# When I Think Back...

by Neville Williams

## Vintage Radio Receiver Design — 1
## The 1920's: a decade of 'give-it-a-go'!

Looking back over the years, vintage radio enthusiasts may well gain the impression that receiver design has been subjected to a bewildering sequence of technical fads and fashions. Perhaps it has but, as this and succeeding articles will show, there have been sober, practical reasons for most of the on-going mutations in components and circuit techniques.

During the '20s, which witnessed the inauguration of public radio broadcasting in Australia, the physical and electrical design of receivers underwent especially rapid and radical deviations — and of little wonder. Within that single decade, wireless broadcasting progressed from pure speculation in the media to an established service, subject to urgent, outspoken demands by the first ever generation of listeners.

Temperamental equipment that could be coaxed to perform for enthusiastic novices might have been tolerated in the early '20s but, by 1930, listeners were demanding receivers and programs that were routinely accessable to every member of the household — not just to the technically inclined.

In urban areas, they reasoned, receivers should logically operate from the power mains and be switched on and off as casually as any other electrical appliance. In the country, listeners had developed their own high expectations — reliable service and upgraded receivers, consistent with manageable battery drain.

Within that same time scale, commercial wireless suppliers had to come up with totally new products to satisfy a totally new domestic entertainment market, with no precedent beyond the humble mechanical phonograph. The guidelines for domestic wireless sets had largely to be worked out by trial and error, 'on the run'!

Not surprisingly, progress in the design of wireless/radio receivers, in the '20s, didn't follow any uniform timetable. While the demands for improved technology and styling were ongoing, some suppliers took longer than others to react — as evidenced by articles and advertisements in the wireless press of the era.

By way of example, I would refer readers to that most informative *EA* reprint: *The Best of Australia's Wireless Weekly — 1927*, available from most newsagents for about $4.

### All shapes, sizes

In that reprint, conservative crystal, regenerative and reflex receivers appear cheek-by-jowl with superheterodynes and neutrodynes. Models with old-time bakelite panels and multiple tuning knobs contrast with trendy single-dial designs. Table models compete with futuristic self-contained consoles and, in a predominantly battery set environment, Colville Moore offer a lone 8-valve 'all-electric' model. All this, extracted from a few weekly issues from a single year.

Behind such product diversity was the fact that receivers on the Australian market in the '20s were a near-random mix of British, European and American imports, plus local designs assembled by everyone from purposeful manufacturers to 'back-yarders' and hobbyists. Suppliers all tended to 'do their own thing' for as long as they could attract sufficient customers.

In this situation, with mostly limited and scattered sales of any one model, documentation in the way of type designation, specifications and circuit details came a bad last. Nowadays, as a result, information about receivers from the '20s usually has to be picked up in any way it can — a fact well known to vintage receiver enthusiasts.

The situation changed abruptly in the early '30s when a new tariff barrier favouring locally-made components and equipment set the scene for large-scale production and promotion of uniquely Australian receivers, along with circuit diagrams and/or service manuals from specialist publishers.

### Indigenous industry

This, as it happened, coincided with the emergence of much improved technology for AC mains-powered receivers and with a drive by the electricity supply authorities to extend the mains into rural areas. That, along with progressively expanding broadcast services, triggered a huge demand for the new-look models, effectively ushering in the so-called 'golden age' of Australian radio — cut short only by the intervention of television in 1957.

Responding to engineering guidance from suppliers of local valves and other components, designers of the new Australian receivers tended to adopt a more uniform response to market needs so that, behind the differing cosmetic exteriors, circuit practice from the '30s onwards evolved on a much more structured basis than had previously been the case.

It is appropriate to observe here that the rush by Australian listeners to equip or re-equip in the early '30s largely wiped out the motley array of receivers from the preceding decade. Of little practical or sentimental value at the time, they were either dumped in toto or dismantled by experimenters seeking reuseable components.

Or, again, dealers accepted them as 'trade-ins' for a suitably tempting figure, dumping them thereafter by the proverbial truckload.

At the original Reliance Radio factory/showroom in York St, Sydney — my first ever job — I remember a stack of old-time battery and semi-electric sets in the musty basement, which ultimately met just such a fate. They cost less to dump than to service and re-sell!

Later, during a brief stint at the E.F. Wilkes factory in Redfern, Sydney — my second job — I was confronted by a pile of one-time 'up market' American made Gulbransen receivers. Boasting type 50 output valves and the chunkiest dynamic loudspeaker I had ever seen, they were so cumbersome that the staff couldn't even be induced to carry them away gratis!

## Now quite rare

In short, with virtually no resale value, comparatively little of that early gear survived intact, with the result that genuine examples of '20s technology are now few and far between. Most of those that do remain are in town museums across the country, in the hands of private collectors, or in antique shops at prices mostly well above what they originally commanded.

One vendor I came across recently was offering a 6-valve AWA receiver 'circa 1925' in ostensibly pristine condition. It carried a price tag — hopefully or otherwise — of $525.

(Perhaps I should mention here that an enthusiast group dedicated to old-time radio and allied interests is the Historical Radio Society of Australia. Our immediate contact in Sydney is Mr Garfield Wells, NSW State Secretary, PO Box 428, North Sydney 2059).

But I have got ahead of myself. Interwoven in time as they certainly were, it may nevertheless be helpful to take a brief look at major technical trends in the '20s, as a broad background to a more detailed examination of indigenous Australian receiver design in the following decade.

## Amateurs, experimenters

In the pre-broadcasting era, most receivers held by members of the public were of simple design, often home constructed: 'catswhisker' crystal sets, or 1-, 2- and 3-valve 'reaction' sets — most commonly a regenerative detector followed by one or two audio stages.

Operated by enthusiastic 'experimenters', they were used to monitor coastal wireless 'traffic', Morse code, speech and music transmissions from amateur radio stations, and the occasional demonstration concert — in short, whatever transmissions the owner might happen upon by interchanging coils and twiddling knobs.

