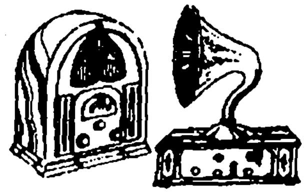
Vintage Radio



by PETER LANKSHEAR

Understanding automatic gain control — 1

For many vintage radio enthusiasts, much of the pleasure from their hobby comes from restoring their receivers to full working order. The functions of Automatic Gain or Volume Control, incorporated in the majority of receivers made after the mid-1930's, are important, and an understanding of what goes on can be of considerable help in fault finding.

First of all, we need to clarify a long-standing confusion — should we talk of automatic *gain* control, 'AGC', or of automatic *volume* control — 'AVC'? Over the years the two terms have often been used synonymously, but strictly speaking the latter term (AVC) is not accurate. 'Volume' refers to the sound level from the audio amplifier and speaker, which is normally controlled manually, whereas it is the receiver's *gain* that has automatic control.

By the late 1920's, the gain of large receivers was nearing the usable limit, and mains operation had made plenty of audio power available — with the result was that careless use of the volume control when tuning across strong signals could produce some very distressing noises. Another problem for listeners remote from transmitters was night-time fading. Some automatic control of receiver gain to compensate for varying signal strengths was needed.

Virtually all AGC systems encountered in valve radios vary control grid bias proportionally to the strength of the received signal. Several methods of generating a negative control voltage were developed, and some of the earliest were the most complex.

As there is no way that all the systems and variations that have evolved can be covered in two articles, we will concentrate on those most widely used, and therefore more likely to be encountered.

The first example of AGC seems to have been used in the RCA model 64, one of the '60-series' all-triode superheterodyne receivers which were very advanced at the time of their introduction in 1928. It used a separate AGC valve biased to cutoff, but with its anode connected to earth via a resistor and the cathode connected to a negative supply of 100 volts. Signals applied to the grid caused a current flow in the valve, producing a negative voltage at the anode proportional to the strength of the signal. This negative voltage was used to control the gain of the RF and IF amplifier valves.

RCA's AGC system was very effective, and various versions were used for several years. Meanwhile, a simpler system was devised by H.A. Wheeler of the Hazeltine Corporation, and released in 1929, to be taken up by some of their licensees — primarily Philco.

Wheeler's AGC system resurrected the valve diode, which had been largely neglected since the advent of the De Forest triode in 1906. After all, as valves were very costly, there had been little demand for a function that provided no amplification. However, diode detection has the great advantages of simplicity with low distortion — and as a bonus, can provide 'free' AGC from the negative voltage developed across the load resistor. Diode AGC became universal within a few years and, adapted for solid state electronics, is still in use.

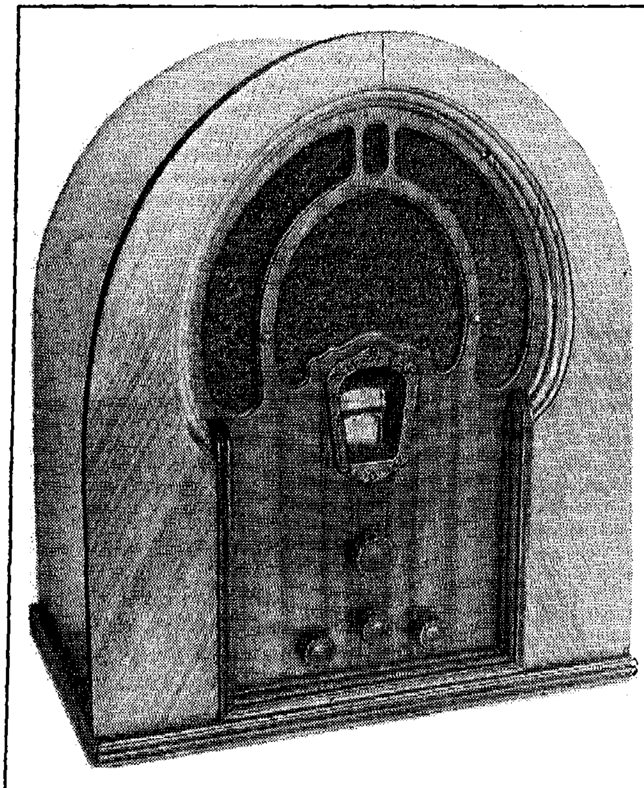


Fig.1: The 1932 model 71 was one of Philco's most popular series of 'Baby Grand' receivers. Advanced for its time, it used RF pentodes as well as a diode for both detection and AGC — a system Philco first used in its 1930 models. This simple and reliable arrangement remained a favourite for many years.

