When I Think Back...

by Neville Williams

Vintage radio receiver design - 6: Pentagrid converters, diode detectors and AGC

Once $^4/_5$-valve superhets, as described in the November issue, had identified and established the prime suburban receiver market, manufacturers sought to devise ways and means of attracting buyer interest to their respective products. Some such measures were mainly cosmetic in the way of cabinetware and controls; others had to do with on-going circuit design and performance.

As indicated in the November article, the single most troublesome aspect of the first wave of $^4/_5$-valve superhets was probably that of gain — or volume — control. It came about because the IF amplifier stage was the only one available for, gain control, and the range of adjustment was simply not sufficient to embrace both maximum gain for weak signals and minimum gain for powerful local stations. To make good the shortfall, it proved necessary also to attenuate the antenna input signal for local stations and this led to difficulties, as outlined in the earlier issue.

Smoother and more effective gain control could conceivably have been achieved by using a variable-mu valve as a mixer, in conjunction with a separate oscillator valve. It would then have been possible, with one bias control potentiometer, to vary the signal conversion — or translation — gain of the mixer, along with the normal stage gain of the IF amplifier. The catch was that it would have transformed the receiver into a 5/6-valve set, with a consequent and unacceptable price increase.

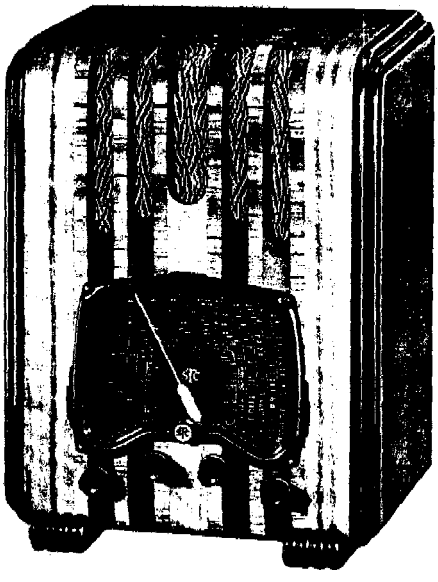
It was left to the valve manufacturers to solve the problem, by the release of special frequency-changer or frequency `converter' valves which could perform the functions of oscillator and mixer more or less independently. For the Australian radio scene, the most notable such valve was the American designed 2A7 pentagrid converter — which was succeeded, in due course, by its 6.3V counterpart the 6A7, and its octal-based equivalents the 6A8, 6A8-G and 6A8-GT.

As a logical derivative of existing tetrodes and pentodes, the pentagrid converter also employed a comparable concentric electrode structure. But in this case there were five grids between cathode and anode — so arranged that they could perform the dual function more flexibly than the existing autodyne concept.

Fig.1, from an early *RCA Receiving Tube Manual,* depicts the electrode structure and the pin connections of the original 2A7 (applying also for the 6A7). Fig.2, from the same manual, shows RCA's typical circuit arrangement

Oscillator and mixer

Grid 1, adjacent to the cathode, served as the oscillator grid and connected to the active end of the tuned oscillator coil L2 via the usual grid capacitor and grid leak. Note that the latter returned directly to cathode, so that the only bias would be that resulting from the oscillatory grid current — typically between 0.2 and 0.5mA.



STC's model 504E mantel radio of 1939 was fairly typical of sets using the 6A8-4 a later version of the 2A7/6A7.

Grid 2 served as the oscillator anode, and connected through the oscillator feedback winding L3 to an HT supply voltage in the range 100-200V.

As I recall from my days in the AW Valve Co, grid 2, often described as the 'anode-grid', was a grid in name only, with the diagram of Fig.1 adding to the fiction. In practice, it was nothing more than two bare side-rods, with no spiral grid, as such. The rods were simply held in place by the mica electrode support discs, connected together and wired to the relevant base pin.

However, being relatively close to grid 1 and cathode, and operating at 100V DC or more, the anode-grid (or side rods) would typically draw around four millamps, completing an inner triode that was well able to oscillate in its own right in conjunction with the associated tuned circuit formed by L3, L2 and C.

Enclosing the inner triode — cathode/G1/G2 — *was* a screen grid designated as G3. Operating typically at 100V DC and bypassed to earth *with* an 0.1uF capacitor, it provided an electrostatic shield around the inner electrodes and also accelerated towards the anode proper those sectors of the electron beam that were not being attracted to the anode-grid side rods.