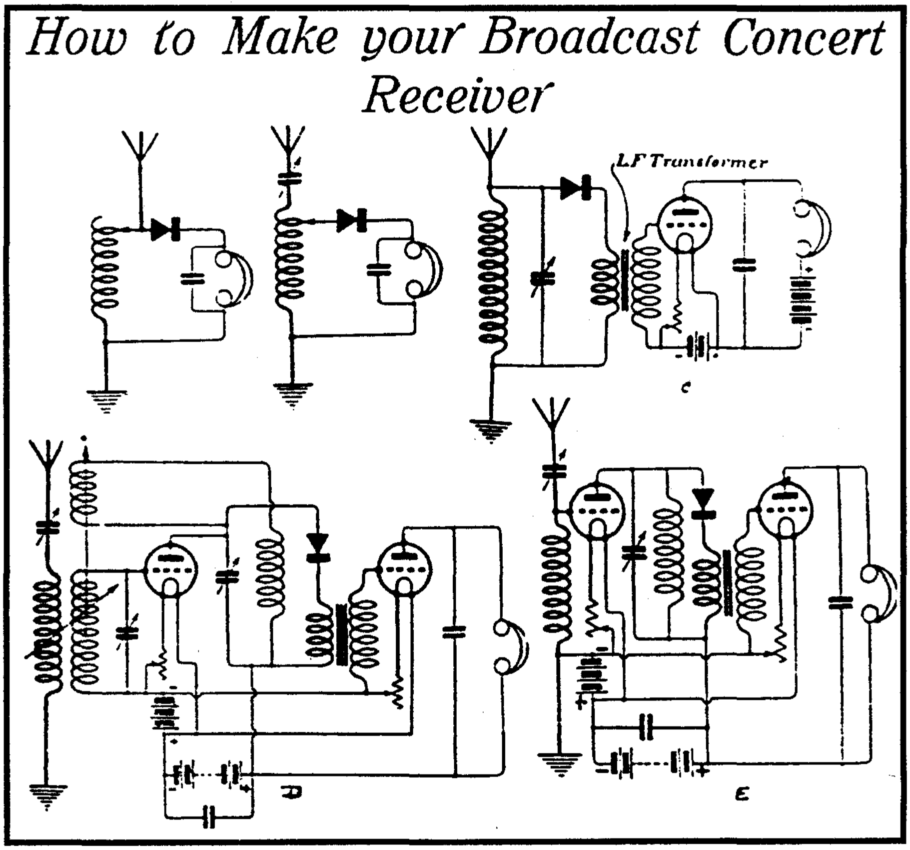


***Fig.1: Circuits for 'sealed' receivers for Sydney's pioneer high-power station 2FC, as suggested in the October 1923 issue of The Australasian Wireless Review. Circuit 'D' uses a regenerative RF amplifier ahead of a crystal detector, followed by one audio stage.***

(A sound documentary of this era is available on the audio cassette 'Loud speakers', from the ABC radio series *Bright Sparks*. It is available for $15, or $45 for the complete 8- session series, from ABC Radio Tapes, GPO Box 9994, GPO Sydney 2001. For phone inquiries or credit card orders, ring (02) 339 1034.)

That some professional valve-based receivers were available at the time is evident from the memoirs of Sydney Newman (*EA*, January '91, p.46) where he mentions a batch of Marconi 'Seven' long-wave receivers imported by AWA, around 1921. While appropriate for official communication services, however, they would have been beyond the means of most amateur enthusiasts.

Doubtless anticipating the commencement of formal public broadcasting by the end of 1923, Electricity House in George St, Sydney, advertised a range of typical components and basic receivers in *Wireless Weekly* for March 9 of that year. Their crystal sets ranged in price from £3/10/0 to £7/10/0 ($7 — $15) with one- to three-valve sets priced from £9/0/0 to £35/0/0 ($18 — $70).

In practice, the crystal sets would have been of little use more than a few miles from a transmitter, being therefore limited mainly to urban areas.

Under favourable reception conditions, small regenerative valve sets could pick up transmitting stations hundreds of miles away — provided they were used with an efficient outdoor aerial and earth and were critically adjusted, with the detector on the threshold of oscillation.

In the longer term, small regenerative receivers won only limited acceptance by would-be listeners to public broadcasting stations. The reason was simple enough: as distinct from 'experimenters', broadcast listeners were less inclined to persist with weak signals and more likely to expect loudspeaker reception, to be shared by the whole family. In terms of circuitry, this translated into at least a 4-valve receiver, typically comprising a tuned RF amplifier stage ahead of a regenerative receiver, and followed by two audio stages. But more about that later.

## 'Sealed set' fiasco

As it happened, the Federal Parliament caused a major 'hiccup' in receiver design concepts in August, 1923 by deciding that the proposed public broadcast stations in Australia should be supported by direct subscription. The idea was that listeners would nominate their preferred licenced broadcaster, pay the specified fee direct to the particular company and instal a receiver capable of receiving that station only.

Said to be the brainchild of AWA's manager Ernest Fisk, the sealed-set legislation cut right across the prevailing concept of sensitive, broadly tuneable receivers, with legitimate access to all available transmissions.

In a rare example of sealed-set mentality, *The Australasian Wireless Review* featured a story on '2FC The First Big Broadcasting Station in Australia' in its September, 1923 issue. The annual subscription fee for the new Farmer & Co (Sydney) station was to be 3 guineas (£3.3.0).

Transmitting on 1100 metres (272kHz), its powerful 5000-watt signal would hopefully dwarf existing amateur transmitters and would not call for anything like the same order of receiver gain or selectivity. By implication, the owner of a sealed set would not want to, nor need to, nor be eligible to tune into other less pretentious stations.

In the next monthly issue, with the opening of 2FC only weeks away, the magazine published a group of suggested circuits for suitable receivers (Fig.1) — the only ones I have ever seen intended specifically for Australian sealed receivers.

Unpretentious crystal sets or amplified crystal sets, the magazine suggested that they should be constructed around a coil/capacitor combination which could be pre-adjusted to limit the coverage to within +/-10% of the allotted wavelength, (I quote) 'allowable under the regulations'.

Presumably, the completed receiver had to be set up in such a way that, to the satisfaction of itinerant radio inspectors, the available tuning range would be no greater than necessary to cope with the combined frequency drift of the receiver and the designated station. This was before the routine use of crystal- locked transmitters.