A typical example

Philco's model 71 is a typical example of Wheeler's AGC system. Referring to Fig.2, the 'detector rectifier' is a type 37 triode, with its cathode earthed and its grid acting as a diode anode (anodes do

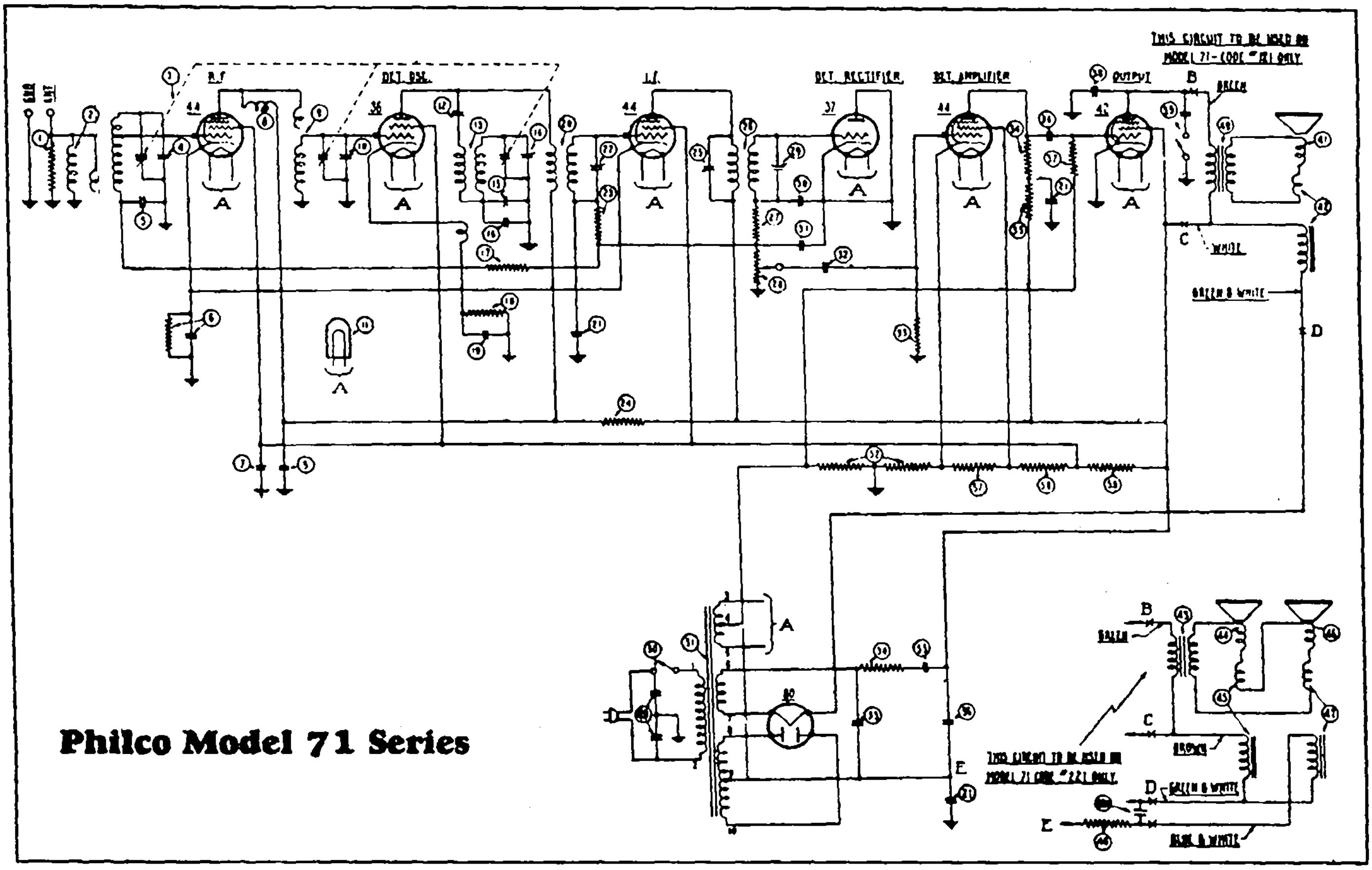


Fig.2: The Philco 71 used the type 39/44, the first variable-mu RF pentode, which had just been released. The autodyne mixer used a type 36 sharp cutoff tetrode, with a 37 triode connected as a diode for detection and AGC. The 42 output valve was also very new, and was to become a standard for many years.

not have to be solid metal). The normal anode is also earthed, and serves as a shield. Rectification of a received signal (in IF form) by the diode causes a direct current, with demodulated audio superimposed, to flow through resistor 27 and the volume control 28, producing a negative voltage proportional to the strength of the received signal.

