Vintage Radio

Automatic gain control (AGC): what it is and why it's necessary; Pt.2

The Healing 403E is a 4-valve superhet receiver with simple AGC. However, only about one third of the available AGC voltage is applied to the converter and IF amplifier valves, presumably to achieve an adequate audio output level.

In Pt.1, we looked at the origins of automatic gain control (AGC) systems and described some of the techniques that have been used over the years. This month, we look at simple, delayed, quiet and amplified AGC systems and describe some common faults in these circuits.

SOME OF THE AGC methods described in Pt.1 are still used extensively in domestic radio receivers while others have gone by the wayside. However, although the advantages of AGC were recognised and enthusiastically embraced by some manufacturers during the mid-1930s, many others neglected to use this very useful feature.

In fact, many receivers lacked an AGC system even into the 1950s.

One explanation for this is that some small (and not so small) manufacturers didn't employ design engineers but just copied the work of others. In addition, some design engineers really didn't understand how AGC worked or they thought that faults in the AGC system would be difficult to find and so left it out. Certainly, AGC faults were not easy to find in the early days, as will be explained later on.

Another reason for omitting AGC was the cost of the extra parts. This explains why AGC was omitted in so many "economy" receivers, especially the 4-valve types designed for the bottom end of the market.

Simple AGC

As the name implies, simple AGC is easy to implement. In fact, it can involve adding just two inexpensive parts to a receiver.

A common method of reducing the gain in a receiver with no AGC is shown in Fig.1. It involves increasing the cathode bias on the converter and IF valves while simultaneously progressively shunting the antenna input to ground using potentiometer VR1.

Conversely, to increase the volume, VR1 is wound the other way. This decreases the cathode bias while increasing the resistance between the antenna and ground. Indeed, this system works well as a manual gain control.

Usually, there was no volume control at the output of the detector as the volume control at the front end of the receiver was adequate. The RF and IF valves were generally remote cut-off types, so that smooth control of the volume was achieved.

Refer now to Fig.2. This shows a simple AGC system as used in many receivers. The differences between it and the circuit shown in Fig.1 are relatively minor.

In this case, potentiometer VR1 has been removed and the cathode circuits of both the converter and the IF amplifier are earthed via fixed resistors. The bottom ("earthy") end of the tuned antenna winding is now earthed at RF via a capacitor of around 47nF, as is the "earthy" end of the grid winding of the IF amplifier valve. A 1-2MΩ resistor is then wired back to the detector load and the AGC circuit is complete.

Basically, just a few extra inexpensive components were needed to upgrade the receiver with AGC. However, depending on the physical layout and other aspects of their design, some receivers used an additional RC circuit in the AGC system.

In some 4-valve sets, like the Healing 403E, where the total gain is relatively low (particularly in the audio section), the full AGC voltage is not applied to the controlled valves. This reduction in applied AGC voltage is achieved using a resistive voltage divider across the AGC line. By doing this, the audio output from the detector can be kept quite high, ensuring that it is adequate to drive the audio amplifier stage. However, it does have the disadvantage that the intermediate frequency (IF) stage could be overloaded by nearby strong stations.

This can occur if there is insufficient AGC voltage being developed to reduce the signal from the converter to a level that the IF amplifier can comfortably handle.

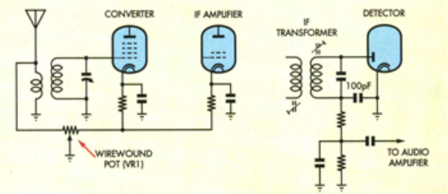

Fig.1: a common method of reducing the gain in a receiver with no AGC. It involves using VR1 to increase the cathode bias on the converter and IF valves while progressively shunting the antenna input to ground

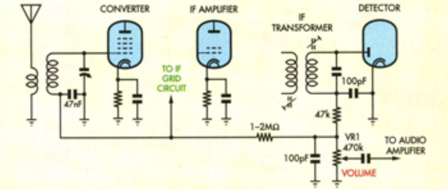

Fig.2: a simple AGC system. The gain of the converter & IF amplifier stages is automatically controlled by connecting a 1-2MΩ resistor between the grid circuits of the converter and IF amplifier valves and the detector load. VR1 then functions simply as an audio stage volume control.

Delayed AGC

As explained in Pt.1, delayed AGC (DAGC) involves delaying the application of the control voltage until the signal strength reaches a predetermined level. This is an improvement on simple AGC because it means that the receiver can operate at full gain on weak signals. The AGC cuts in only on stronger signals, when it's needed.

So how much more complicated is delayed AGC than simple AGC? In some cases, the circuits are quite complex but usually only a couple of extra parts are required.