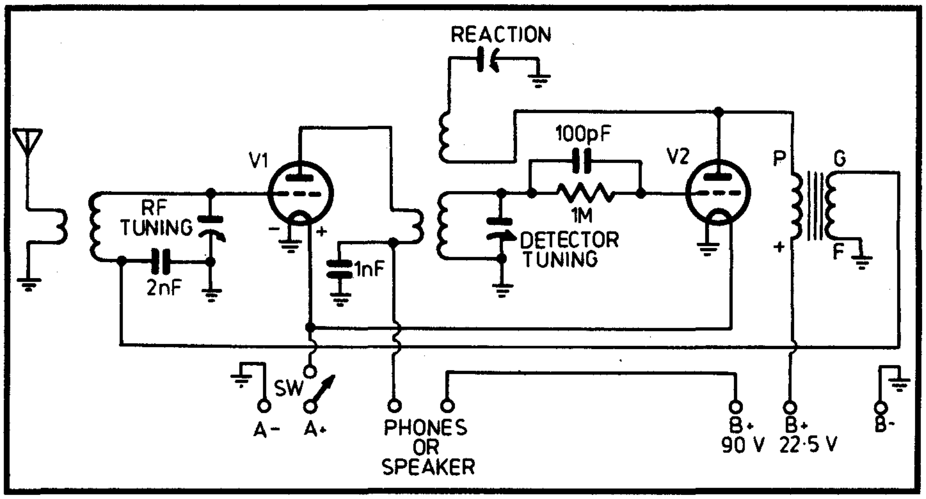


***Fig.2: In this simple reflex circuit, the incoming signal is amplified by V1 before being passed on to the regenerative detector V2. The detected audio passes through the transformer back to the grid of V1, where it is again amplified before being applied to the phones or speaker.***

Rejected *en masse* by prospective listeners and a potential financial disaster, the sealed set concept lasted less than a year. As from July 17, 1924, public broadcasters like 2FC were re-licensed either as A-class stations, financed by a collective licence fee payable to the Government, or as B-class stations supported by advertising revenue.

From that date, having taken out an annual, comprehensive 'wireless licence', listeners were once again free to use general-coverage receivers, listening to whatever signals came their way.

As before, the more eleborate the receiver, the more stations they were likely to hear, hopefully on a loudspeaker.

Speaking personally, I have never encountered an identifiable sealed set and I can only assume that most of those which were sold during the 6-odd month currency of the scheme were smartly updated for general coverage of the medium- and/or long-wave broadcast bands.

## Early broadcast sets

Typical of the early, small general-coverage broadcast receivers was a Colmovox 3-valve 'Junior' model, marketed both as a do- it-yourself kit or built up, by Colville-Moore Wireless Supplies Ltd, of Rowe St, Sydney. It comprised a regenerative detector using panel mounted plug-in coils, followed by two audio stages.

As advertised in *Wireless Weekly* for August 13, 1926, the cost of the basic kit, with a polished maple cabinet, preassembled and engraved bakelite panel, and wiring diagram was £6/5/-. Valves, plug-in coils, batteries. headphones and other 'extras' necessary to make it go added up to another £5/6/10.

In today's currency, just under $24, that doesn't sound like a lot of money. But at the time, it would have represented a typical month's wages, or as much as we'd now pay for a large colour television receiver! Such prices provided a powerful incentive to cut costs by any available means.

## Reflex principle

In an effort to secure a more comprehensive receiver for reduced outlay, some designers resorted to the so-called *reflex principle. It involved using one of the valves for two distinct functions, thereby saving a valve and its attendant current drain.*

For example, in a simple non-reflexed vintage receiver, the incoming signal might be fed via a tuned aerial coil to the grid of a triode RF amplifier stage. From the anode, after amplification, it would pass through a tuned RF coil to a detector and thence through an audio transformer to a single audio stage — a configuration sufficient for reception of distant stations on headphones, or possibly strong locals on a loudspeaker.

In a reflexed version of the above (Fig.2) the 'grid' connection of the audio transformer would typically be wired back to the bottom of the aerial coil, the junction being bypassed to earth with a capacitor of around 2nF — sufficient to allow the tuning circuit to behave normally, but not so large as to prevent the much lower frequency audio signal from reaching the grid.

In short, the audio signal would be fed up through the tuning coil to the RF amplifier grid so that this would be subject to two quite distinct input signals, one superimposed on the other.

As a result, there would be two different signal components in the plate current — one at the original signal frequency feeding the detector, the other at the superimposed audio frequency. By inserting a pair of headphones between the primary of the RF coil and B-plus, the audio component would be heard as before, having been separately amplified as it passed through the reflexed valve.

Ostensibly, the receiver would equivalent to the original three-valve design (RF amplifier — detector — AF amplifier) but using only two valves — one doing two jobs. In all fairness, however, this last statement needs to be qualified.

The actual saving in a typical reflexed receiver was limited mainly to a valve and socket and the attendant current drain; the other peripheral components and wiring were still required. Besides that, reflexed receivers generally have tended to be somewhat temperamental for the following reasons:

- Having to handle two signals at once, reflexed stages could be more subject to overload on strong signals, leading to increased distortion in some situations.
- By reason of inherent non-linearity, an RF amplifier stage may partially rectify an incoming RF signal and generate a residual detected resultant across the audio load in its anode circuit. This may interact unfavourably with the formally detected signal which it is supposed also to be amplifying.
- The deliberate re-routing of signal back through a receiver circuit could aggravate stability problems arising from other sources — e.g., inherent RF stage instability, detector regeneration and HT supply feedback.

While the above-mentioned considerations have limited the appeal of the reflex principle, the fact is that reflex receivers have featured from time to time in do-it-yourself articles and in the inventory of receiver manufacturers. Collectors of vintage receivers can at least be forewarned if they come across one in which a single valve appears to be doing two jobs.

(The 'Vintage Radio' feature in the December, 1990 issue of *EA* deals with a mid-'30s model AWA Radiolette using an IF amplifier reflexed to function also as an audio stage. Because of detection effects in the stage, as noted above, the audio volume control could not completely silence the receiver — a well known flaw in this particular configuration).