Capacitor 30 is the 'reservoir' capacitor charged by the rectification of the IF signal, and capacitor 31 filters any IF from the audio. The audio signal is coupled out to the audio amplifier through capacitor 32.

The junction of the filter resistor and the volume control is the source of the AGC voltage, which is connected to the grid circuits of the RF and IF amplifiers. Resistors 17 and 23, together with bypass capacitors 5 and 21, have a long time constant and filter out any audio component — leaving a negative DC voltage to control the gain of the RF and IF amplifiers.

The first receivers using diode AGC were TRF's with sharp cutoff type 24 tetrodes as RF amplifiers, but gain control of these by bias variation was not very satisfactory as only a small increase would cut the anode currents right off. This was a problem even with manually controlled receivers, and it was finally solved by the 'variable mu' or 'super control' RF type 35 and 51 tetrodes, introduced in 1931.

These two valves had been developed independently and were so similar that they were combined in the 35/51, essentially a 24 with the control grid wound with a variable pitch. Whereas an increase in bias to 8.0 volts was sufficient to cut off the anode current of a 24 completely, the new valves took about 40 volts to achieve a smooth reduction to cutoff. This simple modification was very successful and thereafter became standard for RF amplifying valves.

The RF pentode

The next improvement was the addition of a suppressor grid to the tetrode to produce the first RF pentodes, the types 39 and 44. As with the 35/51 these had variable-mu characteristics, and again the two were very similar and were replaced by the 39/44.

Although these pentodes had 6.3 volt heaters and were originally intended for car radios, Philco anticipated the eventual changeover to 6.3 volt from 2.5 volt filament valves for domestic receivers and used them for their 1932 models, including their model 71. By now all of their sets were superheterodynes.

For manufacturers who still preferred the 2.5 volt filament series of valves, the type 58 variable-mu RF valve was in production by the end of 1932 and was one of the first group of valves made by Australia's AWV Co.

Using diodes

Other radio manufacturers were adopting the simple and very satisfactory diode AGC, but using triodes was uneconomic and inevitably diode valves were produced. The first American valves made for detector and AGC service were the G-2-S and G-4-S double diodes, made by Grigsby Grunow and first used in their Majestic radios in 1932.

These were used for full wave detection and AGC, as used by Stewart Warner in 1935 in their model 136 — as described in this column for June 1991. However, as will be described in the next of these articles, the extra diode also made *delayed* AGC practical.

Duo-diode triodes

If two combined diodes were more economic, why not include a triode as well — and provide a diode detector, AGC and audio amplifier all in one envelope?

In the middle of 1932, a triode with characteristics similar to the proven 27 and sharing a cathode with a pair of small diode plates was released as the 2.5 volt heater type 55 and the 6.3 volt type 85. These proved to be the successful progenitors of a large number of dual-function valves with one, two and even three diodes, combined with triodes and with audio and RF pentodes.

Even some sensitive output pentodes had diodes. The 55 and 85 were fine for transformer coupling to the output stage, but as resistance coupled amplifiers, with a stage gain of only about 6 times, were inadequate for shortwave receivers.

The solution was to incorporate the first really successful high-mu triode with the diodes to create the type 75, capable of providing about 10 times the gain of the low-mu valves. So popular was the 75 that variations and close relatives were used as long as valve receivers were made. Some of the better known derivatives were the 2A6, 6B6G, 6SQ7 and 6AV6.

British and European valve makers compromised with triodes with a mu in the region of 30 to 50, popular examples being the EBC3 and EBC33.

With the availability of dual valves, diode generated AGC became increasingly popular and eventually only very inexpensive and some reflexed receivers did not have some form of AGC.

One application where AGC is essential is of course car radios. Not only must they have very good sensitivity, but also the wide variations in signal strength encountered, often at short intervals, demand an effective AGC system. Car radio development, especially in America where they could be afforded, increased rapidly with the introduction of 6.3 volt heater valves and AGC.

