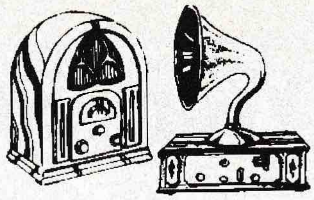
Vintage Radio

by PETER LANKSHEAR



Diode detectors

All radio receivers, no matter how simple or complex, have one essential feature — a detector. Before the mid 1930's a variety of detectors were used, with varying degrees of success. But then, the diode found increasing favour, until today its use is universal. However, like so many devices that appear to be simple, its operation is actually quite complex...

Early in the history of radio, the major problem in reception was devising a reliable means of converting the high frequency currents induced in the aerial, into a usable and intelligible signal. Unbelievably weird and wonderful devices were dreamed up, from freshly killed frogs' legs to capillaries filled with a deadly potassium cyanide solution.

One odd feature about many early detectors was that there was no clear understanding of how they worked. Most practical of the early systems was the coherer, a small tube of metal filings that, in the presence of RF voltages, clumped together to provide a low resistance path to direct current provided by a battery in series with a sensitive relay.

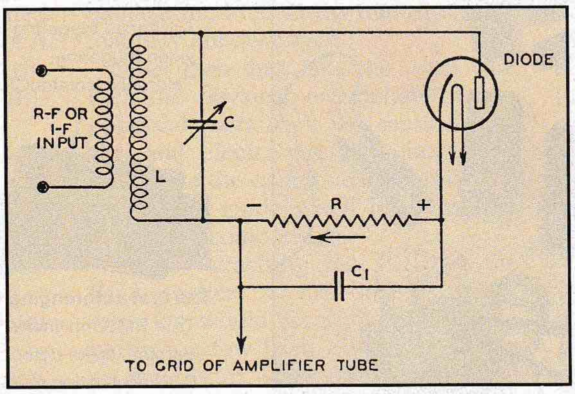
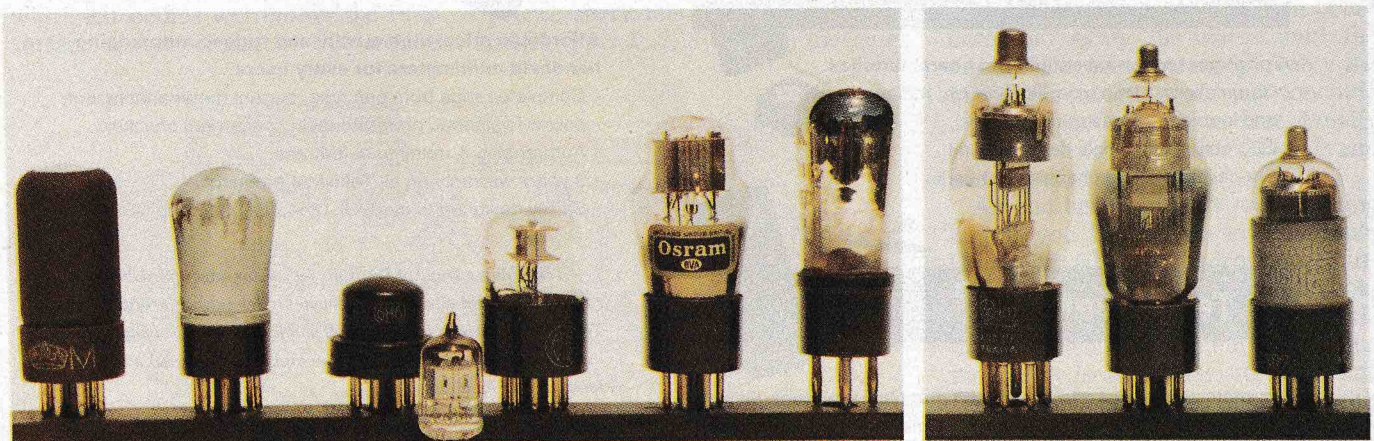


Fig.1: The basic diode detector is simply a half wave rectifier. Any one point of the circuit can be earthed, but it was usual practice for this to be the cathode.

Coherers gave no indication of the relative strength of the received signals, and could not discriminate against interference. In any event, the coherer proved to be so erratic that Marconi soon developed the 'Maggie' or magnetic detector, which depended on the changes in hysteresis of a moving iron wire band in a high frequency field. Listening on headphones gave the operator a much closer sense of reception conditions, and the computer between his ears was better able to interpret what was being received.