## Typical family set

Price and running costs notwithstanding, the Colmovox 4-valve receiver mentioned in the March, 1989 instalment of this series, was more typical of the average family receiver of the mid '20s. (See Fig.3). While physically similar to the 'Junior' model mentioned earlier, it included a separate tuned RF stage ahead of the detector, to ensure improved range and selectivity, and to minimise the risk of detector radiation.

Tuning involved separate dials for the RF and detector stages but, by careful selection and/or trimming of the plug-in coils, the dials could be made to 'track' reasonably well, each needing to be set to about the same reading for particular stations. With two audio stages, the set could be used with a loudspeaker or, for personal listening, with headphones and with the audio section partially disabled to conserve battery life.

A comparable 4-valve set advertised in *Wireless Weekly* for August 13, 1926 was the 'Selectrodyne', from the Radio-W'less Mfg. Co, of 317 George St, Sydney (Fig.4). Depending on the cabinet and extras, it cost between £26/10/0 and £36/10/0. Arguably, perhaps, it was advertised at the time as 'the only 4- valve set that will bring in 3LO (Melbourne, 800kHz) without interference from 2BL (Sydney, 855kHz)' — already much less than the 10% separation envisaged in the sealed set era.

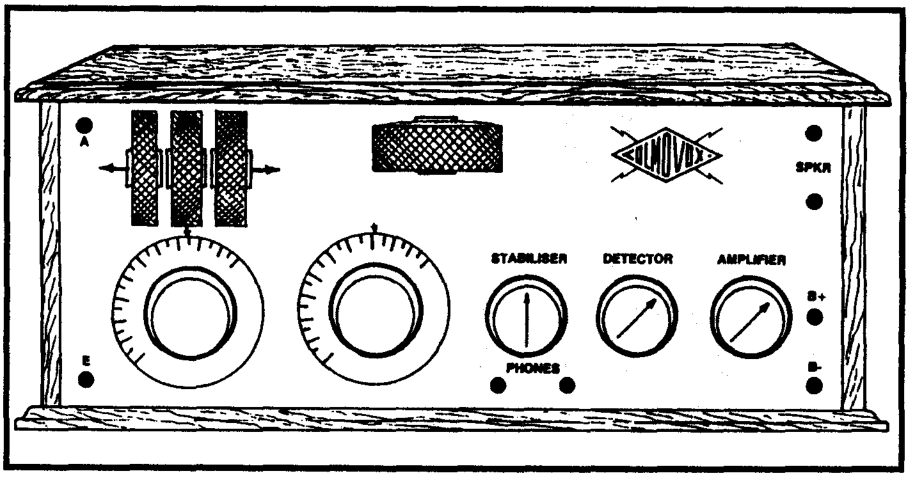
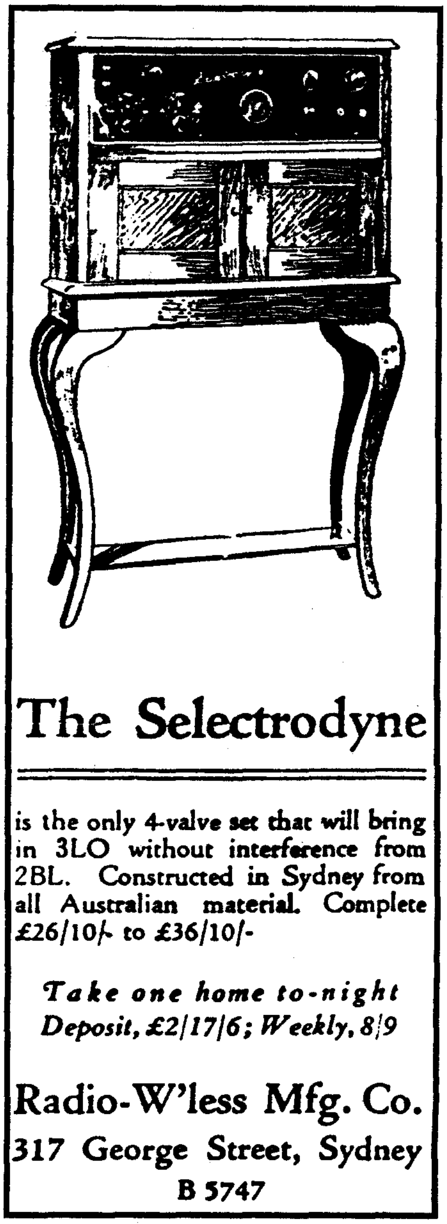


**Fig.3: The panel layout of a typical 4-valve battery wireless set from the mid '20s. It represented a manageable compromise for many listeners between inter-station performance and purchase/running costs.**



# The Selectrodyne

is the only 4-valve set that will bring in 3LO without interference from 2BL. Constructed in Sydney from all Australian material. Complete £26/10/- to £36/10/-

*Take one home to-night*
*Deposit, £2/17/6; Weekly, 8/9*

Radio-W'less Mfg. Co.
317 George Street, Sydney
B 5747

**Fig.4: The Australian-made 4-valve 'Selectrodyne' advertised in 1925 for up to £36/10/0. The cupboard section would normally accommodate the batteries, with the loudspeaker standing on top.**

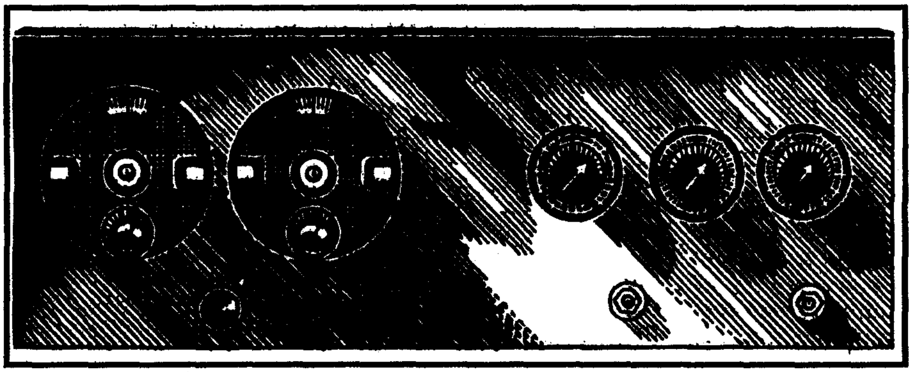


*Fig.5: The front panel of an 8-vale battery superhet, described for home construction in Wireless Weekly for July 29, 1927. The dial on the left is for oscillator tuning; the one to its right tunes the loop, which connects to three terminals at the rear of the receiver.*

The circuit diagram of yet another 4-valve receiver in this general class appears on page 94 of *The Best of Australia's Wireless Weekly* mentioned earlier. Known as the 'Marco 4', it, along with others like the 'Browning Drake' often featured, in the old days, in arguments between between enthusiasts who favoured this receiver or that!