Problems for listeners

Although it make receivers more docile, AGC was not initially always an unqualified success. For one thing, it made accurate tuning more difficult for some users, by appearing to flatten the response curve. Consequently, several different types of tuning indicators were developed.

In some locations, such as cities with high electrical activity, the sensitivity of many receivers could be sufficient to raise inter-station noise to unpleasant levels, and local/distance switches were often fitted as a compromise. These simply desensitised the receiver, generally by adding extra bias to the RF or IF amplifiers, and were satisfactory in strong signal locations.

More sophisticated methods were muting, quiet automatic gain control, or squelch circuits which set receiver sensitivity to a predetermined level by applying a large biasing voltage to the detector diode, audio amplifier or IF stage. When the threshold was reached, the bias was overcome and the receiver operated normally. Most of these systems caused distortion, especially around the threshold level, and eventually were to be confined to communication systems and radio telephones.

Probably the most successful method of coping with difficult tuning and between station noise was pushbutton tuning, still popular in some applications. Last month's column described an advanced motorised example, the Ekco PB289.

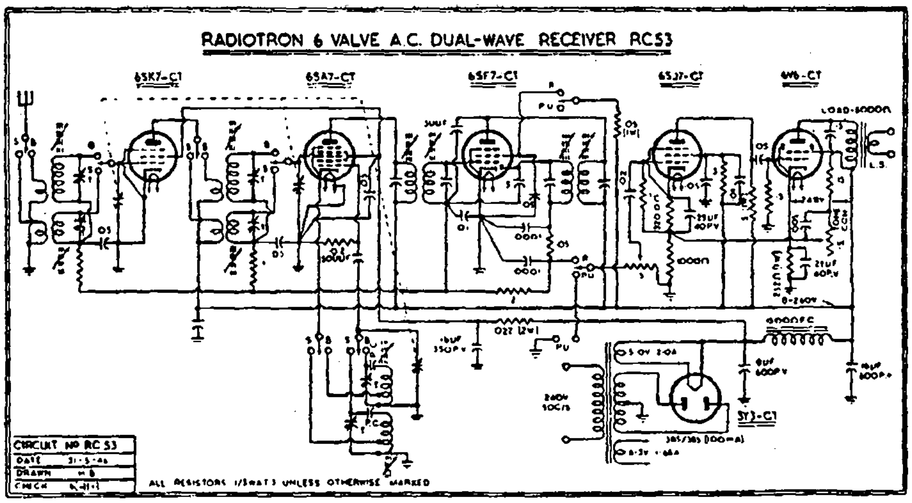


Fig.3: This AWV circuit was drafted 14 years after the Philco 71 appeared. The valves were of a later generation, but the 80 rectifier was still standard, by now repackaged with an octal base as the 5Y3-GT. Although there are differences in detail and refinements such as negative feedback, the AWV circuit arrangement is basically the same as that of the Philco. The concept of a single diode detector also providing AGC is still used in many of today's solid state receivers.

Diode biasing

Diode biasing of the first audio stage made use of the negative voltage that is developed across the detector diode load resistor, and was used in some instances by direct coupling to the grid of a low-mu resistance coupled triode. Usually the diode load resistor was the volume control, so that the bias at the grid was dependent on both signal strength and control setting.

By simplifying loading on the diode, direct coupling is beneficial in minimising detector distortion and with low-mu resistance coupled triodes, especially the types 55 and 85, was a reasonably satisfactory system. However, volume control noise could be a problem, the low-mu triodes often did not have sufficient gain, and diode biasing was not suitable for the high- mu triodes that replaced them.

A variation of diode biasing was tried for a while, by using the resistance coupled semi-remote-cutoff pentodes 2B7 and 6B7. Plenty of audio gain was available and with the variable-mu characteristics of the valve there was an element of audio AGC, but noise caused by the action of moving the slider of the volume control was a problem.

In the next article we will look at delayed and amplified AGC, and the problems — some which can be unsuspected — that AGC faults can create. ❖

Vintage Radio

by PETER LANKSHEAR

Understanding Automatic Gain Control — 2

Last month we looked at the origins of automatic gain control or 'AGC' and the simple systems that evolved. Now we will cover more elaborate methods and some of the faults, often unsuspected, that AGC can provide.

Advantage was soon taken of the availability of a second diode in dual valves. Balanced or full wave detection reduces the necessity for IF filtering and was used for a while, but as the signal and AGC voltages developed are halved, and a centre-tapped IF transformer winding is necessary, half wave operation became standard.