Immediately beyond this screen was the 'signal grid' G4, connected to the signal input tuned circuit L1/C. Beyond this again was another screen grid, G5. Connected internally to G3, this served the same purpose as the screen grid in an RF tetrode or pentode, by reducing the direct capacitance between signal grid and anode.

Frequency conversion

In normal operation, the wanted input signal would be fed to G4, being impressed on the anode current much as it would in an ordinary tetrode or pentode mixer/amplifier. In the pentagrid structure, however, the electron stream had already passed through 01 and thus been modulated with the oscillator signal, deliberately tuned above the signal frequency by (typically) 455kHz.

Intermodulation — or heterodyne effects — took place such that a multiplicity of signal components appeared in the anode current, including the original signal and oscillator frequencies plus direct harmonics of each and resultants at a variety of sum and difference frequencies. Most were rejected by the IF amplifier system, which was pre-tuned to the intended intermediate or 'difference' frequency nominally 455kHz.

If this sounds very like what was said about the autodyne frequency changer in previous issues, it is, but with one vital difference: in the autodyne, the same control grid was directly involved in both functions — oscillator and mixer. If a variable negative bias was placed on the grid to reduce the conversion gain of the mixer, it would ultimately interrupt the oscillator, rendering the receiver inoperative.

In the case of the pentagrid converter, the inner triode was substantially unaffected by what was happening in the outer mixer section, so that the receiver designer was free to manipulate conversion or 'translation' gain by applying a control bias to the signal grid G4. Valve designers made the best of the facility by giving G4 a remote cut-off characteristic, comparable to that of contemporary variable-mu RF pentodes. With increasing bias, the translation gain of the 2A7 fell from 520uS (microsiemens, or uA/V, formerly called 'micromhos') at -3V to a mere 2uS at -45V.

Receiver designers breathed a sigh of relief when the 2A7 became available, abandoning the autodyne at the first opportunity, along with local/distant switches or compound gain control circuits. *Once* again adequate control could be achieved simply by varying simultaneously the bias of two stages: the mixer and the IF amplifier.

The success of the American-designed pentagrid converter prompted European valve manufacturers to produce their own frequency converters. But apart from the Philips 'octode', the American/-Australian made 2A7/6A7/-6A8 series reigned supreme in Australian receivers until the emergence of multiband receivers called for an upgraded converter with better performance at the higher frequencies. But that is another story.

Erratic sound level

Adequate gain control per medium of variable bias opened the way to the solution of another annoying problem in the early 1930's, namely a tendency for the volume level of receivers to vary spontaneously and erratically. Having been set for comfortable listening, the volume level, for no apparent mason, would suddenly become uncomfortably loud or drop to a whisper — a situation which resulted in numerous complaints and/or service calls.

In a few cases the problem turned out to be a faulty valve, a loose clip on the voltage divider, an intermittent cathode bypass, or such like. More commonly, no fault would be found and, back on the service bench, the set would perform perfectly. In such a case, attention would focus on the electrical environment in which the set was being operated.

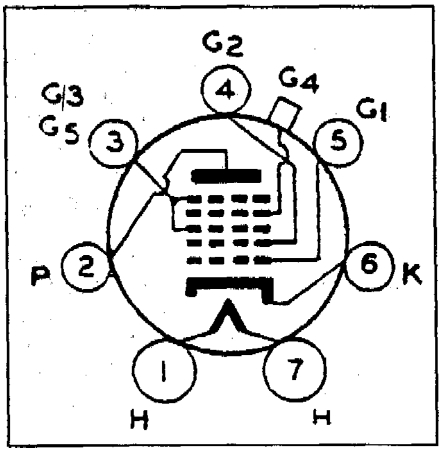


***Fig.1:** Pin connections for the 2A7 **pentagrid** converter, as **viewed from** the underside. The cathode, G1 and G2 provide the basic triode oscillator.*

As distinct from country areas, few receivers in urban homes were provided with a regular antenna and earth. There would be no earth, as such, and the antenna would be a few metres of 'bell wire' tacked to the picture rail. In these circumstances, the amount of signal fed through the primary of the antenna coil could be affected by the household electrical wiring and what lights and appliances happened to be switched on or off at any given time.

More subtly, house wiring in the early 1930's was commonly run through steel conduit, which was subject to erratic earthing by reason of rust and expansion/contraction effects with variations in ambient temperature. Given that receivers were often plugged into lamp sockets via 2-way adaptors, extension leads and/or bodgie power points, it added up to a very unstable environment for incoming radio signals.