While some such receivers may have been marginally easier to set up and use than others, the chances are that, when optimally adjusted, there would have been very little difference between the performance of contemporary 4-valve 'TRF' receivers — so described because they used a tuned RF stage ahead of the detector.

With hindsight, looking back at some of the circuits, there is good reason to speculate whether the regeneration — or 'reaction' — actually operated around the detector, or the RF amplifier, or both. By offsetting the losses in the associated tuned circuit(s), the end result may have been much the same: boosting the gain and sharpening the selectivity, to a limit set by the onset of active oscillation.

Even without visible feedback circuitry, triode RF amplifier stages, with grid and anode circuits tuned to the same frequency, were prone to oscillation by reason of the valve's own anode/grid capacitance.

Oscillation could be suppressed by using a lower gain valve or reducing the filament voltage with a rheostat; alternatively, the associated coils could be rendered 'lossy' by design or resistive loading — measures which prejudiced gain and possibly selectivity. The answer in many cases, including Fig.3, was to fit a so-called 'Stabiliser' control (see separate panel).

More elaborate TRF designs will be discussed in the next article. In the meantime, AWA (Amalgamated Wireless A'Asia) threw out a major challenge to local manufacturers with a completely different kind of receiver.

## The superheterodyne

Conscious of the growing listener demand for improved gain and selectivity, and taking their cue from RCA (Radio Corporation of America), AWA released a range of Australian-made 'Radiola' superheterodyne receivers (see *EA* for July 1990, pages 45- 47). As most readers will now know, 'superhets' operated on a quite different principle to conventional receivers using RF amplifiers and detectors tuned to the signal frequency.

Briefly, incoming signals were/are 'heterodyned' by an inbuilt tunable oscillator, effectively shifting them down to a much lower, so-called *intermediate* frequency. In the mid 1920's this was typically in the range 50-60kHz. At this reduced frequency, they were passed through a pre-tuned IF (intermediate frequency) amplifier, which could provide much higher gain and better selectivity than was then practicable at the original signal frequency.

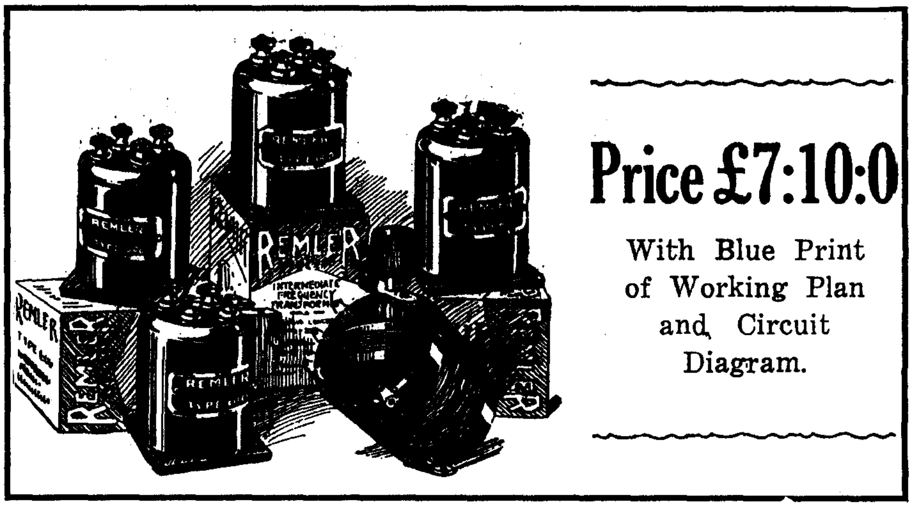
The process did not prejudice the original modulation so that, when subsequently fed to a detector, the audio content was recovered in the usual way, hopefully free of interference from other stations. For the user, however, those early superhets had certain 'off-putting' peculiarities which set them apart from other receivers of the day. (See Fig.5)

First off, the local oscillator, being tuned within 50-60kHz of the incoming signal, could all too easily radiate a spurious signal within the broadcast band, creating interference in nearby receivers. To minimise the problem, superhets were not normally connected to large outdoor aerials, being used instead with frame aerials sitting atop the receiver and tuned by the receiver's own aerial tuning dial — controlling what came to be known as the 'loop condenser'.

In practice, the signal pickup by a large resonant frame aerial, similar in frontal dimensions to the receiver itself, compared favourably with that of a routine outdoor aerial/earth combination. It offered the further advantage of being directional, such that it could be orientated edge-on to favour a wanted station, and/or broadside-on to reject an interfering signal or even a distant source of static.

## Double-spot tuning

A further peculiarity of early superhets was that a wanted station could be received with the local oscillator tuned



Price £7:10:0

With Blue Print
of Working Plan
and Circuit
Diagram.

*Fig.6: A coil and IF transformer kit advertised for the 8-valve superhet receiver, as illustrated. The IF transformers are wired into circuit much the same as audio transformers. No mention is made of their resonant frequency.*

*below* the station frequency. Always a potential source of confusion, this was commonly referred to as 'double-spot' tuning.

As a corollary of the above, any one setting of the oscillator dial could conceivably bring in two entirely different stations, one above and the other below the oscillator frequency and separated from it by the IF. This came to be known as 'image reception'.