The problem was now that, although the magnetic detector was reliable, it was insensitive. A major step forward came in 1904 when Professor John Fleming, during research work for Marconi, tried out a some special lamps that Thomas Edison had given him.

Many years before, Edison had discovered the uniconducting properties of an incandescent lamp with a metal plate positioned near the filament. Fleming's experiments confirmed the



Left: A selection of double diodes. The Cossor DDL4 at the right dates from 1933, and the five octal valves are all variations of the metal 6H6. In the front is a popular 6AL5/EAA91 miniature double diode. Right: Three Australian designed diode pentodes. At the left is a 6B7S, with its 6G6G octal equivalent in the middle. At the right, with its integral lead shield, is the novel high gain 6AR7GT.

practicality of his 'lamp diode'. As a detector, it was more efficient than the magnetic detector and with consistent performance. But the filament required lighting and was subject to burning out, and before long, strong competition was coming from the various crystal diodes that evolved during the next few years. These were the first semiconductor diodes.

Meanwhile, little use was being made of the vacuum diode. Crystal diodes were at least as efficient, did not require a filament battery, and had the further advantage that they didn't burn out. Further, there seemed little point in making a diode valve, when, with a little extra effort, a grid could be included to make a much more useful triode.

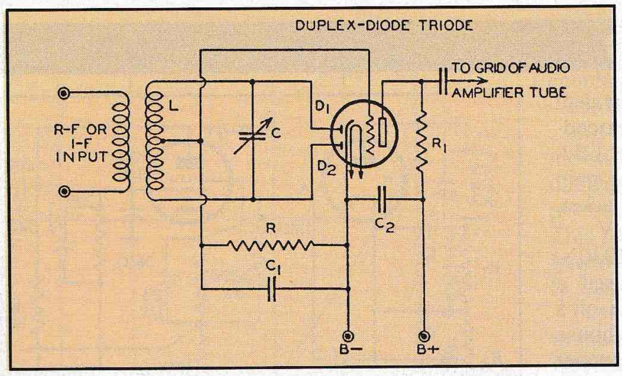


Fig.2: Full wave rectification had the advantage of not needing much IF filtering of the audio signal. In this circuit, direct coupling biased the triode grid from the rectified signal, but this was only suitable for low-mu valves.

Diode reborn

With its high sensitivity, especially with regeneration, the triode grid-leak detector was the universal detector for most of the 1920's. But by the end of the decade, several of its shortcomings were becoming apparent, and with the availability of the indirectly heated cathode valve, the biased or plate detector became the preferred type.

Then, shortly after 1930, the diode was rediscovered, and with its low distortion and ability to provide automatic gain control, it became pre-eminent. In the solid state form, it has remained so ever since, and the diode detector circuit has made the transition from valve to solid state technology with little change in the basic circuit.

At first, general purpose triodes were used as diodes, either with the anode and grid strapped together, or with the grid used as the diode and the valve anode earthed to provide shielding. But an obvious move was to make specialised detector diode valves.

Twin diodes in the form of power rectifiers had been around for some years, but in 1932, the Chicago firm of Grigsby Grunow produced the first indirectly heated detector double diodes — the type G-2S and the G-4S. Soon afterwards, in Britain, Mazda introduced the AC/DD, using the European standard four volt filament.

As diode detectors provide no amplification, an additional valve was necessary to maintain overall receiver gain; but this added to the receiver's price. It was not long before manufacturers made use of the surplus space within a valve envelope and added a general purpose triode — all sharing a common cathode.

Two types were produced, the only differences being the heater rating, 2.5 volts for type 55, and 6.3 volts for the type 85, and the combination proved to be immediately successful. As a resistance coupled audio amplifier, the triode, with characteristics similar to the ubiquitous type '27, provided a stage gain of 5-6 times, sufficient with local stations to drive a pentode output stage.

Meanwhile, British makers were not far behind and in 1933, most introduced dual function valves — but with a higher-mu triode than the American pattern, giving a stage gain of about 30 times.

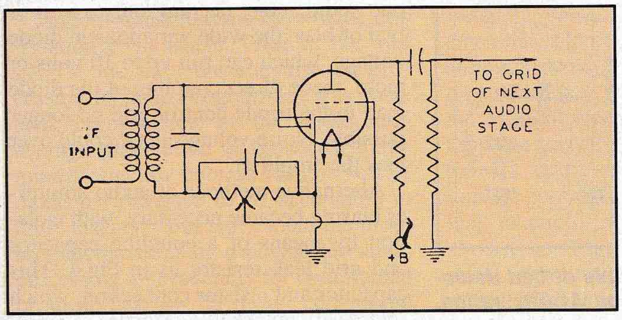
Insufficient gain

Combined with the higher gain output valves available to English receiver makers, this combination proved to be more than adequate. But with the advent of shortwave transmissions, the 55 and 85 were found to provide insufficient amplification, and so the 75 and 2A6, with an amplification factor of 100 times were developed.