Automatic gain control

While the immediate answer might have been installation of a new power circuit and/or a better antenna and earth, an attractive proposition for manufacturers was the incorporation of so-called `AVC' (automatic volume control) which would hopefully counteract changes in signal strength with an automatic and complementary readjustment of the receiver gain.

It may be helpful to note here that, in recent years, technical writers have preferred the term AGC (automatic gain control) to AVC. Not only it is more accurate, but it is also more appropriate what the technique is applied to video or other equipment where the information being processed is something other than sound waves.

AVC/AGC was not a new idea, having already been featured in up-market receivers — as, for example, a 9-valve set manufactured in Sydney by Airzone for Palings and marketed, by arrangement, under the Victor label.

The technique involved the use of a diode detector, so wired that it would deliver a demodulated audio signal plus a negative DC voltage proportional to the strength of the incoming carrier. By applying the negative voltage to the variable-mu stages in lieu of a manually controlled bias, the front-end gain of the receiver would diminish automatically with increasing signal strength — and vice versa.

In short, it could obviate front-end overload by powerful local signals, counteract the effect of abrupt changes in signal strength and, by way of a bonus, compensate to some extent for night-time fading from distant transmitters. With the signal level from the detector thus regulated, the function of the manual volume control knob was simply to adjust the sound from the audio system to the required level.

Ironically, while the first-ever thermionic valve had been a diode, the only versions readily available around 1930 were power supply rectifiers. Small-signal detector diodes suitable for use in mains receivers were virtually unobtainable. As a result, designers of receivers such as the Victor, mentioned above, resorted to the use of triodes like the 27 or 56, with the grid serving as the diode anode. The anode was simply earthed, serving only as an impromptu shield around the diode elements.

In an up-market receiver, an extra valve provided just another reason for the higher price. But at a competitive budget level, an extra valve wired as a diode was no more acceptable than the same valve serving as a separate oscillator. The problem, in short, was to translate AGC into mass-produced 4/5-valve superhets — without adding to the cost.

Duo-diode triodes

Once again, valve manufacturers came to the rescue, aided by the fact that detector diodes could be very small — by reason of the relatively low voltage and current that they were required to handle. By fitting an otherwise ordinary valve with a slightly shorter grid/plate assembly and a slightly longer cathode, enough of the cathode could be exposed to serve one or two tiny circular or semicircular anodes, accessed through extra base pins.

The first such valve to become readily available in Australia was the 55, a general-purpose triode with a 2.5V heater, a 6-pin base, top-cap grid connection and two small-signal diodes suitable for detection and automatic volume (gain) control.

While it made possible a 4/5-valve superhet with AGC, the 55 proved a disappointment for another reason: with an amplification factor of 8.3, it offered a stage gain, as a resistance coupled amplifier of just under six times. As a detector/amplifier, this would have been roughly a tenth that of a 57 as an anode bend detector — resulting in a serious loss of receiver sensitivity.

There was an urgent need for a high-gain triode, which valve manufacturers subsequently met with the 2A6, followed in order by its 6.3V equivalents the 75 and the octal-based 6B6-G. With an amplification factor of 100, these offered a stage gain as a resistance-coupled amplifier of around 56, which just about restored the status quo.

I remember with lingering dismay the first prototype we cobbled together at Reliance Radio of a 4/5-valve superhet with AGC. Based on an existing model with a pentagrid converter and routine coils and IF transformers, the third socket was rewired to accommodate a duo-diode-triode instead of the anode-bend detector. An AGC circuit replaced the variable cathode bias system, and an audio volume control was inserted between the detector output and the triode grid.

Selectivity problem

The receiver certainly worked smoothly enough, but gave the impression of being atrociously broad in terms of selectivity — with stations seeming to overlap one into the other. We all agreed that, even if such a receiver eliminated complaints about erratic changes in volume level, there would be at least as many other complaints to do with poor apparent selectivity.

It transpired that the problem was the result of two effects — one real and the other subjective. The reality was that, whereas an anode-bend detector responded purely to the voltage across the associated input circuit, diodes were power operated, responding to the signal input voltage but at the same time drawing current from the source. In effect, a diode detector shunted the input circuit with a resistance about half that of the associated diode load. The end result was an immediate loss of both gain and selectivity in the associated IF transformer.

