Addicted to the bottle?

Whether you call them valves or tubes or even vacuum tubes or thermionic devices, these little bottles have a long history and don't seem to be going away. JOHN WATKINSON almost lays down the sword and indulges in a little nostalgia.

THE VALVE WAS THE first practical electronic amplification device and for a long time there wasn't anything else, so the art advanced to a very high level indeed. Probably all of the foundations of linear circuit design were laid using the valve, and some of the first digital computers were valve based. Early attempts at integrated circuits were also made with valve technology.

It's useful to appreciate how the thing works. Various electrodes are supported on mica plates inside an evacuated envelope. This is commonly made of glass, but quite a few metal envelope valves were also made, using glass only as an insulator where the connections come out. A heating element raises the temperature of a slim metal tube that runs up the centre of the envelope. This is called the cathode, and it's coated with a barium-based compound that emits electrons when heated. Surrounding the cathode is a larger metal cylinder called the anode that can be seen through the envelope if it is made of glass. If this is connected to a positive supply, electrons from the cathode will be attracted and a current will flow. However, if the anode is made negative, the electrons are attracted back to the cathode and no current flows.

Thus a simple two-electrode device, not surprisingly called a diode, has the ability to pass current in one direction only. This is useful for logic circuits and for rectification of AC to DC, whether that be in a power supply or in a PPM.

We can have more fun by adding a further electrode in the annular space between the anode and cathode. This is usually a helix of thin wire with quite a large space between the turns, hence the name of grid. The grid acts like the handle on a water valve, or the gate on a FET if you want to keep the conversation technical. The voltage on the grid affects the flow of electrons from the cathode to the anode. If the grid is made negative with respect to the cathode, the electrons are repelled and can't reach the anode. If the grid is made less negative, the effect lessens. At a slight negative voltage the grid may as well not be there and the valve conducts fully. Thus a small signal at the grid can control a much larger current flowing between anode and cathode.

The valve is basically a high impedance device. No current flows in the grid except to charge stray capacitance. Quite a high voltage is needed to get the electrons to jump across a vacuum. Very low powered valves might use 30 volts. Valve portable radios used 90V, table radios used 250V and high-grade audio amplifiers might use as much as 350V. Clearly to drive loudspeakers an output transformer is needed.

It should be clear that the only type of valve available is one that works with a positive power rail. There is no equivalent of the NPN/PNP pair. Thus a push-pull output stage driving a single-ended load will typically require a centre-tapped output transformer.

One common misconception is that valves get hot because of the heater. They get hot because of the anode current, in the same way that transistors get hot because of the collector current.

The valve and the transistor are both devices that control current flow using a third terminal. Both are non-linear, in that the transfer function is not a straight line. The difference is that the transistor is highly non-linear, whereas the valve is only mildly non-linear.

In order to make a transistor or a valve linear, it is necessary to use negative feedback. This compares the output with the input and uses the gain to minimise the difference. The first precision operational amplifiers were developed using valves and were as linear as any of today's silicon. They were used in analogue computers to carry out mathematical operations (hence operational amplifiers or op-amps). The Boeing Superfortress bomber had valve analogue computers controlling the gun turrets so that any turret could be slaved to another to make more lead arrive at the same point in the sky. Interestingly, valve-based electro-hydraulic systems like this made possible the rapid actuators on early disk drives.

You can put a high-grade silicon op-amp in series with an audio system and you can't hear it. The same is true of a high-grade valve op-amp. Thus the 'valve sound' is a myth. Valve circuitry does not

fundamentally 'do something' to the sound: it depends on how the designer uses it. Poorly designed valve equipment can sound terrible, just like silicon-based equipment.

Confusing a technology with performance is dangerous, but it's exactly what marketing tries to play on. The new Jaguar saloon car is made of aluminium. Unfortunately its weight is very nearly the same as the XJ6 of 1968 that was made of steel and had an iron cylinder block. In the same way, just because an item has valves in it there is no guarantee of what it will sound like.

Having said that, in order to save money, a lot of valve equipment doesn't use operational amplifier techniques, but instead uses a single triode or pentode for a gain stage. Using a single transistor would be distortion suicide, but with a single valve, the resultant distortion is relatively small and sonically pleasant. This is the origin of the valve sound myth. Putting a single-valve gain stage in an audio chain adds a small amount of second harmonic distortion that some people find to their liking. It's actually an effect, but one that can't be turned off. It's fine if you like that kind of thing, but it does turn the process into an art form rather than reproduction. It's not too hard to make digital systems do the same thing with modern DSP. Then you could turn it off when it's not needed.

Valve circuits clip gently under overload, whereas silicon devices just go to the rail. However, if overload is not entered, it is perfectly possible to design a valve circuit and a silicon op-amp circuit that are utterly indistinguishable in sonic character. This is because with sufficiently stringent design criteria, neither will have any character at all.

I could very easily have accepted myths about valves, because I can remember the first transistor radios that were launched with a fanfare of marketing hype about what a fantastic technological leap they represented. In fact they sounded like strangled cats and were inferior in every respect except portability to the lovely old valve radios that people chucked out. I used to get these old radios from jumble sales for next to nothing and they sounded great and picked up many more stations than the transistors.

They had big illuminated dials with names like Kalundborg and Motala that sounded exotic and far away. I never thought I would get to go to some of these places. Nor did I expect ever to be able to explain exactly how these valve radios worked and why they sounded better than transistor radios.

The disappointment of the transistor radio may have contributed to my becoming a cynic; that and being told by a nurse that a hypodermic injection wouldn't hurt. The insecurity of youth leads one to be quietly cynical, but when as a student I found there were other cynics on the planet, I was able to dispense with the quiet bit. I learned that a cynic is the name given to people who know what's coming by people who don't and have regarded it as a compliment ever since.

The transistor radio disappointment was followed by the disappointment of the transistor audio amplifier. These devices used Class B whereas valve amplifiers had always used Class A. The transistor amplifier brought with it the abomination of crossover distortion and it took many years before designers got rid of it. Unfortunately not before another myth had become established; namely that Class A amplifiers were automatically better. Now, where did I put that sword?

I've remembered! The port of an old reflex loudspeaker on its back makes an excellent sword stand. ■

The up-side of valves:

- **In guitar amplifiers the distortion enhances the timbre.**
- **Valve power amplifiers have more benign overload characteristics: soft clip.**
- **Simple valve stages introduce second harmonic distortion that sounds 'warm'.**
- **Valves are unaffected by the electromagnetic pulse due to a nuclear explosion.**

The down-side of valves:

- **Valve power amps work in Class A and get very hot, wasting a lot of power. They need big heavy transformers.**
- **Don't expect a valve amplifier to sound good if it has poor transformers.**
- **Valves wear out.**
- **The marketing budget may exceed the design budget.**