonly put in mains chains, to take the warming up shock from the cold low resistance heaters.

On diagrams the heater chain/wiring is normally not drawn with the rest of the stages.

CONNECTIONS

Like lamps Valves have limited lifetimes 2000 hours for the bigger ones & 20,000 hours for CRTs etc, & most come with a pin connection base standard for easy replacement. These are give names like... B7G, B9A, MO, IO, P, P5, B9, B7, B5/4, UX7, UX5, UX4, etc.



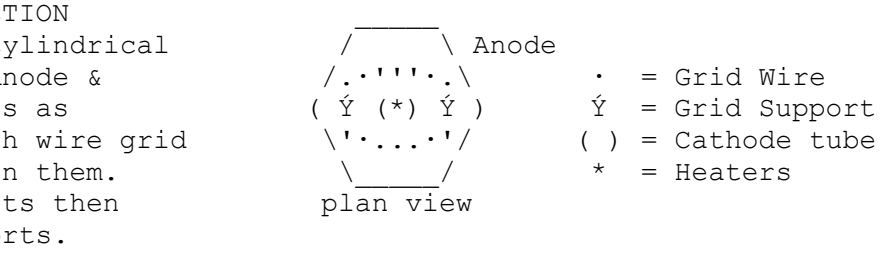
Many valves have top cap connections usually for Anodes on Tx & power valves like TV sweep tubes, but may also be a sensitive control Grid on Rx valves!

Getter marks are shiny silver/black areas where Magnesium has been vaporised onto the glass to catch the last remnants of gasses in the evacuated tube. A white getter mark indicates air has got into the valve & it is useless!

With the all glass construction & a good magnifying glass, it is often possible to determine not only what the internal constructions are (diode, triode, pentode etc.) but often also their pin out connections. But I have seen tetrodes assemblies wired up as a "rectifier diode internally" though (must have had a surplus?).

INTERNAL CONSTRUCTION

Most valves are cylindrical design with the Anode & Cathode electrodes as coaxial tubes with wire grid structures between them. Punched Mica sheets then support the supports.



VALVE NUMBERS

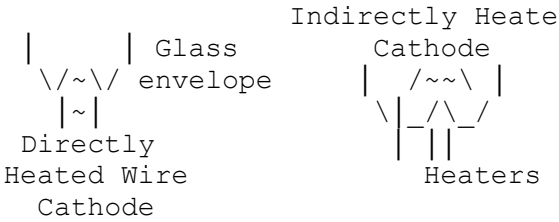
There are several systems! Some reflect the heater voltage & valve type, while others have no meaning at all.

EBC33 has 6.3V heaters (E) having Diode detector (B) & a Triode (C) with electrical & connection valve type 33.
CV123 is a UK military type, often with loads of commercial equivalents.
12AU7 is a 12V heaters (2x 6.3V) double triode.

A good valve data book will give you all the information for the type number & include direct equivalents. But like transistors, many applications may not need a direct equivalent, but electrode connections & heater voltages are most important to get right!

CATHODE

The Cathode can be directly heated by current through the Cathode wire, or indirectly heated with insulted wire inside the Cathode tube. Electrons boil off the hot Cathode electrode, normally helped buy an emitting coating enabling lower temperatures to be used (dim red glow). Without the coating the Cathode has to be very HOT, more like a lamp!

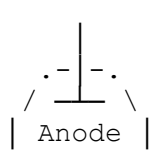


Directly heated Cathodes on AC supply often use a centre tapped AC supply, or a "hum dinger" pot across heater line to minimise hum due to the heater voltage.

The boiled off electrons form a cloud in the vacuum, & can be attracted to the Anode electrode if it is positive (or very near) with respect to the Cathode.

ANODES

These attract the electrons & have to absorb kinetic energy from the fast moving electrons & radiate it as heat. On power valves Anode structures are designed to radiate the heat away, or may even be externally finned to do this.

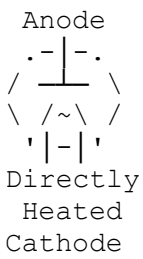


If the electrons are very fast then they can dislodge electrons in the Anode causing secondary emission from the Anode to other electrodes. To stop this some power valves use carbon/carbonised Anodes which better soak up electrons to stop most of this unwanted emission.

DIODES

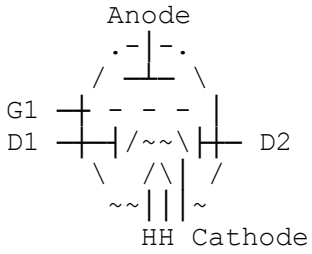
These use the 2 electrodes in an evacuate tube to conduct current one way.

