Vintage Radio

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Reflex receivers – why they were necessary

Above: the Kriesler 11-41 was a popular 4-valve reflex receiver from the 1950s.

Valves were expensive in the early days of radio and so designers came up with clever techniques to minimise the valve count. One technique was known as "reflexing" and involved using the same valve to work as both an RF or IF amplifier and as an audio amplifier.

COMPONENTS such as tuning capacitors, inductors (both fixed and variable), resistors and fixed capacitors were in common use during the Spark Era, at the start of last century. However, valves (when they finally made an appearance) were initially extremely expensive and fragile. Suffice to say, they didn't have a long life.

Initially, obtaining a high vacuum inside a valve was quite difficult and most of the early valves were of the "soft" variety. This meant that they had a small amount of gas left inside, due to manufacturing limitations. As a result, these valves were rather variable in their performance, even between supposedly identical types.

Another problem that had to be overcome was how to maintain a good vacuum. This could only be achieved if the glass and metal leads through the glass envelope had the same coefficient of expansion. If the coefficient was different, air would eventually leak into the valve and it would become gassy. Occasionally, even today, a valve with a purple glow inside it will be seen and this is often an indication that the glass to metal pin seal is not perfect and air has leaked into the valve.

Incandescent light globes were the first items to have metal pins or wires protruding through a glass envelope. However, this created no real problem, since the vacuum created was satisfactory for their operation and the glass-to-metal seals were not as critical. In some cases, the globe was filled with an inert gas such as nitrogen to prevent evaporation of the filament.

One problem with valves was that the metals used inside them (ie, for the elements and filaments) had to be carefully selected, otherwise they could emit gases when they became hot. These gases could then "poison" a valve and adversely affect its performance.

So early attempts at making valves into viable amplifying devices encountered many difficulties. However, their potential to revolutionise radio was obvious and so a great deal of effort was put into solving these problems.

It is for these and other reasons that valves were by far the most expensive and fragile components in early valve receivers. As a result, the engineers and experimenters of that era searched for ways in which each valve could be made to do more than one job, to minimise cost.

Reflexing

One of the first to achieve dual usage of valves was W. H. Priess, a US Navy worker who patented the principle of reflexing during WWI. This technique involves passing a signal through the same amplifier twice, at two significantly different frequencies – usually once at a radio or intermediate frequency (ie, RF or IF) and then at audio frequency (ie, after the modulated signal from the IF stage has been detected).

Initially, there was little interest in reflexing for a couple of reasons. First, it was no doubt kept a military secret during the war and so was not widely known during those years. Second, the principle, although sound, initially proved tricky to implement. However, valves were still very expensive in the 1920s and this led some manufacturers and enthusiastic experimenters to refine the technique and this eventually yielded good results

In theory, reflexing meant that one valve did the job of two. However, as there was always some compromise in the operating conditions of the valves for each different frequency, the actual improvement was always somewhat less that this.

Reflexing was used for only a relatively short time overseas but in Australia, it was still being used in some receivers as late as the early 1950s. It was initially used in high-end receivers in the early 1930s, then in receivers at the bottom end of the market to reduce valve count (and thus cost).

This is not to say that reflex receivers performed poorly because they were aimed at the bottom end of the market. Some sets did leave something to be desired but others were very good receivers.

How reflexing works

The mere thought of restoring a radio receiver with a reflex stage has sent cold shivers down the backs of many enthusiasts. As a result, such sets have either been shunned or used simply as non-working show items.

I must confess that during my early days as a serviceman I wasn't all that keen on dealing with reflex sets. There were just so many wires and components going here, there and everywhere and a real mix of signal leads. However, most of the reluctance to service reflex sets (as with AGC stages) was due to the fact that servicemen lacked the test equipment that we have today.