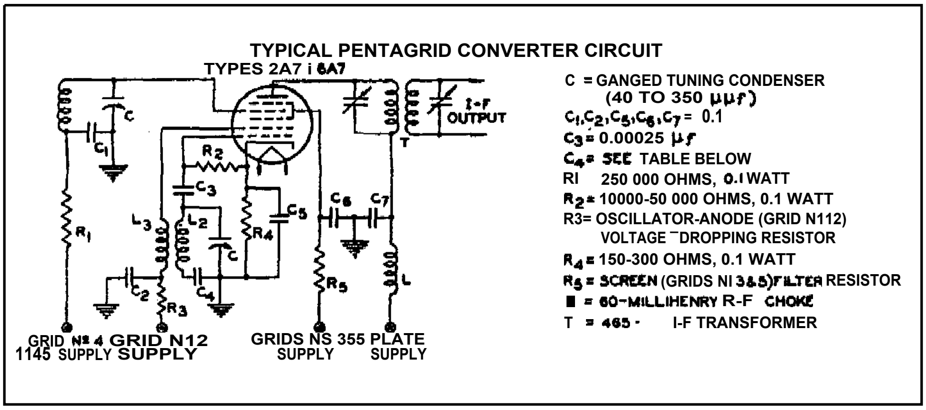


Fig.2: RCA's typical circuit for the 247 pentagrid converter, from an early RCA receiving tube manual. The oscillator circuit (bottom), the RF signal Input circuit (left) and the IF output circuit (right) can be readily identified.

The subjective effect was due purely to the interaction of AGC with the tuning routine. In the case of manual gain control, detuning the receiver to either side of resonance caused the sound volume to fall away at the same decibel rate as the slope of the selectivity curve. But with AGC, detuning the receiver reduced the strength of the incoming carrier — yet at the same time the receiver gain was automatically increased, thereby partially offsetting the loss of sound volume.

To the user, the set appeared to be *less* selective. In fact, it may not have been so because, when an adjacent signal was encountered, the consequent reduction in gain could well be sufficient to render the original signal inaudible.

But real or subjective, possible consumer dissatisfaction caused manufacturers to take a long, hard look at IF channel design before committing themselves to diode detectors and AGC. The immediate result was that IF transformers wound with multi-strand ('litzendraht') wire became a necessity rather then an option.

Instead of single-strand wire, the windings were wound from so-called 'litz' wire comprising (typically) seven or more strands of 41 B&S enamelled wire, spun together to form a single silk-covered conductor. Because high frequency currents tend to flow on the surface of conductors, litz wire exhibits a lower RF resistance than a single wire of the same overall dimension, yielding a winding with a significantly higher 'Q'.

(This assumes, by the way, that the strands are all tinned and soldered together at each end of, the winding. Fractured strands reduce winding efficiency).

While this was not the end of the story, the use of litz wire for IF transformers and the secondary of the antenna coil showed the way to more practical designs.

The art of tuning

Even so, consumers had to become accustomed to receivers equipped with AGC. Instead of just tuning for the loudest signal, they had also to learn to tune for the 'deepest' sound, with good bass and an absence of carrier 'swish' and/or sibilants on speech. It became almost routine to walk into a house and hear an 'edgy' voice or distorted music emitting from the new radio — a clear indication that it had not been correctly tuned.

One answer to the problem was the provision of a small back-lit tuning meter, visible through a cut-out in the dial or cabinet front. With a full-scale sensitivity of about 10mA, it would normally be wired into the anode or cathode circuit of the IF amplifier. Under no-signal conditions, the meter would read full scale. When tuned to a station, AGC would reduce the anode or cathode current and the pointer would swing back towards its rest position. On the scale behind the pointer was an arrow and the words 'Tune for the greatest swing'. It was a useful fitment, but one that because of its cost was largely confined to up-market models.

Rather than becoming involved with a mechanical tuning meter, some manufacturers released receivers with tuning indicators contrived from low-current filament lamps or neon devices — none of them all that impressive.

Once again valve manufacturers came up with a practical answer, in the form of an 'electron ray' tuning indicator, subsequently dubbed a 'magic eye'. The first of these, the 6E5, was released in Australia around 1935, by which time most manufacturers had swung over to 63V valves. I understand that a 2.5V version was also released, but I cannot recall ever having encountered one. European manufacturers came out with their own configurations and type numbers, which appeared on the local market in limited numbers.