In *Wireless Weekly* for July 29, 1927 (p.36 in the reprint *The Best of Australia's Wireless Weekly — 1927*) readers setting up a home-built 8-valve superhet were encouraged to experiment with the controls, writing down the best setting for the loop dial for each station and the two possible settings for the oscillator dial. This done, they could double-check their figures and list the best combination for each individual station.

Interestingly enough, in this and similar articles of the period, I found no mention of the actual IF used, nor any reference to pre- or post-IF alignment.

Home hobbyists were simply warned to use only matched sets of IF transformers, connecting them into circuit as per the markings (see Fig.6).

While none of the above peculiarities was likely to deter a technically informed listener, they did set the superheterodyne apart as 'peculiar' and perhaps not the wisest choice for the average family, reliant for technical guidance on the average local supplier.

If, as a collector, you come across one of these early superhets, don't be surprised by the lack of any information about the intermediate frequency.

As noted earlier, it will probably lie in the region 50-60kHz and therefore well below the range of any ordinary modulated test oscillator or signal generator.

In such a case, the intermediate frequency could most easily be deduced by pre-setting the receiver oscillator in about mid-range and tuning the signal generator across the broadcast band to identify the two frequencies at which the test signal is heard. The intermediate frequency will be half the difference between them.

For example, with the receiver oscillator at about mid range, signals may be heard from the signal generator when its dial reads either 960 or 1080kHz.

The difference between the two is 120kHz, indicating an IF amplifier pretuned to 60kHz. It follows that the receiver oscillator must have been set to 1020kHz — 60kHz above 960kHz and 60kHz below 1080kHz.

Ironically, most modern Wien-bridge audio signal generators cover the frequency range up to at least 100kHz, but the signal would not be modulated. It would have to be observed with a CRO, or as a DC voltage across the detector grid resistor using an electronic voltmeter.

In the second of these articles we shall be looking more closely at the superhet configuration in the context of the '30s, when it re-emerged to dominate receiver design for domestic and most other applications — this, for what we described earlier as 'sober, practical reasons'. ■

*(To be continued)*

# When I Think Back...

by Neville Williams

## Vintage Radio Receiver Design — 2: Batteries give way to mains operation

If the twenties saw the birth of radio broadcasting, no less importantly the end of the decade marked a quantum leap in receiver technology. From being the province of technicians, wireless sets became a piece of family furniture and, for urban listeners at least, the tedium and expense of batteries became a thing of the past.

As indicated in the last chapter, battery powered superheterodyne receivers made a noteworthy appearance on the market around 1925, setting new performance standards in terms of gain and selectivity — and to a degree, signal-to-noise ratio.

Their radically different circuit configuration and behaviour, however, prompted some buyer resistance in the marketplace, creating a demand for high performance receivers of less radical design.

For would-be purchasers, put off by the 'peculiarities' of 1926-vintage superheterodyne receivers, the obvious high-performance alternative was a conventional configuration, with at least two tuned radio frequency stages ahead of the detector and audio system — commonly described as a 'TRF' circuit.

Already a familiar term, 'TRF' acquired a somewhat broader connotation than in the days of the old regenerative 4-valvers (see previous chapter). In effect, it signified the alternative design approach to the superheterdyne principle. New receivers were either TRFs or superhets — a distinction that, as we shall see, carried over into the early 1930's.

In traditional form, with polished maple box and black bakelite panel, a typical TRF receiver with two RF stages called for three sets of coils, three separate variable capacitors and three separate tuning dials — one of each for the respective RF stages and the detector. To simplify tuning, the capacitors and coils would hopefully have been double-checked during manufacture, so that all three dials would end up at about the same reading for each individual station.

Some manufacturers went one better, by matching the tuned circuits well enough to allow the capacitors to be physically 'ganged' together and operated from a single tuning dial — a feature that became progressively more popular during the late 1920's (see Fig.1).

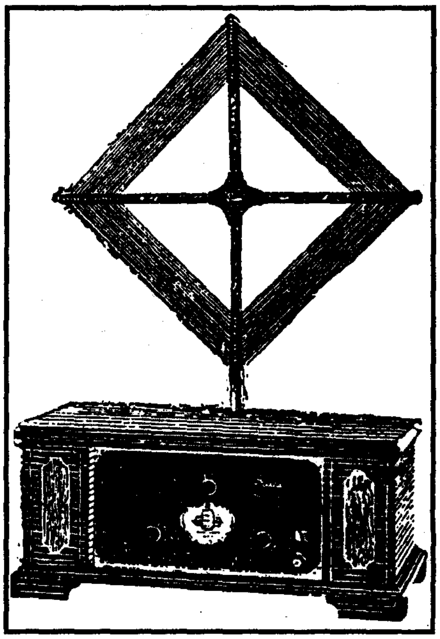


***Fig.1: Announced in 'Wireless Weekly' for September 27, 1927, this 8-valve 'Priess De Luxe' receiver from Manufacturers Products boasted a frame aerial, single dial tuning and five RF stages, some untuned. The two-tone etched 'malloy' panel is said to give a 'refined appearance' and to combat possible hand capacitance effects.***

### Single dial tuning

In some cases the capacitors were lined up behind the dial, sharing a common shaft. In others, they were mechanically coupled by radial links, or by flexible concentric couplers (Fig.2). Yet another approach was to use a 'drum' dial mechanism, with two capacitors on either side, arranged with their axes parallel with the panel. With four capacitors, so driven, it was possible to accommodate three tuned RF amplifiers ahead of the detector.

In due course, component manufacturers progressed to the production of single-unit 2-gang, 3-gang and 4-gang tuning capacitors — even if these were not particularly rigid assemblies in the early stages.

But that was not the limit, with some receivers boasting five RF stages, some untuned (see Fig.1). Viewed from this remote point in time, one might be pardoned for wondering whether the untuned stages were always justified, or whether an important consideration was simply to add to the valve count to compete with 8-valve superheterodynes such as AWA's console model 'Super-8'.

As also indicated by Fig.1, some large TRF receivers were equipped with a panel-tuned frame aerial, offering the same directional properties as when used with a superhet.

