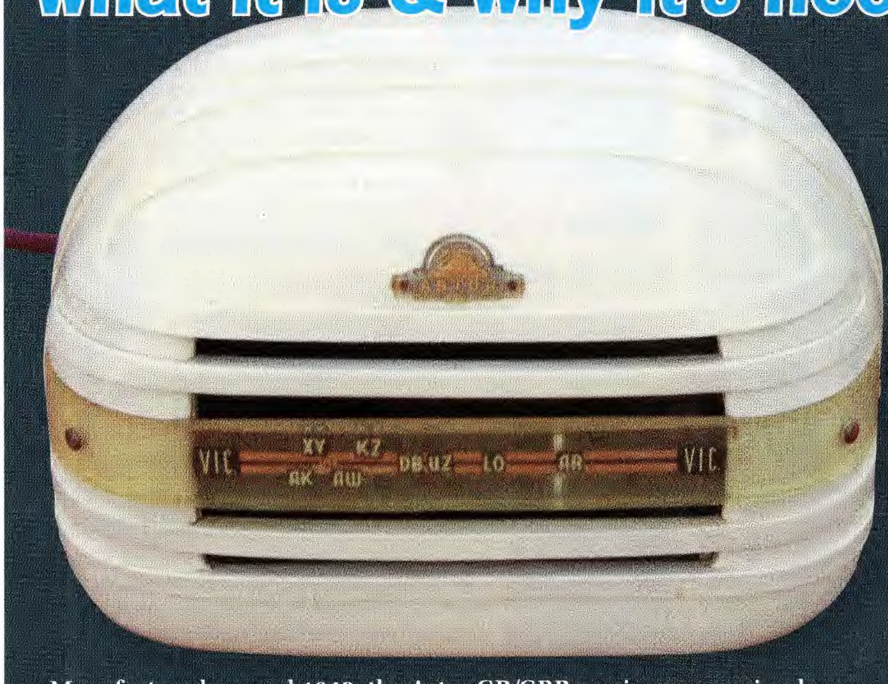
Automatic gain control (AGC) – what it is & why it's necessary; Pt.1



Manufactured around 1948, the Astor GR/GRP receiver was a simple 3-valve TRF receiver. It had no AGC and featured a simple volume control which varied the back-bias on its 6G86 variable-mu RF valve.

The development of AGC (automatic gain control) circuits in the late 1920s and early 1930s was an important milestone in domestic radio receiver design. It allowed stations to be received at the same volume when tuning across the band, regardless of signal strength.

WHEN RADIO (or "wireless") first made its appearance, it was necessary for receivers to use every bit of RF (radio frequency) and audio frequency gain available. However, as receivers became more sensitive and gains improved, this situation quickly changed. Receivers became much more capable of pulling in weak signals but there was one drawback. If a receiver was tuned to a weak signal, the gain then had to be manually reduced when tuning to a strong station in order to produce the same audio output level or volume.

On a set with a loudspeaker, there would be a burst of quite loud and probably distorted audio until the volume control was hastily wound back. That was bad enough but if the listener was using headphones, their ears would be ringing for quite some time afterwards.

Once caught, most listeners would turn the volume control down while they tuned across the band. This meant that strong stations were easily heard but it had the disadvantage that weak stations might be inaudible. So it was a compromise as to just how far the volume control was wound back while tuning.

DXing

In the early days of radio, many listeners became interested in the hobby of "DXing" which involved receiving and identifying distant stations. Of course, these stations were much weaker than any local stations and it was all too easy to get a sudden loud burst of sound from the loudspeaker as one of the local stations was tuned.

Coupled with the inevitable static crashes, this ran the distinct risk of not only damaging the loudspeaker but also frightening hell out of the listener (and any innocent bystanders). Permanent damage to the listener's hearing was also possible if headphones were being used.

To minimise this problem, it was therefore necessary to keep one hand on the volume control as the set was tuned. That made tuning receivers with no AGC (automatic gain control) a rather tedious and awkward job.

In the simpler receivers, the regeneration control acted as the volume control but more complex receivers did have a separate audio-stage volume control. In fact, many of the more complex receivers were likely to have both audio and RF stage gain controls.

Another problem with early receivers was the variations in audio level due to signal fading. At night, the signal strength from a distant station often varied continuously, from almost non-existent at times to quite high at other times. This signal "fading" was inevitable and forced the listener to continuously vary the volume control to keep the audio at an almost constant level.

Distant stations were also likely to suffer from selective fading which introduced considerable distortion on AM signals. Unfortunately though, AGC cannot overcome this particular problem. It can be overcome to a large extent by using phase-locked single sideband (SSB) reception but this is a specialised technique that's used more in communications equipment rather than in domestic receivers.

The Mullard Meteor 600 4-valve receiver (circa 1947) was another economy receiver with no AGC. The volume was controlled by varying the back-bias to the first two valves (both variable-mu types) in the line-up (ie, to the ECH35 converter & EBF35 IF amplifier stages).