Previously, about the only very-high-mu triode had been the type '40, with an amplification factor of 30 and an adaptation of the trusty '01A. But this had not been very successful. The new diode/triode on the other hand proved to be very satisfactory, and variations were in use in the majority of receivers for as long as valve radios continued to be made.

Another similar and very useful development, which appeared shortly afterwards, was the double diode/pentodes type 6B7 and 2B7. As resistance coupled amplifiers, the gain possible from these valves was similar to that of the high-mu triodes, but they had the added advantage of also being suitable for a combined IF amplifier and detector stage, and permitting designers greater flexibility.

There was special significance in Australia for the diode/pentode, for its popularity in reflex receivers, where the IF stage doubled as an audio amplifier. It is worth noting that two special diode/pentodes were developed in Australia for this application. First, the



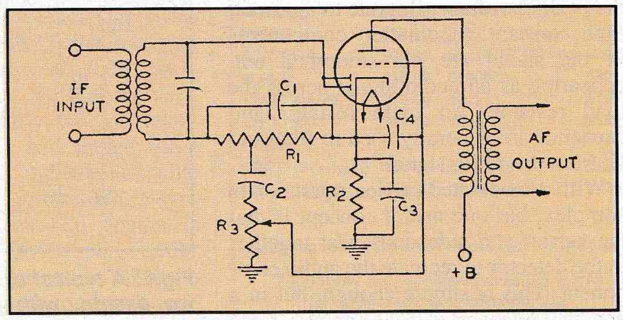


Fig.3 (left): In this variation of diode biasing, the volume control became the detector load resistor, varying the bias and applied signal simultaneously. Technically a good system, it could be noisy when the volume control was operated. Fig.4 (right): This commonly found system used automatic bias for the valve, and as the volume control did not carry any DC, noise was not a problem. However, distortion from poor AC/DC load ratios could be excessive.

6B7S and later its octal based equivalent the 6G8G, which were in effect extended variable-mu versions of the 6B7. Later came the unique higher gain 6AR7GT with its lead shielding jacket, which was also developed by AWV.

For a while during the early 1930's, some English made receivers used a non-vacuum diode about the size of a one watt resistor, the Westinghouse 'Westector'. This was a small copper oxide rectifier, which preceded the germanium diode by about 10 years.

The Westector was reasonably efficient — an example in the writer's collection still has a forward to reverse conductance ratio at 1.5 volts of about 150:1. Nowadays, modern solid state diodes are quite as efficient as their valve predecessors, and of course are in extensive use. In AM detector service, solid state and vacuum diodes are essentially interchangeable.

The diode detector is capable of excellent performance, with the ability to handle large voltages with low distortion, and in practice, the driver stage (usually an IF amplifier) will overload before the diode detector. However, design limitations, some of them avoidable, often considerably degrade performance.

Fig.1 is the basic circuit of the diode detector, comprising a tuned circuit, a diode and a resistive load. The circuit can be earthed at any point — generally the cathode. Operation with an unmodulated carrier is straightforward, the diode acting as a rectifier charging the capacitor to the peak value of the RF voltage present. Traditional, but not necessarily optimum, values of components are 100pF for C1 and 500kΩ for R.

The signal voltage from the IF transformer is applied to the diode anode and via C1 to the cathode. C1 charges up to the peak IF voltage. But due to the small time constant, modulation components of the signal are not smoothed out, appearing as an audio signal across the load resistor. An extra resistor and capacitor are generally used to filter out IF from the audio signal.

With a modulated carrier, operation is complex, but one useful concept is that the carrier and sidebands beat together in the detector to recreate the audio component. This is simple enough, but in a practical receiver, various complications and limitations can occur with detectors in common use. And as we will see, the standard diode detector is not always used to its best advantage.