How the 6E5 worked

As illustrated in Fig.3, the 6E5 was based on a small general purpose triode in an ST-12 valve envelope, with the cathode extending into a display assembly occupying the domed top of the bulb. This involved a shallow cone-shaped target electrode about 20mm in diameter, with a phosphor coating similar to that used for green screen cathode-ray tubes. A small metal vane — the ray control electrode attached to the triode anode, protruding on one side into the space between the cathode and target.

hi use (Fig.4) the cathode was returned to earth directly or via a cathode bias circuit. The grid was connected to the AGC (AVC) line and the anode fed from the HT supply through a suitable load resistor. The target was connected direct to B-plus. In operation, electrons attracted from the cathode would strike the surface of the target electrode, causing the coating to glow a bright green. The indicator was normally mounted so that the top of the bulb was visible through the dial scale, or through a small hooded escutcheon set into the adjacent front panel.

With no signal input, there would be, at most, only a small negative potential on the triode grid. With a consequently high anode current, voltage drop across the anode resistor 'R' would result in a relatively low voltage on the anode and the ray control electrode.

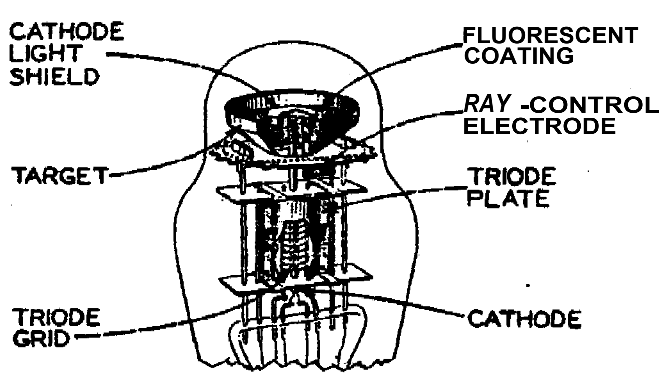


Fig.3: The electrode structure of the 6E5, taken from RCA literature. It was the first electron ray Indicator to be widely adopted in Australia, and was followed by quite a few variants released by RCA and other manufacturers.

Under these conditions, the ray control electrode would repel the adjacent electrode stream, creating a triangular 'shadow' extending on either side by about ±45°. With the cathode and ray control electrode hidden by a small internal shield, the user was aware only of a conical electrode, glowing bright green except for a 90° triangular shadow.

Tuning the receiver to a station would generate a negative voltage on the AGC line, therefore on the indicator valve grid. The anode current would fall, the anode voltage would rise and the shadow angle would be reduced — the edges of the illuminated area appearing to move together. The user was instructed to tune for the 'smallest shadow'.

'Magic eye' tuning indicators were less 'clinical' and more visible than small milliamp meters and, with their gimmicky name, became a strong promotional feature in the mid 1930's. They gradually disappeared, however, as listeners learned to do without them and especially when they realised that they had to be replaced from time to time when the 'magic glow' dimmed.

Mid-1930's receiver

Prompted by a stream of application data from the respective valve manufacturers, a style of domestic urban receiver gradually emerged that reflected Australian technology of the mid-1930's. It could be summarised as follows.

(The valve types shown in brackets are octal-based alternatives, which were either available as imports in all-metal construction or in view as octal-based glass types).

- Frequency changer: 6A7 (6A8-G) pentagrid converter, with automatic gain control.
- IF amplifier 6D6 (6K7, 6U7-G) variable-mu pentode also with automatic gain control.
- Detector/amplifier: 75 (6Q7, 6B6-G) duo-diode high-mu triode providing diode detection, delayed AGC feed voltage and audio voltage amplification, with provision in some cases for phono input.
- Output valve: 42 (6F6, 6F6-G) pentode, with treble limiting and, in most cases, top-cut tone control.
- Rectifier. 80 (5Y3-G) with field coil filter system.
- Tuning indicator 6E5.

Fig.5 shows a typical circuit using the above valve complement. It is not based on any one specific receiver but, like earlier circuits in this series, is typical of the em — while also providing a basis for relevant comment, beginning with the frequency changer.

Unlike the autodyne, discussed in earlier articles, the configuration of a pentagrid converter did not lend itself to much variation, apart from minor differences in the choice of component values. Grids 1 and 2 were simply wired as a triode oscillator, with the usual grid isolating capacitor and a resistor ('grid leak') returning direct to cathode.

Grids 4 and 5 provided a separate variable-mu tetrode function, accepting the wanted signal from the antenna coil, mixing it with the oscillator signal per medium of the internal electron stream, and delivering the required difference — or 'intermediate' — frequency to the IF system at 455kHz or thereabouts.