Although combined detection and AGC was used frequently right into the transistor era, it has limitations. Unless receiver audio gain is fairly high, simple AGC can limit the ability of weak to medium strength signals to drive the output valve fully, and reduces receiver gain with even the weakest signals. This is not much of a problem for radios intended only for local station listening, but it is obviously undesirable for higher performance receivers.

The usual solution is to use an independant AGC diode, with delay in the commencement of control action until the signal reaches a pre determined level. This is done by biasing the AGC diode by returning its load resistor to a point negative with respect to its own cathode.

Delayed AGC has another desirable characteristic. Once the signal generates sufficient voltage to overcome the delay, gain reduction action is more effective than that of simple AGC. Detector output increases linearly until the delay point is reached. At this stage the gain curve becomes flatter than with simple AGC, resulting in a more constant detector output over a wide range of signal strengths.

Fig.1 shows the circuit of a receiver incorporating a typical delayed AGC circuit, with the right-hand diode of the EBC3 connected by a .0001uF (100pF) capacitor to the anode of the EF5 IF amplifier. The voltage drop across the 6000-ohm cathode resistor of the EBC3 places the cathode about 3 volts positive with respect to earth. The AGC diode therefore will be inactive until its signal reaches a peak level of 3 volts.

Note that the left-hand diode of the EBC3 is used as the signal detector, and as its DC load is formed by the 0.5-megohm volume control, which is returned directly to the cathode, the detector receives no delaying bias and thus operates normally.

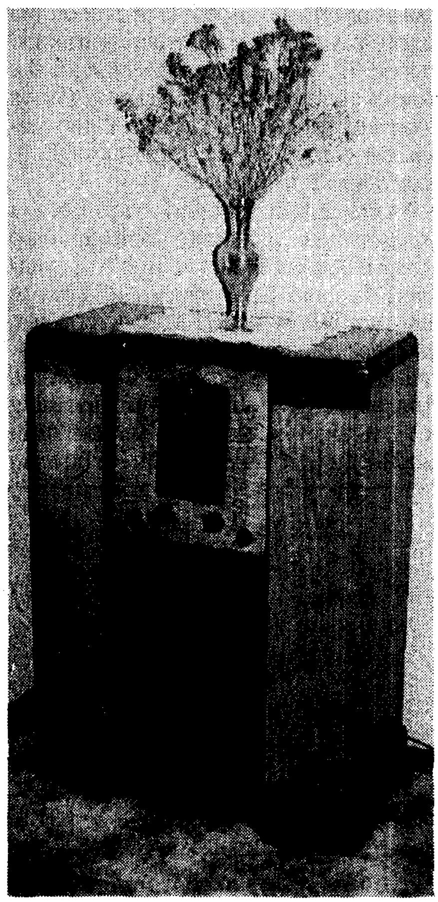
Just what is connected to a diode influences detector distortion and is least with a pure resistive load. However, AGC lines always have bypass capacitors, which make loading complex and their presence increases signal distortion. By connecting the AGC diode to the primary of the IF transformer, loading on the signal detector is reduced although not eliminated. There is still an increase in distortion at the point where the AGC diode does conduct, and as a compromise, delay voltages are usually kept sufficiently low that the transition point occurs with weak signals where good quality is not vital.

To reduce the possibility of leakage or breakdown of the coupling capacitor upsetting the AGC system, the AGC diode was often connected to the secondary of the IF transformer, but at the cost of greater distortion.

Separate AGC amp

High performance receivers sometimes have a separate AGC IF amplifier stage operating in parallel with the signal channel, to take advantage of the benefits to be gained by separating detection and AGC functions. Greater delay voltages can be used, detector distortion is minimised, and as the AGC amplifier can operate at full gain at all times, there can be an effective amplification of the control voltage. Furthermore, the selectivity of the AGC channel can be tailored for the best results.

Stromberg-Carlson's model 837 is a typical example. Reference to Fig.2 shows that the IF signal is split to feed the grids of a pair of 6B7S valves. The upper 6B7S is a conventional IF amplifier and diode detector. Coupling between the two main coils can be adjusted with the IF transformer tapped winding operating as a variable selectivity control, and the diode load resistors R10, R11, and R12 are switched to compensate for changes in detector output as selectivity is changed. Although not used for AGC, the negative voltage developed



The handsome Stromberg-Carlson 837 of 1937 had a specification to match its appearance, including delayed AGC.