Some circuits also apply differing amounts of AGC to the RF valves. For example, in a 6-valve set, the RF amplifier may initially receive no control voltage until the signal is at a moderate level while another stage (usually the IF stage) may receive most of the control voltage. Then, as the signal increases further, the AGC voltage applied to the first valve may increase dramatically but vary only slightly for the IF stage.

That's because the latter must be able to handle a strong signal in all situations.

In many receivers with two IF stages, the second IF stage has normal bias applied and is not connected to the AGC circuit. This is intended to ensure optimum noise figures and overload characteristics. Many converter valves, such as the 6BE6, are notoriously noisy and if the RF stage gain is throttled back immediately the DAGC threshold is reached, noise would intrude into the received signal.

Another variation often occurs with multi-band receivers. In these sets, AGC may be applied to the converter on the broadcast band but may be omitted on shortwave bands. This is done to ensure good frequency stability of the local oscillator.

Typical DAGC circuit

Most run-of-the-mill delayed AGC systems are relatively simple. Fig.3 shows a circuit with a delayed AGC system that was common from the late 1930s through to the early 1950s.

As shown, the detector circuit is quite conventional. The detector return circuit goes to the cathode of the duo-diode-triode, whereas the AGC diode load is tied to chassis so that its plate is negative with respect to the cathode.

This means that the signal level that's applied to the AGC circuit must exceed the cathode bias of the triode section of the valve before AGC action occurs. Once this level is exceeded, a negative control bias is applied to the AGC line.

The controlled valves are normally biased via bypassed cathode resistors. Note that the take-off point for the AGC diode is the same point as for the detector.

A variant of this circuit applies a positive voltage to the AGC line in the absence of signal. However, the cathode bias of the controlled valves

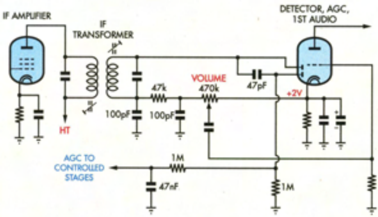

Fig.3: a circuit with a delayed AGC (DAGC) system. The detector circuit is quite conventional, whereas the AGC diode load is tied to chassis so that its plate (anode) is biased negative with respect to the cathode. This type of circuit was common from the late 1930s through to the early 1950s.

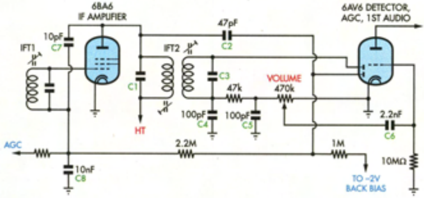

Fig.4: this simplified delayed AGC circuit relies on a -2V to -3V back bias which is obtained from the power supply. Bias for the triode amplifier is obtained from contact potential bias across the 10MΩ resistor.

is greater, so the net effect is that the valves do have negative bias. As the AGC circuit starts to operate, the positive voltage on the AGC line decreases and eventually becomes negative with strong signals.

This one could catch you out, as we usually expect the AGC line to be negative with respect to the chassis at all times.

An even simpler delayed AGC system relies on the back-bias networks that were fitted to later valve receivers – see Fig.4. This is similar to that shown in Fig.3 but there are a few important differences.

First, the duo-diode-triode (eg, 6AV6) has its cathode earthed and the bias for the triode amplifier is obtained from contact potential bias across the 10MΩ resistor (due to the electrostatic field from the plate). Back bias is obtained from the power supply and is usually between -2V and -3V. This is set so that the RF stages are operating at their optimum bias level. It saves at least two cathode bias resistors and their associated bypass capacitors, as the cathodes of the RF valves can now be connected directly to chassis.

As a result, in this circuit, there is always bias on the AGC line whereas the circuit in Fig.3 starts from 0V. When the signal level at the AGC diode exceeds the back bias level, the negative voltage increases and controls the gain of the receiver.

Note that the take-off point for the AGC diode is from the plate circuit of the IF amplifier (ie, following via C2) and not from the secondary of the IF transformer. This has a couple of advantages.

First, the signal level at the plate of the IF amplifier valve is higher than at the output of the IF transformer, which means that a greater AGC voltage can be developed. This is necessary in some receivers. For example, I converted an HMV Little Nipper to 32V operation a number of years ago. This meant that it had only 32V on the plates and its output was initially quite distorted due to the fact that the IF amplifier stage was easily overloaded with such low HT voltage.

The cure for this overloading was to convert its AGC system to the scheme shown in Fig.4.

The second advantage of the method shown in Fig.4 is improved AGC response as the receiver is tuned. By way of explanation, each tuned circuit in the IF amplifier chain increases the selectivity to the receiver. The more tuned circuits, the greater the selectivity.

By the time it reaches the detector, the 455kHz IF signal has been through four tuned circuits and so the selectivity will be quite high (ie, only the tuned station will be heard).

By contrast, the selectivity at the plate of the IF amplifier will be well down, which means that adjacent station signal strengths will also be quite high. However, this is exactly where the signal is picked off for the AGC diode.