As with simpler receivers having only a single RF stage, 'front-end' instability posed a considerable problem for the more ambitious TRFs. While due basically to the grid/plate capacitance within the triode RF amplifier valves, it was aggravated by the stray coupling be-

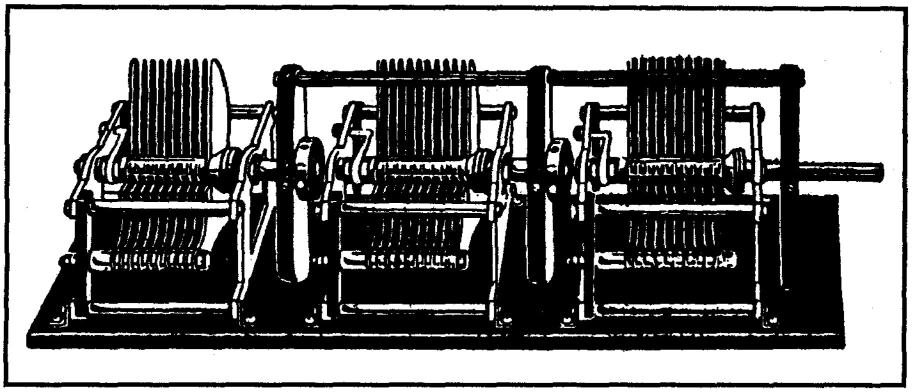


*Fig.2: Typical ganged tuning condensers, as advertised by Murdochs, the onetime specialist mens store opposite the Sydney Town Hall. Prices for such assemblies varied with brand from about £3 to £6 — a week's wages, or more!*

tween the multiple RF stages and particularly between the large, normally unshielded coils.

Attempts to combat the problem by using lower gain valves or deliberately reducing the 'Q' or goodness of the tuned circuits tended to limit the peak performance of the receiver. Alternatively, relying on filament rheostats to control the gain could prove confusing. In most cases, fitting a 'stabiliser' potentiometer, as explained in the last article, provided a more manageable method of control to meet particular situations.

## The neutrodyne

Pending a fundamental cure for instability in the way of screen-grid valves (See *EA* June 1990, page 43), many designers resorted to the use of *neutralisation* — a technique that had been worked out in the early 1920's, but adopted only sparingly. (As reported in *The Australasian Wireless Review* dated August 1923, the 'Neutrodyne' principle was introduced 'recently' by Professor L.A. Hazeltine M.E., of the Stevens Institute of Technology, New York, to the Radio Club of America.)

In practice, the neutralising circuit took many forms, the most common being to tap and extend the winding supplying the anode of an RF amplifier such that the signal voltage at the lower end would be in opposite phase and, ideally, of equal amplitude to that at the anode. By connecting a small, adjustable capacitor between the lower end of the extended coil and the grid (Fig.3), it became possible to cancel the effect of the direct anode/grid capacitance.

Variations of the scheme included tapping and extending the grid winding instead, and returning the free end to anode via a neutralising capacitor.

Yet another approach involved phasing the interstage coupling transformers in such a way that the necessary neutralising voltage could be picked up from a convenient point in an adjacent stage.

Whatever the configuration, the purpose of a neutralising circuit was to introduce capacitive *negative* feedback around each RF stage, sufficient to exactly balance out the *positive* feedback resulting from the inherent anode-grid capacitance.

(At a time when positive and negative feedback, as such, were not part of the jargon, the failure of early experimenters to comprehend the idea is perhaps understandable!)

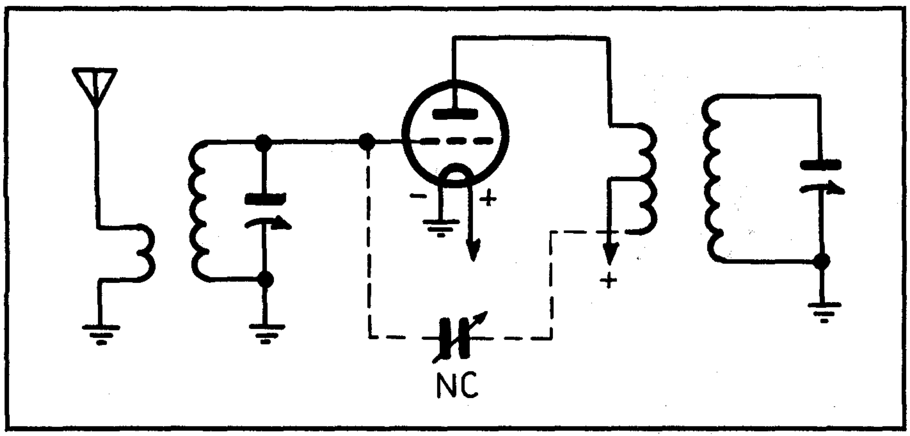


*Fig.3: Perhaps the most common form of neutralising circuit, calling for an extended and centre-tapped anode feed coil.*

That aside, as applied to a generation of otherwise normal TRF receivers, Hazeltine's term 'neutrodyne' provided a measure of technical mystique which enabled them to compete to better advantage in the marketplace with 'superheterodynes'.

Over the years, the principle was applied to elaborate (e.g., 8-valve) receivers right down to simple — even reflex — designs with a single RF stage. In some cases, 'neutrodyne' was used purely as a descriptive term to indicate use of the technique; in others, it was featured on the front panel in the manner of a brandname. Neutrodynes, like superheterodynes, came in all shapes and sizes — some good, some very ordinary.

## Adjustment procedure

Whether the average neutrodyne receiver operated to best advantage throughout its lifetime is another matter. Setting them up called for a critical adjustment procedure, which could all too easily be negated by well-intentioned but ill-informed experimenters.

Setting up typically involved tuning the receiver to a strong signal near the centre of the dial scale. Then, one by one, the RF amplifier stages would be disabled by disconnecting one filament supply lead or interrupting the connection within the socket with a scrap of cambric tubing. The valve itself would be left in position.

In the normal way, the signal would still be faintly audible, being fed through the disabled stage by the grid-plate capacitance of the inert valve and/or the neutralising circuit. The signal would normally increase as the neutralising capacitor was adjusted to either its maximum or minimum value, diminishing at some median setting.

The aim was to select the setting corresponding to minimum signal level, indicating that the grid-plate and neutralising capacitance were substantially cancelling each other in terms of signal transfer.