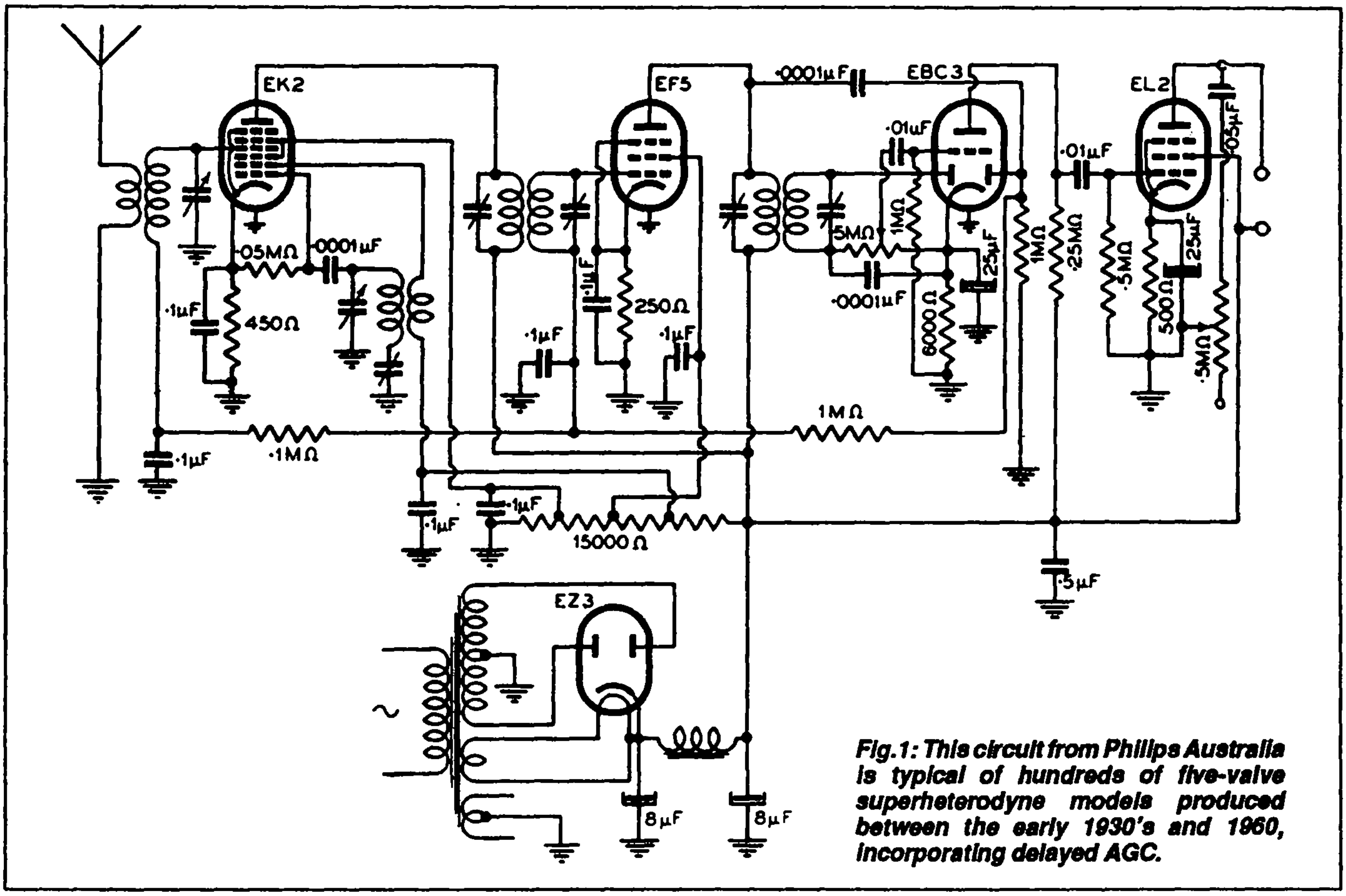


Fig.1: This circuit from Philips Australia is typical of hundreds of five-valve superheterodyne models produced between the early 1930's and 1960, incorporating delayed AGC.

across the diode load resistors does perform an additional function to drive the 6E5 tuning indicator.

The lower 6B7S AGC amplifier operates at full gain with fixed cathode bias and its output is coupled by an IF transformer to one of its own diodes, to be rectified to produce the AGC voltage in the usual manner. R16, the normal bias resistor, in series with R17 places the 6B7S cathode about 20 volts above earth, providing a much larger delay voltage than is practical with the usual combined detector and AGC valve. Resistors R14 and R15 divide the AGC voltage, so that only one sixth of the AGC voltage is applied to the mixer and IF valve.