Originally, reflexed stages were included in tuned radio frequency (TRF) receivers. These sets typically had an RF stage followed by a detector. The

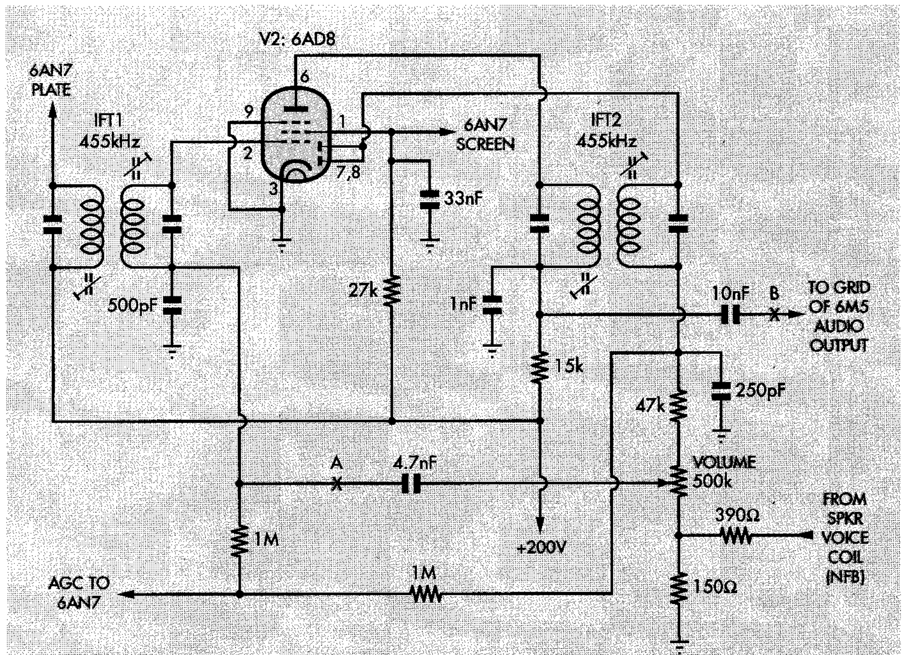


Fig.1: the IF (intermediate frequency) amplifier, detector and reflexed audio stage of the Kriesler 11-41 & 11-49 radio receivers. The detected audio signal at pins 7 & 8 of the 6AD8 are fed back to the grid via the primary of IFT2, a 47kΩ resistor, the volume control, a 4.7nF capacitor and the secondary of IFT1.

audio output from the detector was then fed back to the input of the RF amplifier valve. From there, the resulting amplified audio signal was typically applied to an audio output stage.

In a well-designed receiver, this system could be made to work quite well. However, most of these early TRF sets were built breadboard style, so layout could be (and usually was) quite critical. Unfortunately, due to incorrect wiring techniques and the inevitable stability problems that followed, many people soon came to the conclusion that reflex circuits were "cranky" and best left alone.

That wasn't to be the end of reflex receivers, however. When superhet receivers were subsequently developed in the 1930s, the breadboard style of construction was quickly abandoned. Instead, the parts were mounted on a metal chassis, with the critical components shielded. This was necessary to ensure stability and consistent performance and this style of construction quickly became the standard technique for Australian manufacturers.

As a result, some manufacturers decided to see if more stable high-performance reflex receivers could be developed using metal chassis and improved shielding. Their efforts proved successful and an early example is the Radiolette model 31/32.

There were others, as I quickly discovered when I looked through the 1938 edition of the Australian Official Radio Service Manual (AORSM). There were at least eight mainstream manufacturers that had at least one reflex model: Aristocrat, Astor, Croyden, HMV, Hotpoint-Bandmaster, National, Fisk-Radiola and Westinghouse. In fact, Fisk-Radiola and its badged stablemate Hotpoint-Bandmaster lead the way with quite a few models, both mains and battery operated.

Kriesler 11-41/11-49 receiver

The final volume of the AORSM has no manufacturers with reflex receivers. In fact, the last reflex receiver featured in the AORSM is the Kriesler 11-41/11-49 (in Volume 12, 1953), so Kriesler appears to be the last manufacturer of these sets in Australia.