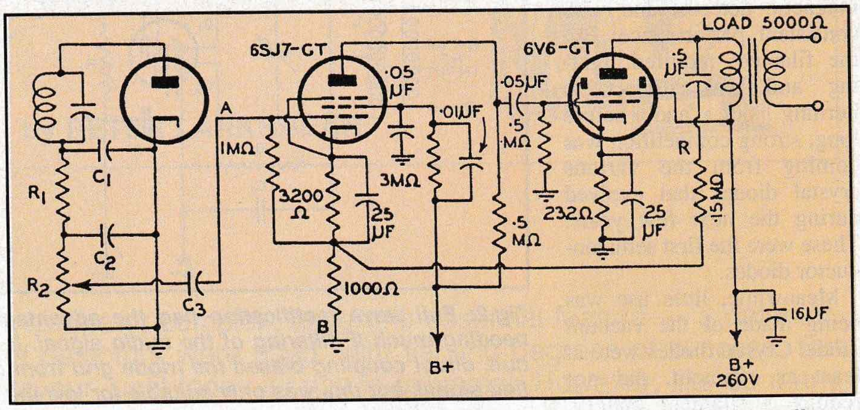


Fig.5: A high quality AWA circuit which overcame most of the detector distortion problems by raising the input impedance at point A by the 'bootstrapping' effect of the negative feedback voltage injected into the 6SJ7GT cathode.

At one time, as in Fig.2, full wave rectification was in fashion, with a diode connected to each end of the IF transformer secondary, and the audio taken from a centre tap. This halves the audio voltage, but simplifies the RF filtering.

There are several ways of coupling the signal to the first audio amplifier, and the method chosen will have a considerable effect on distortion. If, as in figure 2, the signal is connected directly to a low-mu amplifier grid with no coupling capacitor, distortion, even at 100% modulation will be quite low.

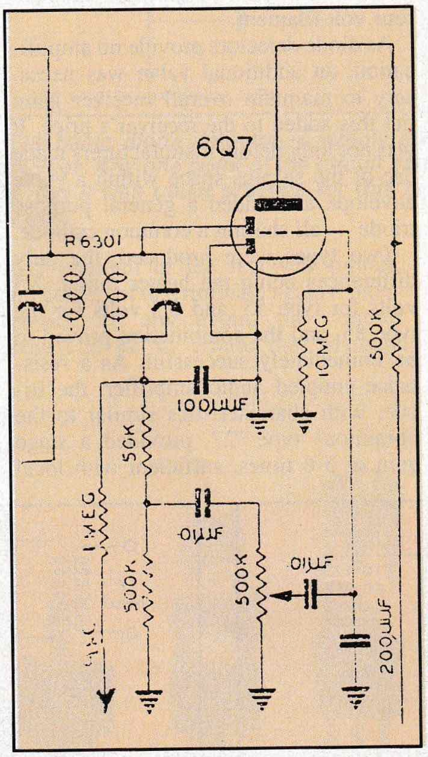


Fig.6: A typical example of bad detector design, with poor AC/DC ratios. Swapping the volume control pot over to the diode load position would improve matters, and it would have cost little more to use the spare diode as the AGC detector.

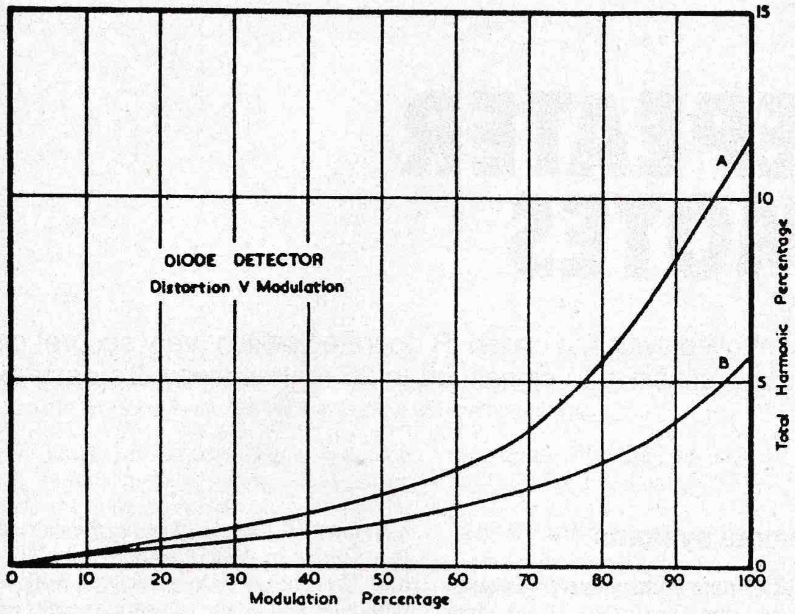
In what is known as diode biasing, the carrier generated negative voltage across the filter capacitor is greater than the peak modulation voltage, and serves to bias the valve. Although a very good system, diode biasing cannot be used with the high-mu triodes.

