History of theThermionic Tube / Valve / Vacuum Tube – Page 1

The following notes have been assembled by Phil (VK5SRP) from original material and material from several web sites, including Wikipedia for a class run at the North East Radio Club, South Australia January 2016.

In electronics, a **vacuum tube**, an **electron tube**, or just a **tube** (North America), or **valve** (Britain and some other regions) is a device that controls electric current between electrodes in an evacuated container. Vacuum tubes mostly rely on thermionic emission of electrons from a hot filament or a cathode heated by the filament/heater. This type is called a **thermionic tube** or **thermionic valve**. A Photo-tube, however, achieves electron emission through the photoelectric effect. Not all electronic circuit valves/electron tubes are vacuum tubes (evacuated). Gas-filled tubes are similar devices containing a gas, typically at low pressure, which exploit phenomena related to electric discharge in gases, usually without a heater.

Although thermionic emission was originally reported in 1873 by Frederick Guthrie, it was Thomas Edison's 1883 investigation that spurred future research, the phenomenon thus becoming known as the "**Edison effect**". Edison patented what he found, but he did not understand the underlying physics, nor did he have an inkling of the potential value of the discovery.

It wasn't until the early 20th century that the rectifying property of such a device was utilised, most notably by **John Ambrose Fleming**, who used the Diode tube to detect (demodulate) radio signals. **Lee De Forest's 1906 "Audion"** was also developed as a radio detector, and soon led to the development of the Triode tube. This was essentially the first electronic amplifier, leading to great improvements in telephony (such as the first coast-to-coast telephone line in the US) and revolutionising the technology used in radio transmitters and receivers. The electronics revolution of the 20th century arguably began with the invention of the Triode vacuum tube.

The simplest vacuum tube, the D**iode**, contains only a heater, a heated electron-emitting Cathode (the filament itself acts as the cathode in some diodes), and a Plate (Anode). Current can only flow in one direction through the device between the two electrodes, as electrons emitted by the Cathode travel through the tube and are collected by the Anode. Adding one or more control grids within the tube allows the current between the cathode and Anode to be controlled by the voltage on the Control Grid or Grids. Tubes with grids can be used for many purposes, including amplification, rectification, switching, oscillation, and display.

Invented in 1904 by John Ambrose Fleming, vacuum tubes were a basic component for electronics throughout the first half of the twentieth century, being used in radio, television, radar, sound reinforcement, sound recording and reproduction, large telephone networks, analogue and digital computers, and industrial process control. Although some applications had counterparts using earlier technologies such as the spark gap transmitter or mechanical computers, it was the invention of the vacuum tube that made these technologies widespread and practical.

History of theThermionic Tube / Valve / Vacuum Tube – Page 2

In the 1940s the invention of semiconductor devices made it possible to produce solid-state devices, which are smaller, more efficient, more reliable, more durable, and cheaper than tubes. From the mid-1950s solid-state devices such as transistors gradually replaced tubes. The cathode-ray tube (CRT) remained the basis for televisions and video monitors until superseded in the 21st century. However, there are still a few applications for which tubes are preferred to semiconductors; for example, the magnetron used in microwave ovens, and certain high frequency amplifiers.

Classifications

One classification of vacuum tubes is by the number of active electrodes, (neglecting the filament or heater). A device with two active elements is a **Diode**, usually used for rectification. Devices with three elements are **Triodes** used for amplification and switching. Additional electrodes create Tetrodes, Pentodes, and so forth, which have multiple additional functions made possible by the additional controllable electrodes.

Other classifications are:

- by frequency range (audio, radio, VHF, UHF, microwave)
- by power rating (small-signal, audio power, high-power radio transmitting)
- by cathode/filament type (indirectly heated, directly heated) and Warm-up time (including "bright-emitter" or "dull-emitter")
- by characteristic curves design (e.g., sharp- versus remote-cutoff in some Pentodes)
- by application (receiving tubes, transmitting tubes, amplifying or switching, rectification, mixing)
- specialised parameters (long life, very low microphonic sensitivity and low noise audio amplification, rugged/military versions
- specialised functions (light or radiation detectors, video imaging tubes)
- tubes used to display information (Nixie tubes, "magic eye" tubes, Vacuum fluorescent displays, Cathode Ray Tubes.