Enter automatic gain control

In summary then, the problem was how to stop the set from blasting the listener out of the room on strong signals while still allowing weak signals to be received at usable volume. The answer was Automatic Volume Control (AVC) or as we more accurately call it today, Automatic Gain Control (AGC).

Basically, AGC works by automatically reducing the gain of the receiver when a strong signal is received. The stronger the signal, the greater the AGC action. As a result, the audio output is kept reasonably constant for all stations regardless of signal strength.

AGC was invented in the US in 1925 by Harold Wheeler but did not come into common usage until well into the 1930s. However, some late-model TRF (tuned radio frequency) receivers using sharp cut-off valves did use AGC circuits. This was not particularly successful as only a very limited amount of AGC could be achieved before the valve cut off completely.

The designers understood that varying the bias on the valves could alter the gain to some degree. The problem was that the gain of sharp cut-off valves does not vary a great deal until the valve is actually near cut-off. Once the valve is near cut-off, very little increase in the bias voltage is needed to fully cut it off and reduce its gain (or amplification) to zero.

When these valves are near cut-off, distortion, overloading and various spurious signals are generated. This makes listening to an AGC-controlled set with a sharp cut-off valve rather unpleasant. This can occur if, say, a 6AU6 is plugged into the valve socket for an RF or IF stage designed to use a 6BA6 with AGC. The cut-off voltage for the 6AU6 is between -4V and -6V, depending on the operating conditions set for the valve. However, it is around -20V for a 6BA6.

The main difference between these two valves is the structure of the signal grid. The 6AU6 has a grid which consists of close, evenly-spaced turns of wire. By contrast, the 6BA6 has closely-spaced turns of wire at each end of the grid structure, with the spacing widening towards the centre of the grid. This is known as a "variable mu" valve.

Progressive cut-off

In operation, as the negative voltage on the grid of a variable mu valve increases, it progressively cuts off the electron flow at the ends of the grid structure. Eventually, with increasing negative bias, only a small section in the middle of the valve is left to do

First marketed in 1954, the AWA Radiola 653P was a 5-valve portable with simple AGC applied to the RF amplifier and converter stages.

the amplifying. However, because the remaining grid structure is so open, large AGC voltage variations now cause only relatively small changes to the plate signal, compared to when the entire valve is operating.

As a result, the gain is progressively and smoothly reduced as the grid bias increases.

Remote cut-off valves

Two early remote cut-off RF tetrodes were the 35 and 51. Introduced around 1931, they were nearly identical and became the 35/51. Basically, they were an adaptation of the sharp cut-off 24 but with a variable-pitch grid.

In operation, the 24 required just -8V of bias to cut it off but the 35/51 required around -40V. In addition, the latter's gain was reduced smoothly as the bias increased.

The 39/44 RF pentodes with remote cut-off characteristics appeared a little later, followed by the 58. More modern valves with remote cut-off characteristics include the 78, 6D6, 6U7G, 6K7, 6SK7, 6AD8, 6AR7GT, 2B7, 6B7, 6B8G, 6G8G, 6BA6, 6BH5, 6BY7 and the 6N8. The relevant battery valve types include the 1D5GP, 1C4, 1M5G, 1P5G and 1T4.

The AGC voltage

Having established that varying the negative bias on a remote cut-off valve would alter its gain, it was necessary to come up with a method of developing this control voltage. The device that found almost universal favour to do this was the humble diode detector.

Some receivers did use valves that acted purely as diode detectors, eg, the 6H6 and the 6AL5. However, valve envelopes were expensive and as the manufacturers became even more innovative, they included one and sometimes two signal diodes in the same envelope as an audio triode. Basically, the cost of producing a valve with two diodes and a triode was not much more than the cost of producing a single-function valve.

The 55 and the 85 are two such triode/diode valve types. In each case, the triode section was similar to the proven 27 valve. They were successful and this prompted the development of similar valve types, some even including tetrode or pentode elements.

The 55 and 85 are not the same, however, as their triode gains are quite different. The 85 has a gain of about six while the 55 (or, in its octal guise, the 6SQ7GT) has a gain of about 60 in a practical circuit. Other valves that proved successful in the duo-diode audio triode role are the 2A6, 6B6G. 6BD7 and the 6AV6.

The duo-diode audio triode valve suited the standard 5-valve superhet receiver, which used a converter, an IF (intermediate frequency) amplifier, a combined detector and first audio stage, an audio output valve and a rectifier. By contrast, economy sets using just four valves omitted the first audio amplifier. As a result, in these sets, the detector and AGC diodes were incorporated into the IF amplifier valve, eg, the 6AR7GT, 6G8G, 6AD8, 6N8 and EBF35 (to name a few).

The impressive 5-band STC Capehart A8551 radiogram dates from the mid-1950s and uses eight valves plus a magic-eye tuning indicator. It is also fitted with a very effective delayed AGC system.