The 300-ohm resistor and bypass capacitor in the cathode circuit ensured the minimum specified bias of -3 volts for the signal grid (G4) under no-signal conditions. With a very strong signal input, the AGC voltage might apply an extra negative voltage to G4 of anything up to -40V, at which point the conversion gain would be reduced from 500uS to a mere 2uS — enormously simplifying the one-time problem of front-end gain control.

Incidentally, to measure the AGC voltage in such a circuit calls for an electronic voltmeter, with an internal resistance of several megohms. Using an ordinary multimeter, minor deflection of the pointer may usefully indicate that a negative control voltage is present but the actual reading is meaningless, because of the shunting effect of the instrument on the very high impedance circuit.

Operation of the oscillator section can be checked by simply unsoldering the cathode end of the 50k resistor and bridging the gap with a DC milliammeter, positive connection to cathode. Normal grid (G1) current over the broadcast band was usually in the range 025 to 0.5mA.

No measurable grid current would indicate that the valve is not oscillating, calling for possible valve replacement and/or inspection of the circuit to identify some other possible fault.

The IF stage is essentially similar to those shown in earlier circuits, except that the gain is controlled by a negative potential from the AGC circuitry reaching the grid via the secondary of the first IF transformer. As in the case of the 6A7, a cathode resistor and bypass ensured that the 6D6 had the required minimum bias applied when there was no signal present to activate the AGC.

The diode detector

Turning to the duo-diode triode, the circuitry to do with detection, AGC and the magic eye function commanded a great deal of attention during the mid-1930's, as I well remember from my involvement in the A.W. Valve Co laboratory and technical publications. Valve manufacturers' recommendations were treated with considerable respect by the engineering fraternity.

When first introduced — or re-introduced — to the domestic receiver scene in the 1930's, diode detectors came in for a fair amount of criticism both for their effect on selectivity, as already mentioned, and for reputedly exhibiting higher distortion than the hitherto widely used anode bend detector.

The damping effect of a diode rectifier on the associated tuned circuit was inarguable, and had to be offset by the use of litz windings — and in due course, by the introduction of ferrite cores.

But analysis showed that distortion was not a problem in a basic diode detector, provided that the design of the receiver was such that the detector operated with an RF input of at least 10V peak — as would normally be the case with automatic gain control.

Where the difficulty arose was in the ill-considered addition of supplementary circuitry to feed the audio amplifier, to derive AGC voltage for front-end gain control, and provide drive voltage for the magic eye indicator. By requiring the detector to work into a so-called `AC' load of much lower impedance than its direct 'DC' load, there would be a proportionate reduction in the modulation depth of the incoming signal which it could handle without distortion.

In a 'worst case' situation, a designer might choose a 1M diode load with the idea of minimising the damping on the input circuit. For audio take-off, he might shunt this with a 1M volume control, fed through a coupling capacitor. A 1M resistor might also be added to feed the AGC system, with a similar resistor to the magic eye grid — both bypassed at the remote end by a 0.1uF capacitor. As a result, the nett AC load would be only one quarter of the DC load, with severe consequent distortion on waveforms involving more than about 25% modulation.

In Fig.5, the direct or DC load for the diode detector is 0.55M, made up of a 50k resistor forming part of an RF filter network and a 0.5M potentiometer the audio volume control. Signal for the audio amplifier is picked off from the sliding contact and, having in mind the tapered element in most volume controls, the audio circuitry may well be shunting only a few thousand ohms of the diode load at typical settings. As a result, its effect on the operation of the diode would be negligible.

The AGC circuit

If the AGC voltage were to be derived from the diode end of this same network — so-called `simple AGC' — it would obviously impose an undesirable load on the detector circuit. It would also have the effect of feeding a negative bias to the converter and IF valves in the presence of even a very small signal, thereby marginally reducing the effective sensitivity.

To preserve the sensitivity to very weak signals, it was/is desirable that a threshold be established such that no AGC voltage would be applied until incoming signals reached a predetermined level. This is achieved in Fig.5 by using a separate diode as the AGC source, fed from the IF amplifier anode via a 100pF capacitor. Since its load resistor returns to earth, current can only flow when the signal peaks are sufficient to overcome the sum of the diode's own space charge and the volt or so of cathode bias.

The technique was/is commonly described as 'delayed' AGC — a rather misleading description, because the word wrongly suggests a time delay rather than a voltage threshold.