Many tubes can be classified under more than one of the above, or example, dual triodes can be used for audio pre-amplification, RF amplification or as flip-flops in computers.

Cathode Ray Tubes create a beam of electrons for display purposes such as the television picture tubes and there are the more specialised functions such as electron microscopy and electron beam lithography. X-ray tubes are also vacuum tubes. Photo-tubes and Photo-multipliers are Electron Tubes relying on electron flow through a vacuum and in those cases electron emission from the cathode depends on energy from photons rather than thermionic emission.

Description

A vacuum tube consists of two or more electrodes in a vacuum inside an airtight enclosure. Most tubes have glass envelopes, though ceramic and metal envelopes (with insulating bases) have been used. The electrodes are attached to leads which pass through the envelope via an airtight seal. On most tubes, the leads, in the form of pins, plug into a tube socket for easy replacement of the tube. Some tubes had an electrode terminating at a Top Cap. The principal reason for doing this originally was the use of four or five pin tube sockets but this was soon also used to avoid leakage resistance through the tube base, particularly for the high impedance grid input and at very high operating (RF) frequencies. The bases were commonly made with Phenolic insulation which performs poorly as an insulator in humid conditions. Tubes intended for high frequency or high power operation usually had a ceramic base. Other reasons for using a "Top Cap" include reduced grid to anode capacitance, improved high-frequency performance, keeping a very high plate voltage away from lower voltages, and accommodating one more electrode than allowed by the base. There was even an occasional design that had two top cap connections. (7193)

The earliest vacuum tubes evolved from incandescent light bulbs, containing a Filament sealed in an evacuated glass envelope. When hot, the Filament releases electrons into the vacuum, a process called **Thermionic Emission**. A second electrode, the Anode or *Plate*, will attract those electrons if it is at a more positive voltage. The result is a net flow of electrons from the Filament to Plate. However, electrons cannot flow in the reverse direction because the Plate is not heated and does not emit electrons. The Filament (*Cathode*) has a dual function: it emits electrons when heated; and, together with the Plate, it creates an electric field due to the potential difference between them. Such a tube with only two electrodes is termed a **Diode**, and is used for rectification. Since current can only pass in one direction, such a Diode (or *Rectifier*) will convert alternating current (AC) to pulsating DC. This can therefore be used in a DC power supply, and is also used as a demodulator of Amplitude Modulated (AM) radio signals and similar functions.

Early tubes used the directly heated filament as the Cathode. Over time many tubes evolved to **employ indirect heating, with a separate electrically isolated "heater" inside a tubular Cathode.** The Heater is not an electrode, but simply serves to heat the Cathode sufficiently for thermionic emission of electrons. This allowed all the tubes to be heated through a common circuit (which can as well be AC) while allowing each Cathode to arrive at a voltage independently of the other usually to provide a Bias voltage to the tubes Grid 1.

The filaments require constant and often considerable power, even when amplifying signals at the microwatt level. Power is also dissipated when the electrons from the Cathode slam into the Anode (Plate) and heat it; this can occur even in an idle amplifier due to quiescent currents necessary to ensure linearity and low distortion. In a power amplifier, this heating can be considerable and can destroy the tube if driven beyond its safe limits. Since the tube contains a vacuum, the anodes in most small and medium power tubes are cooled by radiation through the glass envelope. In some special high power applications, the anode forms part of the vacuum envelope to conduct heat to an external heat sink, usually cooled by a blower.

Klystrons and Magnetrons often operate their anodes (called **Collectors in Klystrons**) at ground potential to facilitate cooling. These tubes instead operate with high negative voltages on the Filament and Cathode.

Heating the Cathode

A wide range of Filament and Heater voltages have been used. The earliest tubes used around four volt and as these tubes were directly heated from Lead-Acid batteries.