One or two audio output pentodes had diodes built into them too, such as the 6BV7.

Early problems with AGC

Once suitable valves had been developed, AGC certainly kept the audio output level reasonably constant, even with wide variations in signal level. It made normal signal level fading much easier to accept but "selective" fading still made listening to distant stations difficult. It did take set designers a few years to get AGC systems working really well, however.

One early problem brought about by AGC occurred because of the way some people tuned their sets. AGC meant that the audio output level remained virtually the same even if the station was slightly mistuned. As a result, many users had difficulty in accurately tuning their sets even though a mistuned station resulted in audible distortion and sibilants and was unpleasant to listen to (I know because my father could never get it right, so I'd sneak up and retune the set when he wasn't looking).

Eventually, some manufacturers solved this problem by fitting "magic-eye" valves to many of the up-market receivers. The pattern on the magic eye indicated the correct tuning position.

Another early problem with AGC was that it emphasised the hiss, crackles, pops and other forms of interference when tuning between stations. That's because the sets were at their most sensitive when tuning between stations due to the increased gain. As a result, set manufacturers came up with various schemes to minimise this problem.

These schemes invariably used the AGC voltage to forward bias a valve or diode in the signal path when the signal exceeded a preset level. However, although these systems worked, any station that was only just strong enough to reach the threshold would give distorted audio. In addition, if the RF signal strength was fading up and down, it may be heard quite well for a short time but then, as it faded down below the threshold level, the audio would suddenly disappear before suddenly reappearing again as the signal level increased.

This system is called "Quiet Automatic Gain Control", or QAGC. And although it wasn't particularly successful on early domestic receivers, variants of it are still used in com-

Photo Gallery: Fisk Radiola Model R49G

RELEASED IN 1939, the AWA Fisk Radiola Model R49G was a 4-valve battery-operated receiver that operated on the broadcast band. It was housed in an attractive wooden cabinet, had an IF (intermediate frequency) of 460kHz and included following valve line-up: 1C6 converter, 1D5G IF amplifier, 1K6 IF amplifier, detector, AGC & audio amplifier and 1D4 audio output. Photograph by Kevin Poulter for the Historical Radio Society of Australia (HRSA). Phone (03) 9539 1117. www.hrsa.net.au

munications receivers. However, it is now called "Mute" or "Squelch" and even some domestic FM receivers use a muting circuit to reduce noise between stations.

To overcome the limitations of QAGC, a number of manufacturers designed receivers with preset tuning. However, although the idea was fine, this meant that the frequency stability of the local oscillator had to be very good, otherwise the set would eventually drift off station. When this happened, the oscillator had to be serviced, which was very inconvenient and costly for the owner.

Mechanical preset tuning was subsequently used extensively in car radios in the 1960s but by then oscillator frequency stability was much better than in 1930s receivers.

Simple & delayed AGC

Initially, AGC circuits were of the simple variety, in that as soon as a signal, no matter how weak, was presented to the diode detector, a bias was applied to the AGC line. This meant that the receiver's gain on even quite weak signals was reduced. In fact, the noise picked up by the antenna when the receiver was tuned off-station was often enough to generate some AGC bias and this was used in some receivers as the standing bias for the AGC-controlled valve stages.

It might seem poor design to reduce the gain of a receiver when it is receiving an extremely weak signal. In practice, however, this did not really cause a problem, as it was quite practical to slightly reduce the standing bias on the AGC-controlled valves to make up for this. In these sets, a single diode usually performed the dual function of detector and AGC diode.

By contrast, delayed automatic gain control (DAGC) uses two diodes – one as the detector and the other as the AGC diode. The detector circuit is usually the same as in sets with simple AGC.

DAGC is obtained by biasing the second diode so that it does not conduct until the signal voltage applied to it is above a preset level (usually between -2V and -3V). The AGC bias developed once that level is reached is then applied to the AGC-controlled valves in much the same manner as for simple AGC. However, by delaying the application of AGC until the preset level is reached, DAGC allows a receiver to amplify weak signals at full gain.

Early servicing problems

In earlier times, radio servicemen were mostly self-taught. As a result, many didn't understand AGC circuits and so were reluctant to work on them. There was a widespread belief in the trade that they were difficult to work on but this was mainly due to their lack of knowledge and adequate test equipment.

What made it hard was that AGC circuits have high resistance values and the average serviceman had ineffective instruments for testing them. As a result, servicemen often had to guess whether this part of the circuit had a problem in it.

Remember also that components were expensive in those days. When I was servicing back in the late 1950s, my wages were $18 per week and a standard RF valve cost $2 or $3. Capacitors were around 15 cents each, so radio parts in earlier times were much more expensive in relation to the average wage. These days, we can afford to replace multiple components when tracking down a fault but that technique wasn't economic until the 1980s.

Next month, we'll take a look at a variety of AGC circuits and describe how they work. We'll also take a look at some of the faults which can be found in such circuits. SC