Note that electrons flow the opposite way to current e.g. -ve to +ve, as electrons were discovered after the properties of current had been determined.



Unlike solid state devices, there is no voltage drop across valve signal diodes as the nearby Cathode electron cloud actually gives up electrons freely to the Anode (space charge current).

In Rx valves, they are often part of a multi valve single tube for IF detectors 8 AGC detectors plus the 1st AF amp stage.

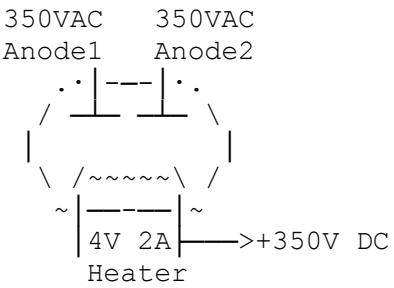


RECTIFIERS

These are just powerful versions of the diode used in power supplies.

Bi-phase designs are common.

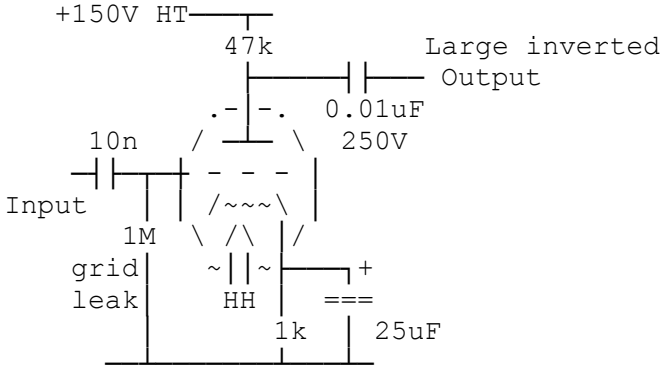
Voltage drop may be up to 30V.



Efficiency diodes rectifiers used in old TV stages, unusually have the Cathode as the top cap with very good Cathode to heater insulation for several kV.

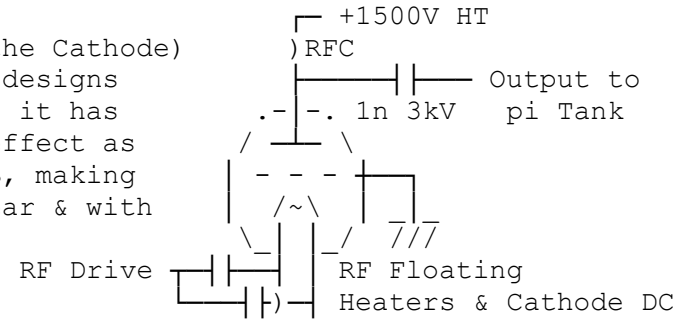
TRIODES

These have a Control Grid between the Cathode & Anode that reduces the flow of electrons. Gain "gm" or "mu" is in Anode mA per Grid Volt. The Grid is usually negative with respect to the cathode, & an AC bypassed cathode resistor is a common way to obtain this bias.



There is quite high capacitance between the Anode to the adjacent Grid & this causes high frequency negative feedback (Miller effect) in these high impedance circuits. The electron flow is proportional to the Grid voltage, but also the attracting Anode voltage, so there is considerable negative feedback in the triode, which keeps the Anode impedance low in common Cathode mode.

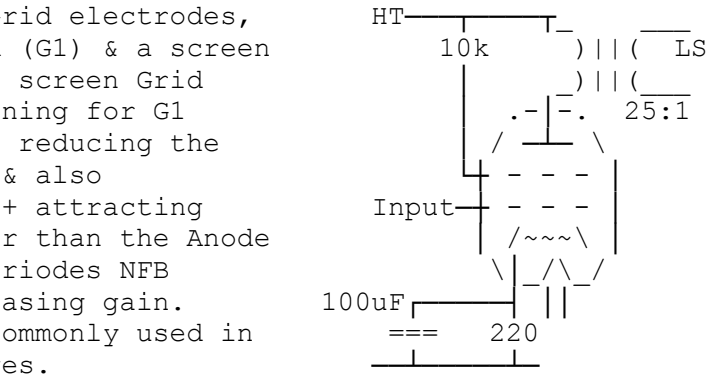
Common Grid mode (drive on the Cathode) is used in some PA & RF amp designs with its reduced power gain, it has the advantage of no Miller effect as well as applying current NFB, making the stage stable, quite linear & with low impedance drive.



