Newcomers' Notebook

If it's not glowing, it's not going

That pocket particle accelerator – the valve

Jules Perrin VK3JFP

Vacuum tubes – thermionic valves – have been around almost since the start of electronics, radio and wireless. The death of tubes, valves, or bottles, has been predicted since at least 70 years ago when solid-state devices arose, but they're not going anywhere too quickly, it seems. As valves still find their uses, here's some simple information and explanations so you can come to grips with them without complex mathematics.

Back before our grandfathers were born, some German physicists intrigued the science world by sending electric currents between metal terminals in evacuated glass tubes, producing strange emissions called cathode rays.

Famously, physicist J J Thomson showed that cathode rays were composed of unknown negatively charged "corpuscles" that are now called electrons.

The race was on to harness electrons in glass vacuum tubes. Thermionic emission of electrons from heated metal in a vacuum was discovered and rediscovered over the late 19th century. Edison is credited with showing that electrons could flow between a heated filament in an electric lamp and a metal electrode placed nearby. It's called the Edison effect (surprise, surprise!).

In 1904, the English physicist John Ambrose Fleming built the first practical vacuum tube termed the 'Fleming valve,' the forerunner of all the valves we know today, which dominated the electronics industry for 50 years.

Is it valve, or tube? In Australia, as in Britain and Europe, the term valve is generally used, but either is acceptable and interchangeable. In the Americas, they are invariably tubes. Elsewhere, anything goes.

The basis of the valve is that, inside the evacuated glass envelope, electrons flow from the heated cathode to the anode, which are separated a short distance. This is a diode (literally, 'two electrodes'). See **Figure 1**.

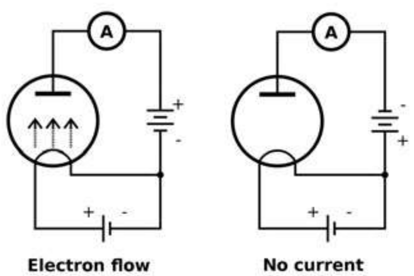


Figure 1. The most basic valve is the diode. When the filament, or cathode, is heated by an electric current, electrons stream off. As they have a negative charge, they will race to the anode when a positive potential is applied, as at left (hence, *particle accelerator!*). When the anode is negative, the electrons are repelled and no current flows (Wikimedia).

A valves cathode may be *directly heated*, as a bare filament wire (of tungsten or nickel alloy) shown here, or indirectly heated, where the filament heats a metal tube (of nickel or nickel alloy). In the former case, the filament wire is usually treated with an exotic substance (e.g, thorium, or barium oxide). In the latter, the cathode's nickel surface is also coated with an exotic oxide. These treatments are to ensure the cathode emits torrents of electrons.

Now, if you can control or vary the flow of electrons between the cathode and anode, you have an amplifier. This is done by putting a 'leaky fence' in the way, called a grid. See **Figure 2**.

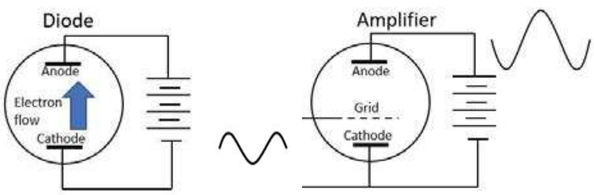
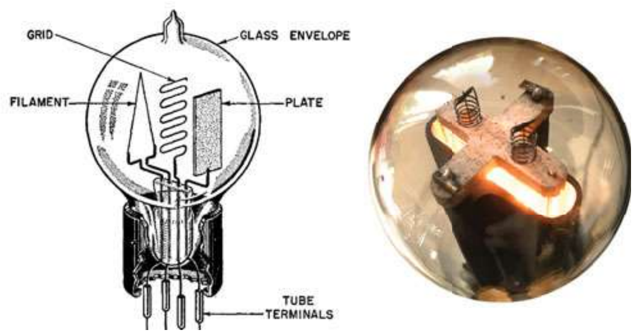


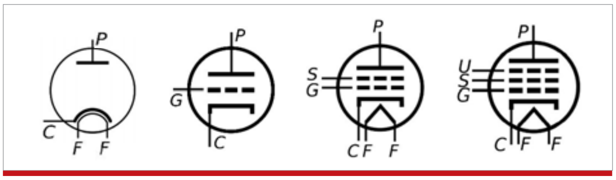
Figure 2. Add another element to a diode – the grid – and you can make an amplifier. Varying the grid voltage creates a corresponding variation in the anode current, but opposite in phase. As the grid signal controls the anode current, the grid is called a 'control' grid.



Basic Triode. Here's the general idea at left and inside the real thing at right, with the filament lit up, showing the grid and the anode (triode drawing – Wikimedia image; triode photo by Phil Wait VK2ASD).

In the beginning, the first valves were diodes, soon followed by triodes ('tri' = 3!). When used at radiofrequencies, triodes circuits can be tricky as the anode signal can feed back to the control grid via the tiny capacitance between anode and grid and the circuit oscillates. To fix this, an extra grid was inserted between the control grid and the anode, called a screen grid or shield. The tetrode was born (tetra = 4).