Applying full AGC only to the RF stage and a fraction to the mixer and IF stages is good practice, but was not done as often as it might have been. AGC degrades shortwave frequency stability of pentagrid mixers of the 6A7 family, but even more important is the performance of the IF amplifier. When receiving strong signals, the IF amplifier may have to deliver 25 or more volts of signal to the diodes. This is well within the capabilities of a well designed IF amplifier, but if it is at the same time subject to an AGC bias of the same order, its own anode current will be severely reduced and the signal will be badly distorted. The effect of this distortion is the same as overmodulation.

Some designers took this into account in larger receivers and either left the IF amplifier without control, or applied only fractional AGC voltage. Other manufacturers simply relied on a 'Local-Distance' switch to bias back the RF and/or IF amplifier to cope with strong signals.

Faults and repairs

Although they have only relatively few components, AGC circuits can produce some significant faults. Fortunately, most problems are readily cured, frequently by the replacement of 'tired' capacitors.

Most common is leakage in the bypass capacitors — traditionally 0.05uF (50nF) or 0.1uF paper types. These capacitors frequently have low resistance, often less than 10 megohms. For a capacitor bypassing a screen dropping or cathode resistor, this resistance would be of no significance, but with two or three capacitors bypassing a typical AGC line, losses can be quite significant.

Many moving-coil multimeters will not give much of an indication with resistances of this order. As suitable replacements are inexpensive, it is a good idea, if there is any doubt, to replace AGC capacitors anyway. Paper dielectric capacitors are no longer available, but plastic or disc ceramic types make superior substitutes and as high voltages are not involved, ratings as low as 50 volts are adequate. Modern components are very small, and the 'original' appearance can often be retained by heating the old capacitor to melt out the wax, removing the contents and concealing the replacement inside the case.

Lead dress can be important, especially for RF and mixer stages. Unfortunately replacing AGC bypass capacitors, which are often mounted beneath coil and bandswitch assemblies, may demand patience and dexterity. These capacitors often complete the circuit between tuning coils and their tuning capacitor rotors, and to preserve stability and shortwave tracking, they should be earthed at the same point as their associated tuning capacitor wiper.

One fault in AGC systems with the diode fed from the anode of the IF stage can cause a complete failure of the receiver. In many receivers the coupling capacitor was a silvered mica ('SM') type, which functioned well for years. These capacitors were made by depositing thin layers of silver on the faces of the mica dielectric plates, with the benefits of a saving in electrode thickness and of accuracy of capacitance — but they had a built-in time bomb!

If as is the case in this situation, the capacitor is exposed to a high potential between the electrodes, the silver coating tends to migrate into the mica, until eventually there is a conductive bridge between the two faces. The result is a short-circuited capacitor, which applies the receiver high tension to earth via the AGC diode.

The best replacement for one of these capacitors is a ceramic type, with at least a 350 volt rating.

One AGC-related fault gave me a lot of trouble the first time I encountered it. The receiver was a simple five valve standard superheterodyne, with a circuit much like that of the AWA in last months column. Occasionally there would be a small but irritating upward jump in volume — and typical of intermittent faults, any attempts at making a measurement caused a disturbance sufficient to make the fault disappear.

The obvious cause would be a shorting AGC bypass capacitor, but these had been replaced. Then I noticed that when the fault occurred with the AGC line disconnected, instead of increasing, the volume dropped! This provided the clue. The fault was an intermittently open .0001uF (100pF) detector load bypass capacitor. This capacitor acts as a similar manner to a power supply input filter capacitor, and when it was open circuited there was reduced audio signal and AGC voltage. With no AGC control the audio signal drop was apparent, but with AGC, this effect was masked by the increase in mixer and IF gain.

Unsuspected fault

There is an often unsuspected problem that can seriously degrade performance in receivers with an RF amplifier stage ahead of the mixer. The symptoms are that the receiver performs indifferently and there is little AGC action. As an example, the Stromberg-Carlson 837 circuit of Fig.2 has a typical broadcast band coupling coil following the 6D6 RF amplifier, and connecting the anode to the mixer grid is a very small capacitor C9. In many cases, as can be seen in Fig.3, this capacitor actually consists of a single turn of wire wound on top of the grid winding, relying only on wire insulation for separation. With one winding having the full HT applied and the other with a negative potential, even a small amount of leakage can be serious.