At first glance this may appear to be a disadvantage but it actually improves the AGC action. What happens is that the AGC remains at a much more constant level as the receiver is tuned from station to station, due to the lack of selectivity at this point. As a result, this eliminates any momentary increase in volume as the desired station is tuned, since the AGC bypass capacitor is already charged and supplying the correct AGC voltage for that station.

All in all, it's a simple and nifty innovation.

Delayed AGC was achieved quite easily with some of the older duo-diode-triode/pentode 2V filament valves. They had a diode at each end of the 2V filament, one of which was used as the detector diode and the other as the AGC diode. A few examples of these valves are the 1B5, 1F7G, 1H6G, 1K6 and 1K7.

Quiet AGC

Although not particularly successful in domestic radio receivers, quiet AGC (QAGC) was originally developed to "mute" the sound when tuning between stations. It typically consists of a diode in the audio signal path which is biased so that it doesn't conduct

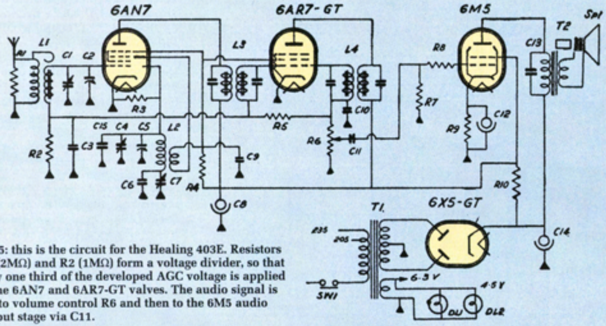

Fig.5: this is the circuit for the Healing 403E. Resistors R5 (2MΩ) and R2 (1MΩ) form a voltage divider, so that only one third of the developed AGC voltage is applied to the 6AN7 and 6AR7-GT valves. The audio signal is fed to volume control R6 and then to the 6M5 audio output stage via C11.

until the AGC voltage rises above a particular threshold. Alternatively, it can be wired across the signal path to earth so that it shunts most of the signal until a preset level of AGC bias is applied. When that happens, it stops conducting and the signal can pass through to the next stage as normal.

Another method is to apply a manually-adjustable voltage to bias off a sharp cut-off audio valve. A separate AGC-type detector is then used to produce a positive voltage when a station is tuned. This swamps the negative bias voltage and turns the valve on so that the audio amplifier operates normally.

Yet another version uses a detector with an adjustable bias. When the incoming signal exceeds a critical level, the diode is biased on and is able to detect the signal which is then fed to the audio output stages.

One of the annoying features of QAGC is considerable distortion in the audio for signals that are just above the critical switching level. This was one of the main reasons that QAGC didn't enjoy widespread popularity. However, the problems inherent with QAGC were largely overcome in later transistorised communications receivers.

Audio AGC

Although AGC and particularly DAGC systems do keep the audio output reasonably constant for different signal strengths, stronger stations do produce stronger signals at the detector. After all, it is only by a change in signal level at the AGC diode (and detector) that a change in the AGC control voltage is achieved.

However, it is possible to make the audio output from all stations approximately the same, even at high signal strengths. This can be achieved by feeding a portion of the developed AGC voltage to a remote cut-off valve like a 6U7G. This is the first audio valve in sets like the HMV 668 and about one third of the developed AGC voltage is applied to this valve.

Reflex receivers

Reflex receivers usually use a single valve as both the IF amplifier and the first audio stage. It is necessary to be cautious in applying AGC to such a stage, as the operating conditions can be more stringent than for a straight IF amplifier.

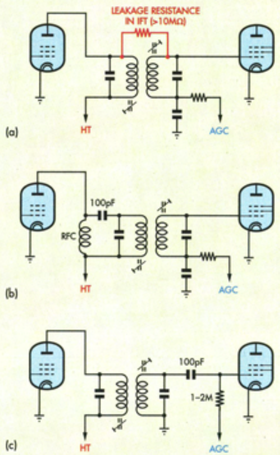

Fig.6: excess leakage between the primary and secondary windings of an IF transformer as shown at (a) can cause serious AGC problems in a receiver. Altering the circuit configuration to that shown in either (b) or (c) fixes the problem by making transformer leakage irrelevant.

In addition, if AGC is applied to this stage, it operates at both IF and audio frequencies. So it does, in fact, have audio AGC as described in the previous section.

Amplified AGC

Amplified AGC generally involves adding an additional IF stage just to feed the AGC diode. As a result, the AGC diode receives a much larger signal than the detector diode and this in turn gives a much larger AGC voltage range to control the RF valves in the front end.

Another method is to use either the first audio valve or a separate valve to amplify the AGC DC voltage. My own preference, however, is to use audio AGC, as described previously.