The Filament supply had to be smooth DC. Most early tube equipment had potentiometers to control the voltage to some of the Filaments, this was done to lower power consumption from the "A" battery and to increase the life of the tubes by not "working them as hard". The Filament control was often used as a volume/gain control.

In the 1920's most tubes intended for battery operation used Filament / Heater voltages of either 1.5 Volt (for dry battery supplies) or 2.0 Volt (for single cell Lead/Acid batteries.

By the early 1930's many homes had reticulated electricity supplies and most of these were AC, but some reticulated DC town supplies lasted up to the 1940's. Where a "Mains Transformer" was used to convert the town supply to the voltages required in electronic equipment most Australian radio manufacturers chose to use tubes with Heaters requiring 6.3 Volt AC.

A strange anomaly was the use of 5 Volt AC for the Filaments/ Heaters of the rectifier tubes that rectified a high voltage winding on the transformer to provide the "B" supply or High Tension, usually between 150 and 250 Volt.

In the USA many domestic radios were built to operate directly from the 115 Volt AC mains supply and to avoid the cost and weight of having to use a power transformer, a "series heater string" was made from the heaters of the valves and this could then be connected to the mains supply, sometimes with a series resistor that was often included as a third wire (resistance wire) in the power supply chord. The tubes had heater voltages of 6.3, 12.6, 18, 24, 36 volt and many other variations, but each tube having the same rated current, usually 150 mAmp. If tubes or dial lamps with other current requirements were included, a balancing resistor was used across the lower current device.

Transformer-less tube equipment were also common in Europe and the UK and these radios and televisions are lethal to service, one side of the circuit is connected directly to the mains supply. This type of circuit is often referred to as **"Hot Chassis".**

So far I have mentioned the **"A"** supply and the **"B"** supply while talking about battery operated equipment. Many battery operated radios from the earliest days of radio to the early 1950's may have had a **"C"** supply. This was Bias supply and the battery used for this function had a series of taps providing a range of low voltages to the Grids of the various Tubes in the circuit. This function was achieved in Mains operated equipment by the use of what is called **Back Bias**, a low value resistor in the negative side of the supply to the common earth rail and/or by using cathode bias resistors for some or all of the stages.

Battery eliminators were a common accessory in the early days of radio and these may have just replaced the B battery or both the A and B batteries.

As no significant current was consumed from the C battery that was usually retained when a battery eliminator was used.

Tube Sockets or Bases

The earliest tubes, like the *Deforest Spherical **Audion*** from c. 1911, used the typical light bulb Edison socket for the heater, and flying leads for the other elements. Other tubes used flying leads for all of their contacts, like the *Cunningham AudioTron* from 1915, or the *Deforest Oscillion*.

The first Rectifiers that plugged into a socket had only three pins. This soon expanded to four, two fatter pins and two smaller pins so the tube could not be plugged in the wrong way round. In the USA a series of five, six and seven pin sockets soon followed with two different seven pin configurations. All of these early Tube sockets had two larger diameter pins for the Heater/Filament leads. During the 1930's many tube socket types evolved with different configurations in the USA, Europe and the UK. Over the years sockets with as many as twelve pins evolved.

This is far to big a topic to be covered here, may I suggest you look up these reference on the Web – This simple explanation is a taste of the information available from Wikipedia - https://en.wikipedia.org/wiki/Tube_socket

Tube Numbering systems

In order that vacuum tubes or thermionic valve numbering had some reason to it, numbering schemes were developed. Using these it was often possible to gain an approximate idea of the tube and its functions. There are two common schemes that were adopted, one used in Europe for tubes primarily manufactured and used there, and the other for tubes from the USA. There was also the Russian, Chinese and Japanese numbering system and details of these can be found via a web search. There is also the CV numbers and other military numbering schemes.