For large Tx valves the triode may even be run with no bias & very large amounts of Grid current, when the Grid is pushed positive by the drive signal, but the Grid must be designed for this, or it will be destroyed! In data books you see mode of operating "class A B or C" with suffix "1 or 2", 1 indicates NO grid current 2 is with Grid current.

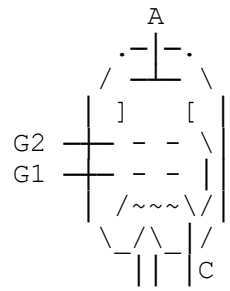
TETRODES

These have 2 Grid electrodes, a control Grid (G1) & a screen Grid (G2). The screen Grid provides screening for G1 from the Anode reducing the Miller effect & also maintaining a + attracting electrode other than the Anode reducing the Triodes NFB effect & increasing gain. Tetrodes are commonly used in AF output stages.



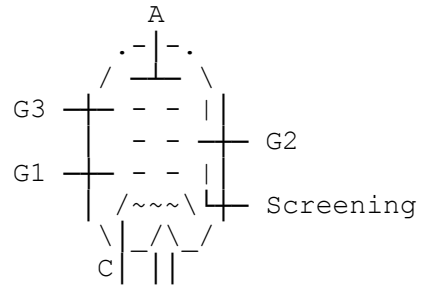
BEAM TETRODE

These have extra earthed electrode structure (attached to cathode) shielding much of the Anode structures electrical effects from the Grids. The Grids may also be exactly in line to improve efficiency, by keeping G2 currents low.

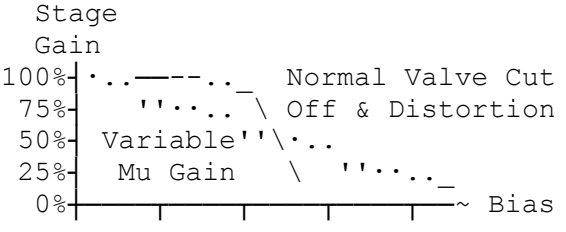


PENTODES

These have an earthed suppressor Grid (G3) between the screen Grid (G2). This also does Grid Anode shielding, but also reduces secondary emission effects, improving gain & linearity. For RF signal amplifiers an outer painted on or inner electrical screening may be used.

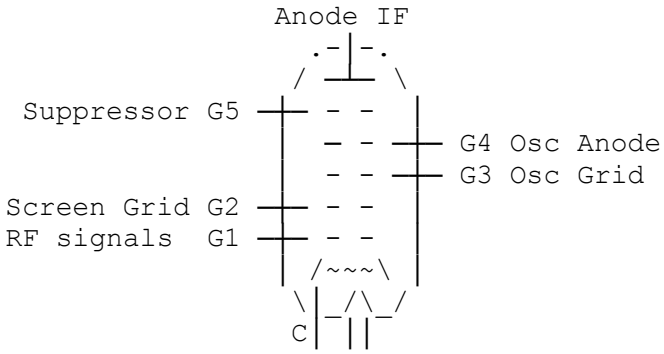


Variable gain (mu) can be obtained if the pitch of the G1 wire in manufacture is made variable, then increasing the -ve bias will slowly reduce the small signal gain of the valve rather than just cut off the whole valve. Rx AGC & Tx ALC use

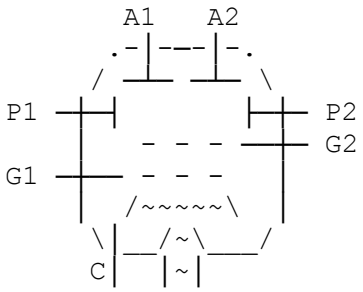


this feature to control gain. 1 2 3 4 5 -Volts

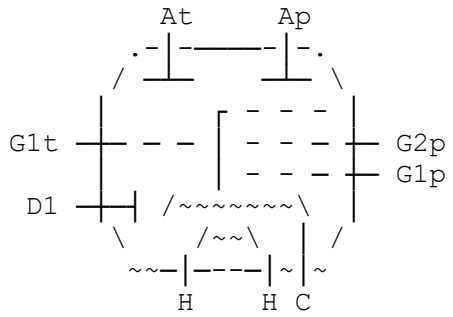
HEPTODES
With more electrodes some valves can be a mixer plus oscillator using the same electron flow.