AGC component values

AGC component values are not usually overly critical although it is best to stick with the values shown on the circuit (or as close as possible to them).

In some HMV circuits, the AGC bypass capacitor is fairly critical, as it is used in a bridge circuit to neutralise the 6BA6 in the IF amplifier. The basic circuit is as shown in Fig.4. As an aside, I restored one of these sets in which bypass capacitor C8 had been increased 10-fold in value. The receiver was unstable because the neutralisation had been upset.

AGC faults

In early days, AGC faults were considered difficult to find. There were several reasons for this:

(1) Most radio technicians were initially unfamiliar with AGC circuits and didn't understand how they worked. Servicemen were usually self-trained and rumour had it that AGC faults were difficult to fix;

(2) AGC circuits have quite high impedances and most servicemen had only a few screwdrivers and spanners, a "calibrated finger" to test grid circuits and a 1000Ω/V meter. In use, a 1000Ω/V multimeter would load the AGC line so much as to make measurements useless. AGC bypass capacitor leakage couldn't be easily tested either; and

(3) The paper capacitors used in AGC circuits in the early days were often leaky almost from new.

All of the above factors conspired to convince servicemen that AGC circuits were hard to service.

By contrast, modern digital multimeters typically have an input impedance of 10MΩ or more and these make it easy to service AGC circuits. It's easy to accurately measure the AGC voltage at the capacitor and on the other side of the AGC resistor and determine which part is at fault. In addition, good quality resistors and modern polyester and ceramic capacitors mean the AGC circuits are now extremely reliable.

However, early AGC circuits could be troublesome and there were several common faults. For example, a leaky AGC bypass capacitor can cause the set to distort badly on strong signals and the volume to vary quite markedly as the set is tuned from station to station.

AGC lead routing

One thing to be careful of when restoring early sets is AGC lead routing. There can be quite high levels of IF energy on these leads following the AGC diode and this can interfere with the AGC action if the leads are incorrectly routed.

Some time ago, I had a peculiar fault in a high-performance valve receiver. If relatively weak stations were tuned, it was possible to advance the volume control to obtain quite good volume. However, on strong stations, I found that the volume decreased as I increased the volume control until eventually, there was no audio output at all!

Fig.4 shows the relevant circuit section. In this case, audio coupler C6 proved to be quite leaky. Because the triode audio valve has such a high grid resistor (ie, 10MΩ) and the contact potential bias is around 0.5-1V, the valve was soon cut off with a high DC output from the detector. The capacitor was replaced and the set then performed normally.

Although capacitors caused most AGC faults, leakage between plate and grid windings will also upset an AGC network. This sort of problem is rare but can be difficult to fix if it does happen because a replacement coil may not be available.

One possible way around this is to alter the circuit configuration shown in Fig.6(a) to the configuration shown in either Fig.6(b) or Fig.6(c). Doing this makes any leakage in the winding largely irrelevant.

By the way, the mica capacitor depicted as C2 in Fig.4 should be replaced if strange things are happening in the AGC circuit. These capacitors can sometimes become leaky.

Check the valves

Don't cross valves off the list of items that can cause problems with AGC circuits. They can become gassy or have low gain and emission. If in doubt, try a new valve.

AGC may be applied to the control grid of valves either through the lower end of the tuned winding or via an RC network as shown in Fig.6(a). And as mentioned earlier, this can cause problems if there is too much leakage between windings.

Usually, variable mu (remote cut-off) valves are used in receiver stages that are controlled by AGC but some receivers use sharp cut-off valves in their IF stage(s). Sharp cut-off valves can be used with AGC but usually in conjunction with a variable mu valve. Only a small fraction of the AGC voltage is applied to the sharp cut-off valve while the variable-mu valve receives the full AGC voltage.

The negative cut-off voltage can sometimes be extended from say -5V to about -10V by feeding the screen via a high-value resistor with the maximum voltage that the power supply can provide. As the valve begins drawing less current with increased AGC voltage, the screen voltage rises and this extends the cut-off voltage.

Summary

Most early AGC circuits work quite well but some were not particularly well designed, despite the fact that efficient AGC systems are not all that complicated. In addition, many otherwise competent vintage radio restorers have trouble diagnosing problems in AGC circuits. However, by understanding how these circuits function and by using modern test equipment, tracking down AGC faults is usually quite straightforward. **SC**

Photo Gallery: Airzone Symphony Leader

THE AIRZONE SYMPHONY Leader, circa 1939, was a 5-valve superhet receiver in a large tombstone-style bakelite case. It featured a large round dial and, on shortwave versions, this changed colour from amber to green when the set was switched from AM to shortwave. The valve line-up is 5Y3, 6V6G, 6B6, 6U7 & 6A8. Photograph by Kevin Poulter for the Historical Radio Society of Australia (HRSA). Phone (03) 9539 1117. www.hrsa.net.au