The Kriesler 11-41 & 11-49 were 4-valve mains-operated mantel receivers, the two models being almost identical. So let's take a closer look at the circuit to see how reflexing worked.

Fig.1 shows the IF (intermediate frequency) amplifier, detector and reflexed audio circuitry stages of these models. The front-end uses a 6AN7 converter valve and this feeds a signal

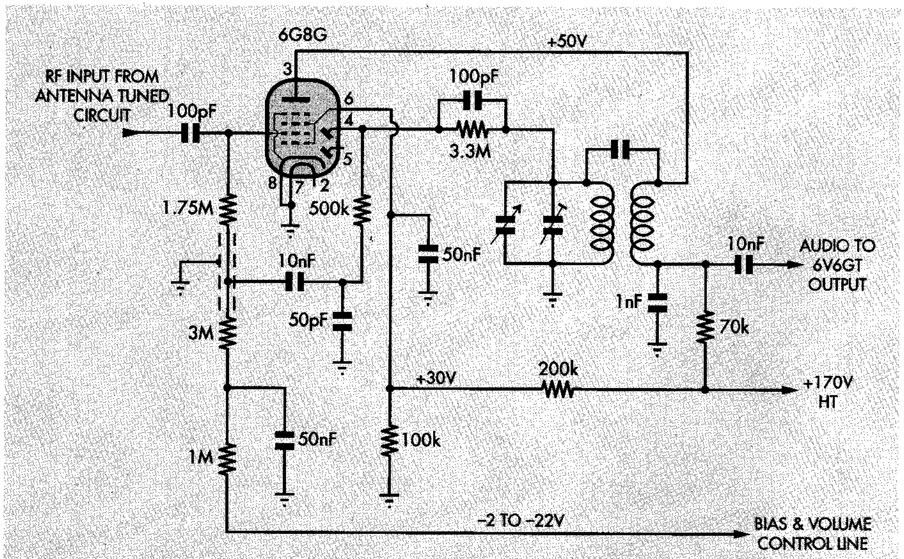


Fig.2: the reflexed circuitry in the Astor GR (Football) TRF receiver. In this circuit, the detected signal on pin 4 of the 6G8G is fed back to the grid via a 500kΩ resistor, a 10nF capacitor and a 1.75MΩ resistor. A variable bias (-2V to -22V) line controls the volume (the lower the bias, the greater the gain).

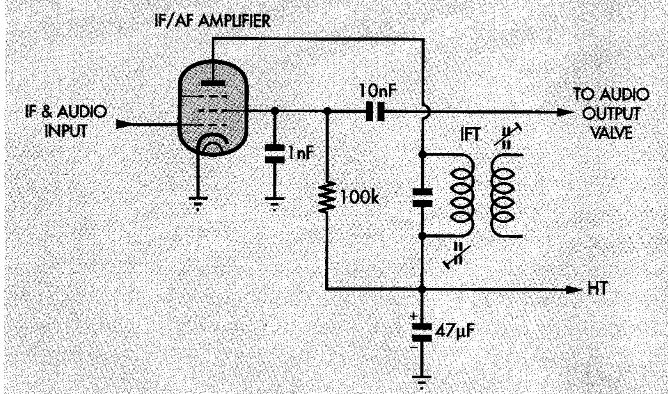


Fig.3: in this circuit, the screen of the IF/AF amplifier is used as the plate for the reflex stage audio output. This gives a gain of about 10-20, depending on the valve.

centred on 455kHz to an IF amplifier stage (V2, 6AD8).

In greater detail, the signal from the converter is fed through a double-tuned first IF transformer (IFT1) to the grid of a 6AD8 IF amplifier. The signal is then amplified and applied to another double-tuned IF transformer (IFT2). The output from this transformer is then fed to the 6AD8's detector and AGC diodes which are tied together at pins 7 & 8. A 47kΩ resistor, 500kΩ potentiometer (volume) and 150Ω resistor form the load for these diodes.