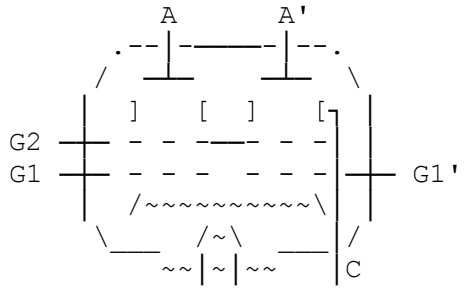
BEAM MIXERS
A good performance mixer can be made using a balanced out of phase Anodes A1 & 2, & a pair of beam bending deflection plates P1 & P2 fed with the balanced local oscillator. The amplified radio signal on G1 is then fed in turn to A1 or A2 depending on of the phase of the balanced local oscillator.



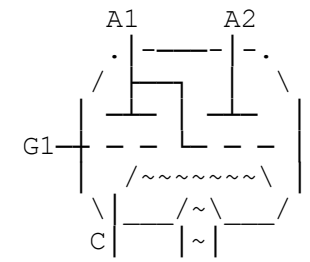
MULTIPLE VALVES
As vales are quite big it is quite common to include more than one in a glass envelope if there will be no interference (e.g. not multiple RF stages). Here a detector Diode, audio Triode & audio output Pentode all share the same Cathode. Sometimes in a diagram only part of the valve may be shown in a part of the circuit.



Some push pull VHF/UHF Tx valves use twin beam tetrode assembles with one Cathode & G2, but two G1s & Anodes. Internal Anode to Grid neutralising capacitors between A'- G1 & A - G1' are possible with push pull valves in one envelope.



INDICATOR TUBES
Often called magic eye or tuning indicators, these give a varying area of green fluorescent display depending on the signal. They are commonly twin triodes, where the anode of the first is the beam altering grid of the second triode & connected to HT with a high value resistor. The second triodes' anode at HT is phosphor coated, or used as an accelerator anode to phosphor on the glass to give the display.

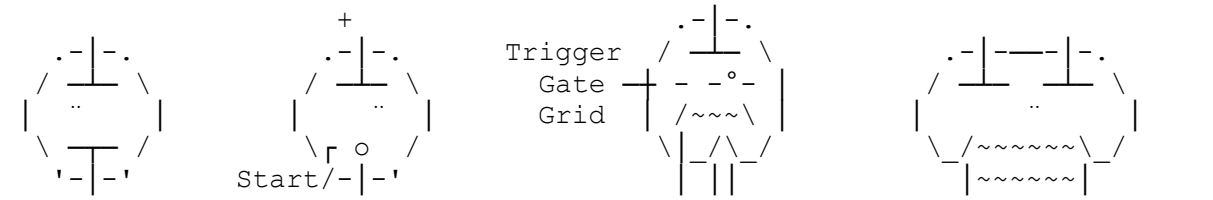


BEAM TUBES

Many types of special electron beam tubes exist other than the Cathode Ray Tube they include Travelling Wave Tubes, Klystrons etc. Most amplify or self oscillate & can produce very useful gains (e.g. 40dB) & powers (kW) at some astonishing frequencies (10s of GHz).

GAS FILLED

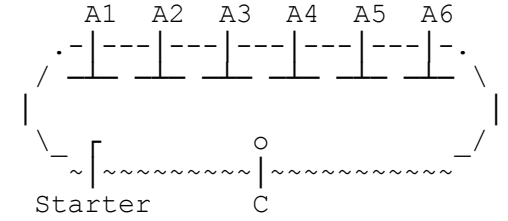
Gases are normally not wanted in valves as it ionises & poisons the Cathode. But cold Cathode tubes using neon, or other gasses do make good shunt voltage regulators (like zeners), & even triggered timebases using a Thyratron. The DOT or sometimes hatching, represents the gas inside the envelope.



NEON	REGULATOR	HEATED	HEATED HIGH CURRENT
80V 2mA	150V 80mA	THYRATRON	GAS RECTIFIER
NOTES:	OA2 = 150v	much typ	1007 cold kathode (octal)
------	OB2 = 90v	See book:	(US militair app's)
(From ON4CBL)	150C1K (octal)	EEV-GenE.	...

More complex neon ones make up NIXI number display tubes, & nowadays Mercury vapour ones make fluorescent lamps & the hart of Plasma TV display panels.

With liquid Mercury as a Cathode, large ones use (before the silicon diode) to be used as large poly phase rectifiers, with 3, 6, or even 12 Anodes, many Amps at several kVs can be rectified this way.



See my bulletins on "Early AVO Valve Tester", "Old Valve Radios", "Microwave Ovens" & for PAs "4CX250B PA Regulated Supplies" & "4CX250B PA Timing & Control", & also "Reforming Caps" or "Oscilloscopes" for CRT information.

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73 De John G8MNY @ GB7CIP