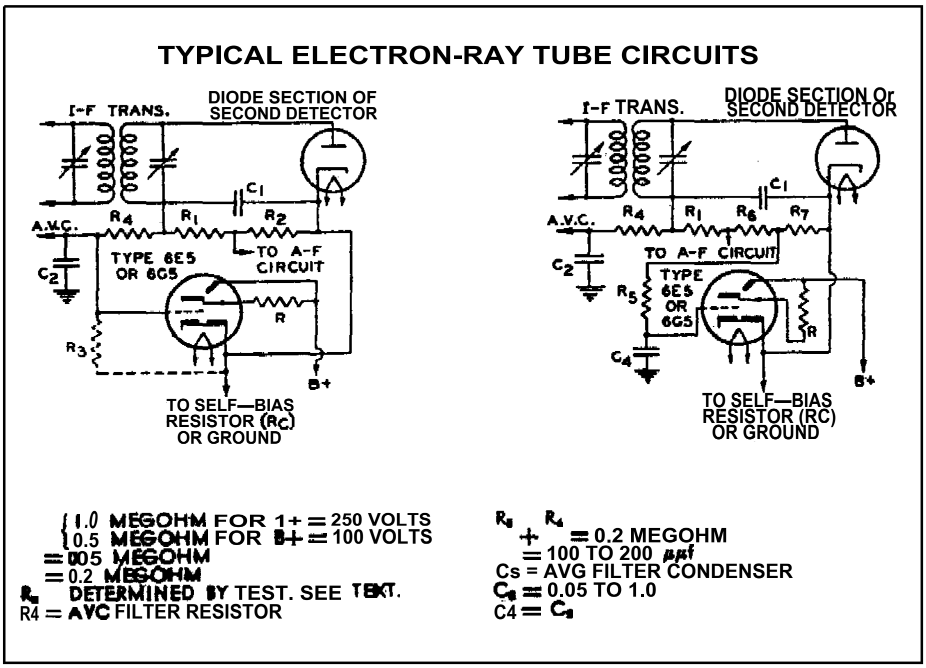


Fig.4: Typical early tuning indicator circuits published by RCA. The circuits were later refined in various ways, and the 6E5 itself was displaced by other types which offered improved display characteristics.