At this point, the resistance to earth of an AGC line is typically 2 megohms. If, for example, the insulation leakage is only 10 megohms, potentially there could be something like 50 volts positive present on the AGC line. In practice the control grids of the AGC-controlled valves act as diodes, clamping this voltage to that of their cathodes, but the grid current flow seriously degrades performance.

The simplest way to check for this condition is to apply power to the receiver with all but the rectifier and output valves removed, and then with a high resistance meter such as a digital or vacuum-tube voltmeter, check for the presence of a positive potential on the AGC line. If there is, disconnect the wire capacitor and replace it with a 4.7pF high voltage ceramic type.

Fig.3: A typical RF transformer with 'top coupling' capacitance provided by a turn of the primary wire closely coupled to the secondary (just visible on the centre winding). Breakdown of the insulation can seriously upset the receiver's performance.

Another possible cause of this problem is leakage across dirty wavechange switch wafers. Aerosol cleaners can be used for cleaning these, but NEVER with the power applied to the receiver — as tracking can occur, with disastrous results.

This has not been an exhaustive coverage of all valve-receiver AGC systems, or even all the faults that can occur. But we have taken a look at the circuit arrangements most frequently encountered, and hopefully given the novice not only some insight into the way they work, but also the confidence to service them. AGC is an essential feature of vintage radio. ❖

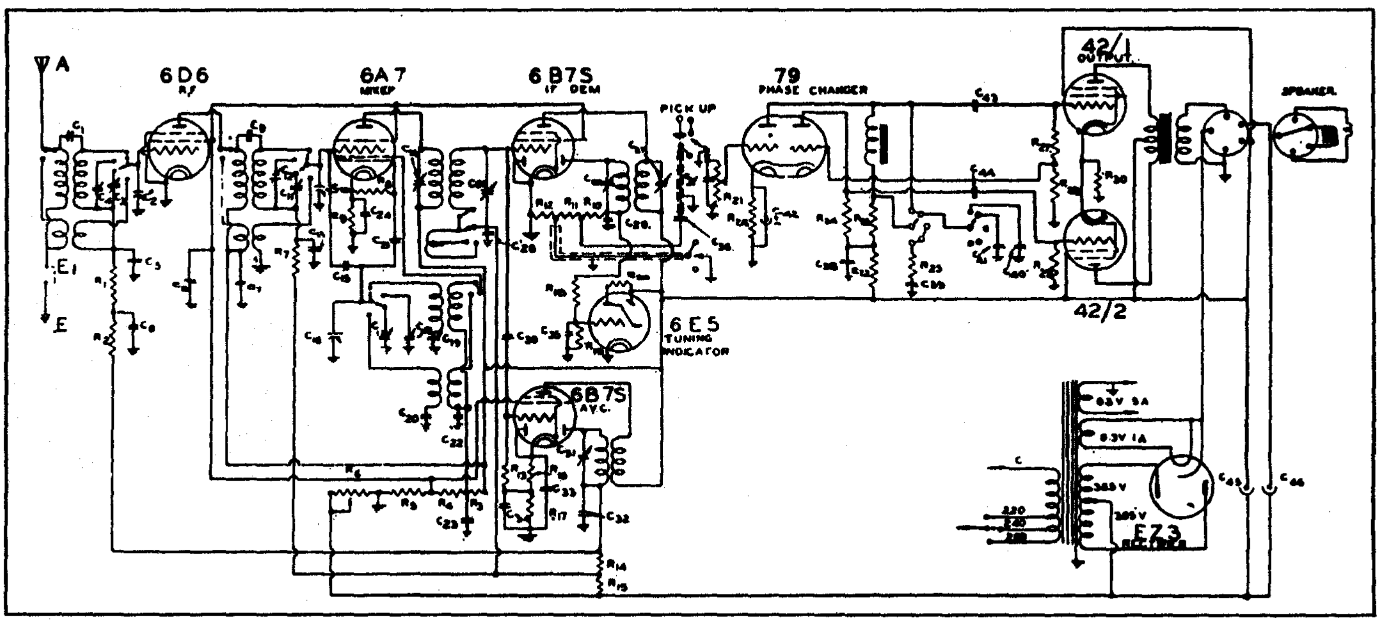


Fig.2: The circuit of the Stromberg-Carlson 837. Provision of separate IF amplifiers for audio and AGC detection reduced the receiver's distortion and optimised amplification characteristics.