Further valve improvements added an additional element to make the pentode (penta = 5), with its 'suppressor' grid to return electrons that have bounced off the anode, thus maintaining the anode current flow. The pentode is common in amateur radio uses.



Valve circuit symbols – diode through to pentode. This is the general way valves are shown in circuits. C= cathode. F = filament (or heater). G = grid. P = plate (anode). S = screen. U = suppressor grid.

There are many, many variations and types of valves and these can be found on the internet (see *Resources* below). I pulled three random valves from my old dust covered valve box. See the line-up in **Figure 3**, along with their symbols showing the pin connections.

Valves are designed and manufactured in a wide variety of ways. The materials used to make the valve elements and the way they are put together impact the efficiency and application of the valve.

The characteristics of a valve relate to its design and intended application, so consult a datasheet for more information. Datasheets are readily found by a Google search on the internet.

12BY7A: This is a low-medium gain pentode found in a wide range of applications – audio amplifiers, RF amplifiers and oscillators, and early TV receivers. From the symbol shown in **Figure 3**, the 12BY7A doesn't use a base locating pin to orient it in a socket. This is achieved by the pin spacing on the base – there's a big gap between Pins 1 and 9.

S2001A or 6146B: This is a common power output pentode used in older amateur radio transceivers from Yaesu, Kenwood, and others. Notice the central spigot on the base of this tube (behind the pins) and the 1B3GT next to it. This has a keyway/pin that orients it in the socket.

1B3GT: This is a high voltage rectifier diode used in old black and white TV receivers and now, perhaps, usually found in technology museums. I include this valve to demonstrate these components made and used before semiconductors came out.

The peak inverse voltage rating for this valve is 30,000 V. The Radio Corporation of America (RCA) datasheet for the 1B3GT, dated Nov 1949, states that "due to the high voltages involved with this diode, it should be shielded as it can produce 'soft x-rays' that are not good for one's health"!

Fingers beware

Caution must be used when working with vacuum tubes. As the cathode is heated to encourage the flow of electrons – producing the alluring glow, whether from directly or indirectly heated cathodes – and the glass bulb can get quite hot, maybe 200° C – enough to burn fingers. The anode is at a high voltage, ranging perhaps from 200 VDC to 700 VDC or more, which can be lethal.

Capacitors used around valve circuits can store a charge for long periods. Should you wish to remove a power valve like the S2001/6146 from its socket in equipment, carefully discharge the exposed anode connector to the chassis beforehand.

Resurgence

The use of valves has not died out following the introduction of solid-state devices. Articles suggest a large portion of the current valve production is used in hi-fi audio and guitar amplifiers. Check out some of the website listed under Resources.

Large, high power vacuum tubes are still used in high power amateur and commercial transmitter applications.

If you have a topic you would like to nominate to be covered in a future instalment of Newcomers' Notebook, email Jules at: jp.bqt@bigpond.net.au

Have fun and stay safe.

Resources

About the vacuum tube:
https://en.wikipedia.org/wiki/Vacuum_tube

The cool sound of tubes:
https://spectrum.ieee.org/the-cool-sound-of-tubes

Introduction to electron tubes:
https://tinyurl.com/2s47u7y2

Valve types and characteristics (pdf):
https://tinyurl.com/3zfunsv8

6L6 at 60 – Vacuum Tube Valley (pdf):
https://tinyurl.com/5faf23nh

The valve museum:
http://www.r-type.org/

RCA Receiving Tube Manual 1975 (pdf):
https://tinyurl.com/45v7v2s6

RCA Transmitting Tubes 1956 (pdf):
https://tinyurl.com/yw8by97x

Principles of Electron Tubes, by Reich (pdf):
https://tinyurl.com/2p9hx5x2

Books to download:
www.tubebooks.org

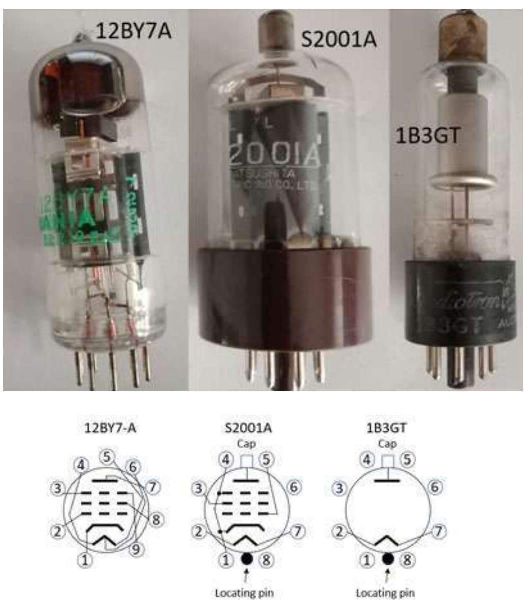


Figure 3. These valves from my shack illustrate the types and varieties used in applications from amateur transceivers to television receivers (photo by author).