A more flexible arrangement is to make the diode load resistor the volume control potentiometer, as in Fig.3, with the moving arm connected to the triode control grid. Electrically, this is a good method, and as well as being used with the low gain triodes, it was used by RCA with the diode pentodes. It has one practical difficulty, though. The slightest wear on the potentiometer track creates noise as the volume is adjusted.

Serious distortion

With the adoption of the high gain triode audio stage, needing only a volt or two of bias, the wide variations in diode voltage, which can run up to 10 volts or more, made direct coupling of the diode load to the triode control grid no longer possible. Noise voltage alone could over bias the amplifier.

Alternative methods of audio amplifier biasing became necessary, with isolation by means of a coupling capacitor and grid leak resistor as in Fig.4. This capacitor and resistor connection, which effectively puts the grid resistor in parallel with the diode load, means that the diode has now different AC and DC loads. Analysis of circuit operation is complex, but the effect of this differen-



Curve B illustrates the distortion from a diode with a 0.5M load operating under ideal conditions. Curve A shows the dramatic increase in distortion when, as in Fig.4, the load is shunted by a coupling capacitor and 1M volume control.

tial loading is to create serious distortion at high modulation levels, and is dependent on the ratio of the loads.

The graph shows what happens with a typical diode load resistor of 0.5MΩ. Curve B is the performance expected with no additional shunting, as in the case with diode biasing, and can be regarded as acceptable. When, however, the load is shunted by a coupling capacitor and a 1.0M gridleak (a common value), curve A shows that distortion at modulation levels above 75% rises drastically. However, these curves apply to low and middle audio frequencies — at high modulation levels, the situation becomes even worse! At 5kHz the reactance of a 100pF capacitor is only about 300kΩ, a significant degree of shunting which can only exacerbate the distortion.

Modern transmissions have made this situation even worse. Prior to the mid 1960's, the only pre-transmission processing of radio programmes was basic peak compression of the audio, and average modulation of broadcast transmitters was low enough for this sort of diode performance to be acceptable to most listeners. But since then, the modern practice of using sophisticated audio processing — especially for commercial programmes — is now considered essential to keep a broadcaster's place in the sun. This actually raises positive going modulation peaks above 100%, with serious consequences for badly designed diode detectors.

The most common remedy is to make the volume control the diode load as in Fig.4. This has the effect at normal volume levels, of tapping the AC loading components down the load and improving the DC to AC ratio. The lower the volume setting, the better the ratio.

A further improvement can be made by the method shown in the AWA circuit in Fig.5. Here the grid resistor is returned to the negative feedback injection point, which the opposing feedback voltage 'bootstraps' — raising the apparent input impedance. A minor limitation is that this system of negative feedback cannot be used with an audio valve sharing its cathode with the diodes. The practical solution was to use a diode pentode in the IF stage.

Poor design common

Again, noise is a possible problem when the volume control is the load, and although with the use of good grade potentiometers many set makers used the system successfully, all too many took the easy option and settled for a 0.5MΩ load resistor and similar value volume control in the grid circuit. A typical example of such bad design is shown in Fig.6. Obviously, under these conditions, distortion at high modulation levels with modern transmissions will be rather noticeable to the discerning listener.

Some examples are even worse! In one English made receiver popular with New Zealand collectors, the designer really had a day off with the detector circuit. The diode load is a 0.5MΩ resistor coupled by the usual capacitor to a 0.25MΩ volume control!

But there's more! Note in Fig.6 how the AGC line feed, a 1.0MΩ resistor, is not fed from a separate diode, but is simply connected to the signal diode load. This has the effect of even further AC loading on the detector, and unfortunately was an all too common practice.

Post war audio stage biasing practice improved matters in some cases. There was increasing use of contact potential biasing, whereby the audio stage grid resistor was increased to about 10 megohms and the contact potential of about 1.0 volt was sufficient to bias the grid of a high-mu triode. Provided that the volume control was the load resistor, this was beneficial to AC/DC loading ratios.

Fortunately, there were good designs, and I am not advocating wholesale rebuilding of detector circuits. However, if a favourite set does sound 'rough' at high modulation levels, it just might pay to look critically at the detector AC/DC ratios. Even swapping the volume control from the grid to the diode circuit can be an improvement.

Next month we look at some low distortion detectors, and others that provide some gain. ❖