American system

First figure indicates the heater voltage	Second and other characters are serial numbers	Suffix letters
0 - Cold cathode		
1 - 0 - 1.6V		G - Large glass envelope
5 - 4.6 - 5.6V		GT - Small glass envelope
6 - 5.6 - 6.6V		M - Metallised
7 - 6.3V Loctal		X - Low loss base
12 - 12.6V		W - Military type base
35 - Around 35V		

Tube Envelopes used for American tubes in the 1930's and 1940's.

During this period glass envelopes for low power Tubes became almost standardised in two designs, the larger G envelope (a bottle shape design) and then the smaller GT envelope. Many Octal based tubes were also produced during this time with rugged metal envelopes mainly for military and car radio uses.

European System

First letter indicates the heater supply

A 4V AC
C - 200mA AC and DC
D - Battery supply 1.2 to 1.4V
E - 6.3V AC and DC
G - 5V AC
K - 2V battery supply
P - 300 mA
U - 100 mA AC and DC

Subsequent letters indicate the type of valve

A - Single diode
B - Double diode
C - Triode
D - Triode output valve
E - Tetrode
F - Pentode
H - Hexode or heptode
K - Octode
L - Pentode output valve
M - Tuning indicator
N - Thyratron
Q - Nonode
T - Miscellaneous
X - Gas filled full wave rectifier
Y - Half wave rectifier
Z - Full wave rectifier

Following figures indicate the base

20 - 29 B8G (Loctal)
30 - 39 Octal
40 - 49 B8A
50 - 59 Miscellaneous constructions
60 - 79 Subminiature constructions
80 - 89 B9A
90 - 99 B7G

If a number is greater than a hundred then the first figure should be disregarded to determine the base.

The tables above were derived from an article here: http://www.electronics-radio.com/articles/electronic_components/valves-tubes/numbering-systems.php

Again, this is far too big a topic to be covered in detail. This is a sample of what can be found on the Web and links to other sites.

Two other good resources are: - http://www.r-type.org/articles/art-170.htm

and http://www.vintage-radio.com/repair-restore-information/valve_valve-numbering.html

A web site with information and cross references for the US and GB military CV type numbers: Virtual Valve Museum: http://www.tubecollector.org/cv-valves.htm

History of theThermionic Tube / Valve / Vacuum Tube – Page 7

Interesting Australian information: http://home.mira.net/~gnb/elec/valvedata.html

Tubes used in Russia and the Eastern Block countries used Cyrillic characters in their type numbers: http://www.jogis-roehrenbude.de/Russian/Russische_Roehren.htm

If you have a western keyboard you will need to type in the codes from the table on this web site. http://symbolcodes.tlt.psu.edu/bylanguage/cyrillicchart.html

For example, if you wanted to search for **6Н1П** you could key in **6N1P** which is the western equivalent, or the codes **6Н1&#1055**

Another example: **6Д22С** is keyed in as **6Д22&#1057**, or you could just type in the western equivalent of **6D22S**.

Most western users will find it easiest just to type in the western equivalent, most of which are well known. One to be careful of is 6C33C which is actually 6S33S in western speak, and many tube suppliers quote it with the Cyrillic C instead of the western S.

Duncan's Amps says "many thanks to Sergey V. Ekilik who provided the information to allow the Cyrillic display and searching to be made available". Some of the letters shown in this table are guesses ?

European users who have a keyboard which supports Cyrillic characters can just type them straight in from their keyboard.

Other Electron Tube data and information web sites:

List of vacuum tubes From Wikipedia: https://en.wikipedia.org/wiki/List_of_vacuum_tubes

Frank's electron tube data: http://frank.pocnet.net/

The Vacuum Tube Museum: http://www.internationalvacuumtubemuseum.org/home.aspx

Tube Data Sheet Locator - Duncan Amps: http://tdsl.duncanamps.com/

Glenn Baddeley - Valve Data: http://home.mira.net/~gnb/elec/valvedata.html

The National Valve Museum: http://www.r-type.org/index.htm

In addition to Photo device, the Tube glass envelope was also used for a number of other device, the most common being, frequency determining crystals.