The resulting audio signal is taken from the wiper of the volume control and applied via a 4.7nF capacitor to the top of a 500pF capacitor (which acts as an RF bypass for the first IF transformer). IFT1's secondary winding has virtually no effect on the audio signal which is now fed directly to the grid of the IF amplifier.

As a result, the 6AD8 amplifies the audio signal along with the IF signal and the amplified signals appear at the plate. IFT2's primary has little effect on the audio signal which is now developed across a 15kΩ plate load resistor.

The 1nF capacitor at the bottom of the primary winding acts as an RF bypass. It's effective at IF frequencies but its impedance at the higher audio frequencies is around 50kΩ. However, this does shunt the 15kΩ plate load resistor to some extent, which reduces the audio performance at higher frequencies.

The amplified audio signal across the 15kΩ resistor is fed via a 10nF capacitor and a 47kΩ stopper resistor (not shown) to the grid of a 6M5 audio output valve which then drives the loudspeaker via a transformer. The 390Ω resistor (bottom, right of Fig.1) provides negative feedback from the speaker's voice coil to the bottom of the volume control, to improve audio quality.

Full AGC

It's not all that common to see the full AGC voltage applied to a reflexed IF/audio stage but Kriesler has done this here. In this circuit, AGC is taken from the top of the 47kΩ resistor (at the top of the volume control) and applied via two 1MΩ resistors to the grid of the 6AD8 reflex stage. Because its plate load resistor is only 15kΩ, the 6AD8 does not have high audio gain – only about 10-12 times.

As a result, the IF amplifier conditions are not far from normal and the stage is not likely to overload on strong signals. By contrast, Astor reflex receivers often used a 70kΩ plate load resistor in the reflex stage.

Because AGC is applied to the reflex stage, its gain at both IF and audio frequencies is reduced with increased AGC control voltage. If not done correctly, this can mean that the actual audio output from the set can be reduced with increasing signal (as mentioned in a previous column on AGC).

Fortunately, Kriesler got it right in this set. There is no reduction in volume when tuning a strong station, as compared to that from a weak station.

By the way, it is quite easy to compare the performance of a reflex set with a more conventional circuit without reflexing. In Fig.1, there are two points marked "A" and "B". If the "A" end of the 4.7nF capacitor is lifted and connected to "B" and the 10nF capacitor is removed (ie, the wiper of the volume control now feeds the audio signal directly to the 6M5 audio output stage via the 4.7nF capacitor), then the set reverts to non-reflexed operation.

Of course, the audio gain will be down as there is now only one audio stage in the receiver rather than two when it is wired as a reflex set.

As a result, when this is done, the variation in the audio level is quite noticeable, particularly if the received signal is relatively weak. However, if the signal is strong, there is not a great deal of difference due to the fact that the audio output from the reflexed stage was reduced, due to the AGC affecting the audio gain.

Astor GR 3-valve TRF receiver

Manufactured from around 1948,

the Astor GR (Football) is a simple little TRF receiver (see May 2009 for a full description). As with the Kriesler 11-41/11-49, it is also a reflex design but the circuit configuration is simpler.

Fig.2 shows details. In this circuit, the RF signal from the tuned antenna circuit is fed to the grid (top cap) of a 6G8G RF stage via a 100pF capacitor. The amplified RF signal appears on the plate (pin 3) and is fed to the primary of the RF tuned coil assembly. The signal on the tuned secondary is then applied via a parallel 100pF capacitor and 3.3MΩ resistor to the 6G8G's detector diode (pin 4).