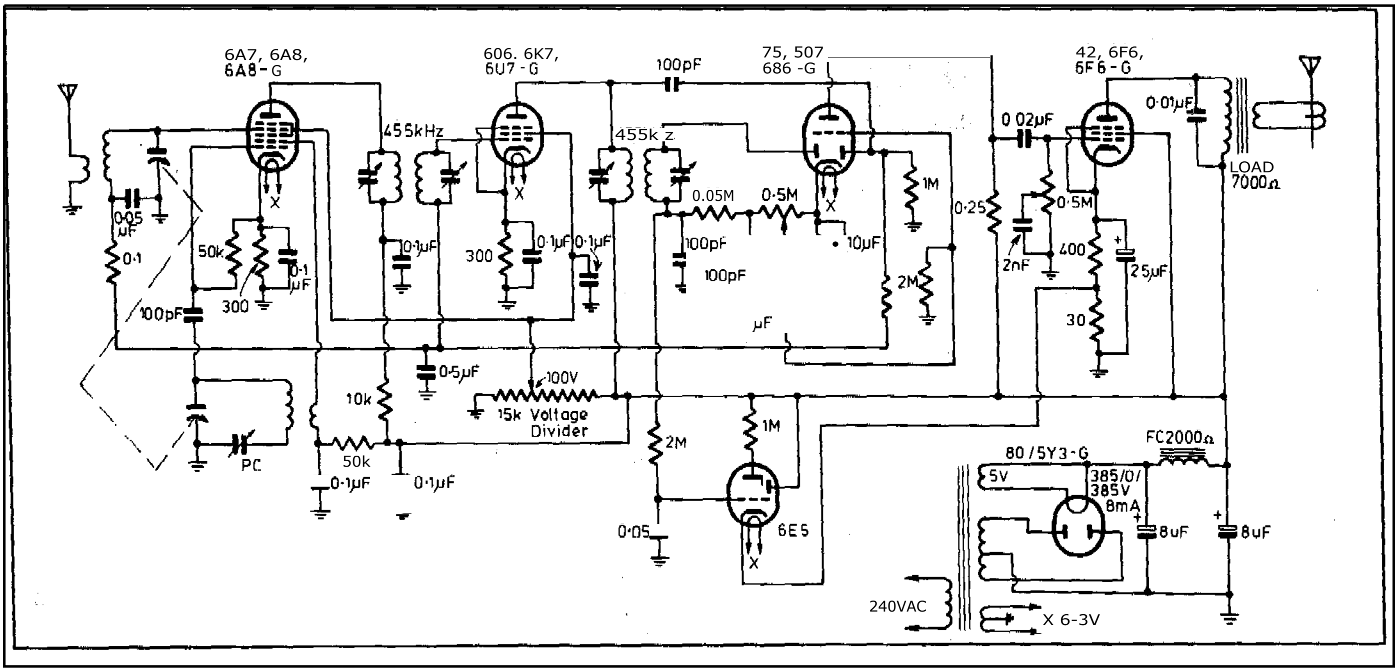


Fig.5: The incorporation of a pentagrid converter and AGC called for basic changes In the design of 4/5-valve superhet receivers, This circuit is not based on any particular model, but is nevertheless typical of overall Australian practice In the mid 1930's, With rare exceptions the 2.5V valves had been superseded and relegated to a 'replacement' role.

That aside, delayed AGC removed one of the potential shunts from the diode load — although it did have its own separate effect on selectivity, by shunting the IF transformer primary.

Ironically, while delayed AGC was desirable in terms of receiver sensitivity, the resulting AGC control voltage was less suitable for activating the tuning indicator. Even though a transmission may have been audible in the loudspeaker, it might not have registered on the tuning indicator, leading to the impression that the indicator was faulty.

To avoid this threshold effect, the A.W. Valve Co suggested in *Radiotronics* No.70 '(November 1936) that the tuning indicator be fed from the detector diode — taking care to minimise the loading by using a 2M feed resistor, as shown.

Potentially flawed

They warned, however, that with the indicator cathode simply earthed, there was a potential path for electron migration from the indicator cathode, by emission to the grid and thence through the isolating resistor and detector diode load, to the positively charged cathode of the detector/audio stage. Thus, instead of the detector diode being simply referenced to its own cathode, it could be exposed to an external bias current. This could prejudice its behaviour in the troughs of weak or heavily modulated signals, where the instantaneous carrier level fell to near zero.

As a precautionary measure, it was suggested that the indicator cathode be biased to a similar voltage to that of the detector cathode. Fig.4 notwithstanding, simple self-bias was not recommended because of variations in target (therefore cathode) current between individual indicators. AWV's preferred approach was to derive the requisite voltage from a relatively stable source — for example, the cathode circuit of the output valve.

One other difficulty had arisen with the 6E5, in that the shadow angle reached 0° with a grid bias of -8 volts. A further increase in signal strength (and AGC voltage) could have little further effect, beyond causing the illuminated edges to overlap. Efforts to overcome this limitation by using only portion of the AGC voltage were compromised by the fact that such measures also affected the sensitivity to weak signals.

The problem was overcome by releasing the 6G5 with a remote cut-off characteristic, being otherwise a plug-in replacement for the 6E5. It retained essentially the same low-level sensitivity, but extended the cut-off voltage by about three times.

Audio system

Now equipped with its own in-built volume control, the audio system shown in Fig.5 was ready for operation from a phono pickup. This involved the provision of a suitable 2-pin socket or twin terminals at the rear of the chassis, plus a 2-way 'radio/PU' switch on the front panel. This was so wired that it would transfer the active end of the volume control from the 50k filter resistor to the live PU connection, the other PU connection being earthed. Some makers included the phono facility, others didn't. For the rest, the 6B6-G triode amplifier and the 6F6-G output pentode are straightforward, with a top-cut tone control and a treble limiting capacitor across the loudspeaker output transformer — fitted for the reasons outlined in earlier articles.

The need to provide a stable cathode bias for the magic eye tube provided sufficient reason to favour full cathode bias for the output valve and this is depicted in Fig.5, as distinct from back-bias shown in the earlier circuit.

Built along these lines, receivers in the mid-1930's were eminently satisfactory for listeners in urban or other well served areas. Servicemen had access to service data for individual models, but the designs were sufficiently consistent from one model to 'the next for a good servicemen not to rely overmuch on the literature. But the process of evolution was not by any means complete. With the success of the 4/5-valve configuration came the challenge to shed yet another valve — with the idea of offering a `second set' in every home. One that would be cheaper, smaller and more portable than the existing console.

On the other hand, the shortwave fad was just around the corner, along with the hi-fi revolution, which was to have a significant impact on the audio systems of ordinary receivers. These matters will be the subject of future articles.

(To be continued)