From there, the detected signal is fed via a 500kΩ resistor, a 10nF capacitor and a 1.75MΩ resistor to the grid of the 6G8G, so that amplification now takes place at audio frequencies. The 50pF capacitor at the bottom of the 500kΩ resistor bypasses any RF signals at this point, while the series-connected 3MΩ and 1MΩ resistors go to a bias and volume control line. This line applies a manually-controlled negative voltage of between -2V and -22V to the grid of the valve.

The 6G8G is a variable-mu valve and the lower the bias the greater the gain (and thus the greater the volume).

The resulting amplified audio appears at the 6G8G's plate and is fed through the primary of the RF coil assembly to a 70kΩ audio load resistor. A 1nF capacitor bypasses any RF signals that may be present, while the audio is fed to the grid of the 6V6GT audio output valve via a 10nF capacitor.

As mentioned, the 70kΩ plate load resistor used in this set is much greater than the 15kΩ resistor used in the Kriesler, although overload does not appear to be a problem. Both sets adequately filter any residual RF/IF signals following the detector, to prevent them being fed back to the RF stage. This is vital to ensure stability.

Screen reflexing

Most reflex stages, such as the two examples given, use plate circuit reflexing. However, it's also possible to use the screen as the plate for the reflex stage audio output. This usually involves using the IF amplifier as the reflex stage.

Fig.3 shows a typical circuit. In this case, the plate circuit of the reflexed IF amplifier is the same as for a conventional IF amplifier. The screen, however, is bypassed at intermediate

Nicknamed the "Football" because of its cabinet shape, the Astor GR was a simple 3-valve TRF receiver with a reflexed RF/audio stage (see Fig.2). It was manufactured from around 1948.

frequencies using a 1nF capacitor, while the usual bypass capacitor of around 10nF now couples the audio to the grid of the audio output valve.

The audio gain using the screen as the plate will be between about 10 and 20 times, depending on the valve used.

Servicing reflex receivers

Reflex receivers do not usually present any more servicing problems than "non-reflexed" sets, nor are they any more difficult to restore. However, because they work at both RF and audio frequencies, it is necessary to ensure that the component values around the reflex stage are correct, ie, all resistors within tolerance, capacitors not leaky and the valves in good condition.

It's also important to remember that relatively few valves are suitable for use in reflex stages. The 6G8G, 6AR7GT, 6BA6 and 6AD8 are valves that work well and although substitutes may work, they will usually not be trouble-free. For example, the 6AD8 in the Kriesler 11-41/11-49 cannot be replaced with a 6N8 although it appears to have reasonably similar characteristics, the exception being the grid cut-off voltage. It could probably be made to work quite well with a few changes to component values, however.

One feature of reflex sets that can annoy some people is the "minimum volume effect". The problem here is that when the volume control is turned right down, there is still some audio output from the loudspeaker. The Kriesler 11-41/11-49 suffers from this problem, which is exacerbated by the 150Ω resistor in series with the "earthy" end of the volume control.

However, although some people might think that this is a problem, most would not even notice. After all, it's only rarely (if ever) that the sound would be turned right down.

By contrast, the Astor GR doesn't suffer from this problem, as the bias can be increased to such a level that no signal gets through the 6G8G valve. In fact, this is a very trouble-free little circuit.

Was it necessary in later sets?

As previously mentioned, reflexing was used in the early days to keep costs down. However, as time progressed and valve prices fell, reflexing was no longer really necessary. Without reflexing, circuit layout and design were not as critical and that suited many manufacturers whose design skills were often lacking.

By contrast, in sets with reflex stages, considerable attention to the circuit design and layout was necessary if the set was to work well.

Most manufacturers were slow

The Astor KM (or Astor Mickey) was a 4-valve reflex receiver from the late 1940s. Its reflexed IF/audio stage is similar (but not identical) to that in the Astor GR and it had the following valve line-up: 6A8G converter, 6B8G IF/ audio reflex stage, 6V6GT audio output stage and 5Y3GT rectifier.

to take advantage of multi-purpose valves. For example, the 6F7 and its 6P7G octal equivalent weren't popular, despite the fact that they contained two valves in the one envelope which could be used for a number of different purposes.

One of the first triode-pentode valves used in receiver audio stages was the 6AB8, as in the 1953 Tasma 1601. This produced a receiver with similar performance to the Kriesler 11-41/11-49, despite the fact that the Tasma 1601 lacked a reflex stage.

Not long afterwards, the ubiquitous 6BM8 came into use and there was no longer any need for reflexing. The last Kriesler valve receiver, the 11-99, used a 6AN7 (converter), 6N8 (IF amplifier, detector and AGC) and a 6GV8 combined triode and pentode output stage. This was a relatively simple high-performance receiver using just three valves (the rectifier was a single silicon power diode in a half-wave circuit).

It's fair to say that reflex sets were still being produced long after their early advantages had been negated by falling valve costs. Improvements in other aspects of receiver design also eventually helped bring about the end of reflexing.

Certainly, there is no advantage in modern domestic radios using reflex circuits. Transistors are cheap and adding one or two transistors to a circuit contributes little to the cost of a receiver.

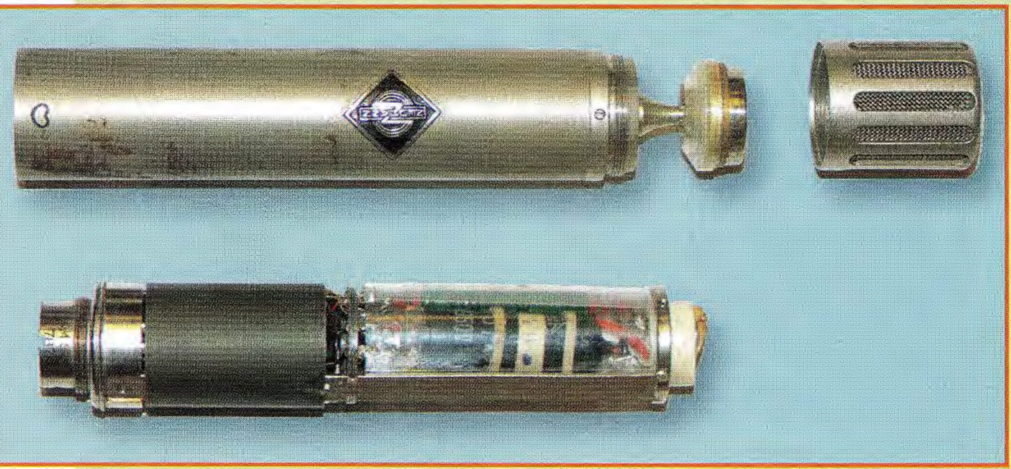
Summary

Reflex circuits filled a niche in the early days of radio when components, particularly valves, were quite expensive. Their advantages were lower costs, lower power consumption (an important factor in battery and vibrator sets), less heat in cabinets and smaller valve inventories for servicemen.

On the other hand, they required more careful design, were not as easy to fault-find if test equipment was scarce and were not as tolerant of components (including valves) which drifted out of tolerance. If you want to learn more about reflex receivers, take a look at the chapter on reflex principles in the "Radiotron Designers' Handbook".

Finally, reflex receivers are well worth having in a restorer's collection. The Astor GR "Football" is a good example of a receiver that brings quite high prices. **SC**

Photo Gallery: Neumann KM54 Cardioid Condenser Microphone



USED FROM THE LATE 1950s and right through the 1960s, this microphone included a tiny AC701 valve. Its specifications would easily match most studio microphones in use today – 0.6% distortion from 40Hz to 15,000Hz and 110dB maximum sound pressure. A matching power supply provided 4V DC at 100mA for the valve filament and 120V at 0.5mA for the plate. The filament supply was heavily filtered to ensure low noise. Photograph by Kevin Poulter for the Historical Radio Society of Australia (HRSA). Phone (03) 9539 1117. **www.hrsa.net.au**