The routine would normally be followed for each separate RF stage. Other procedures may well have been specified for other circuit configurations, but it needs little effort to imagine how far astray the adjustments could have ended up at the hands of an owner/experimenter, curious to discover the effect of simply twiddling 'those curious little screw things'! (Fig.4)

Or, yet again, the effect of swapping valves around, or of substituting other types — without any thought to the fact that their grid-plate capacitance could be quite different from that of the valve for which the particular stage had been optimised.

Vintage receiver enthusiasts who may have occasion to restore a receiver using one or more neutralised RF stages should be aware of these considerations.

## Why not mains power?

With its relatively uncomplicated controls, a receiver as illustrated in Fig.1 posed a standing invitation for any member of the family to switch on and listen through any program that happened to be on air. The one obvious deterrent was the knowledge that to do so would flatten the batteries that much sooner.

If only such receivers could be run from the AC power mains, like other domestic appliances. Unfortunately, it was easier said than done!

Of necessity, virtually all receivers produced up to about 1927 were designed around existing battery type valves which required the provision of pure DC voltages as under for the filament, the anode (or plate) and the grid:

- The 'A' or filament supply — 2, 3, 4, or 6 volts at up to 1.0 amp, or thereabouts.
- The 'B' or anode supply — nominally 22.5, 45, 67.5, 90 or 135 volts at up to about 20 milliamps.
- The 'C' or grid bias supply — typically in 1.5 volt steps up to minus 9 volts, with negligible actual current drain.

To obtain supply voltages of that order from the AC (alternating current) power mains required the use of a suitable step-down transformer, a rectifier to produce a unidirectional current, and a filter to smooth out the inherent ripple and ensure pure, hum-free DC (direct current).

Because of the relatively low anode current required by battery type valves, there was no particular problem in providing a suitable 'B' or high tension supply, such as the one pictured in Fig.5.

Of comparable dimensions to a couple of medium size B-batteries, a so called 'B-battery eliminator' could deliver a maximum supply voltage of around 130-150 volts, plus a selection of lower voltages corresponding nominally to those available from the intermediate tappings on ordinary B-batteries.

Perhaps it should be mentioned in passing that, while these intermediate voltages served the purpose, old-time experimenters were often puzzled because they appeared to be much lower than anticipated when measured on a voltmeter. The confusion was due to the fact that the low-resistance voltmeters of the day placed a heavy current load on the source being measured, reducing it to well below what it would have been when supplying the very modest drain of, say, a regenerative detector.

For safety's sake, commercial B-battery eliminators were designed to isolate the DC output circuitry completely from the mains potentials — although the isolation may not always have met the very strict specifications that currently apply to present-day mains-sourced supplies like battery chargers and plug-packs.

Curiously, an article on page 52 of *EA*'s 1927 *Wireless Weekly* reprint describes a home-made B-battery eliminator with no mains isolation transformer at all. While included, I understand, for its historical interest, readers should be warned NOT to attempt duplicating it, even for historical reasons. It could be positively dangerous to have lying around, because of the direct connection between B-minus and one side of the mains!

Some B-battery eliminators also provided a range of negative bias voltages, to obviate the need for a C-battery.

While this was technically easy enough to arrange, it was equally no big deal; C batteries were relatively inexpensive and, with virtually zero current drain, could be expected to last for their shelf life.

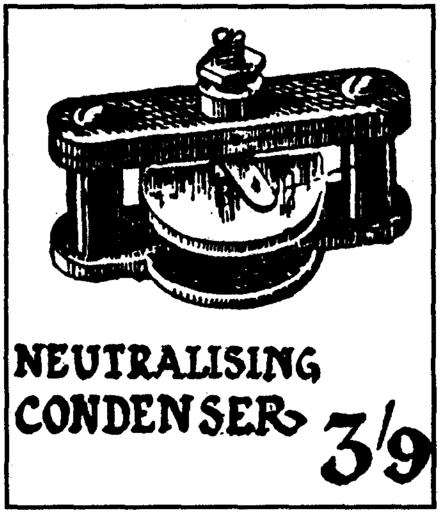


***Fig.4: Pictured here about actual size, neutralising condensers (capacitors) offered an open invitation for experimenters to 'fiddle', often to no good purpose.***

## Filament supply

The real problem for all-mains operation was to supply the valve filaments. While it would have been no problem at all to step the mains voltage down to 2, 3, 4 or 6 volts, the filaments could not be supplied with raw AC for two main reasons:

Firstly, with the respective ends of the filament swinging plus and minus by the peak value of the AC waveform, the end effect would be rather like having a substantial 50Hz AC signal superimposed on the wanted program signal, causing a prominent 50Hz hum. This problem can be alleviated, but not eliminated, by earthing the filament circuit at an exact centre-tap rather than either end.

The second problem was that, by design, the filaments in battery valves were relatively small in diameter, to minimise the amount of current required to heat them to incandescence.

When fed with AC, the filament temperature tended to vary over each successive half-cycle and, with it, the electron emission. Therefore, quite apart from the spurious signal problem, as above, the emission — and basic efficiency — of the filament would be modulated at the half-cycle rate: 100Hz.

These days, with solid-state rectifiers and other technology, and with very high value electrolytic capacitors readily available, an adequately rectified and filtered A-supply would doubtless be practical — but back in the 1920's, rectifiers were clumsy and inefficient and capacitors larger than 4uF were hard to come by. The most practical answer was to rely on a conventional lead/acid battery or 'accumulator' to supply the filaments — kept 'topped up' by a small or 'trickle' charger connected permanently in circuit.

While this arrangement could be provided by the set owner using separate components, the battery service department of the Clyde Engineering Company, Sydney, made it a little less cumbersome with the self-contained unit illustrated in Fig.6.

Containing an isolating transformer, an electrolytic rectifier and either a 4-or 6-volt accumulator, it was self-regulating and could be left connected permanently to the power mains and the receiver. The only maintenance required was the occasional addition of distilled water to the cells and rectifier.

Because of the buffering effect of the storage battery, the DC output voltage varied little from the expected value and, according to the advertisement, mains hum was 'at all times negligible'.

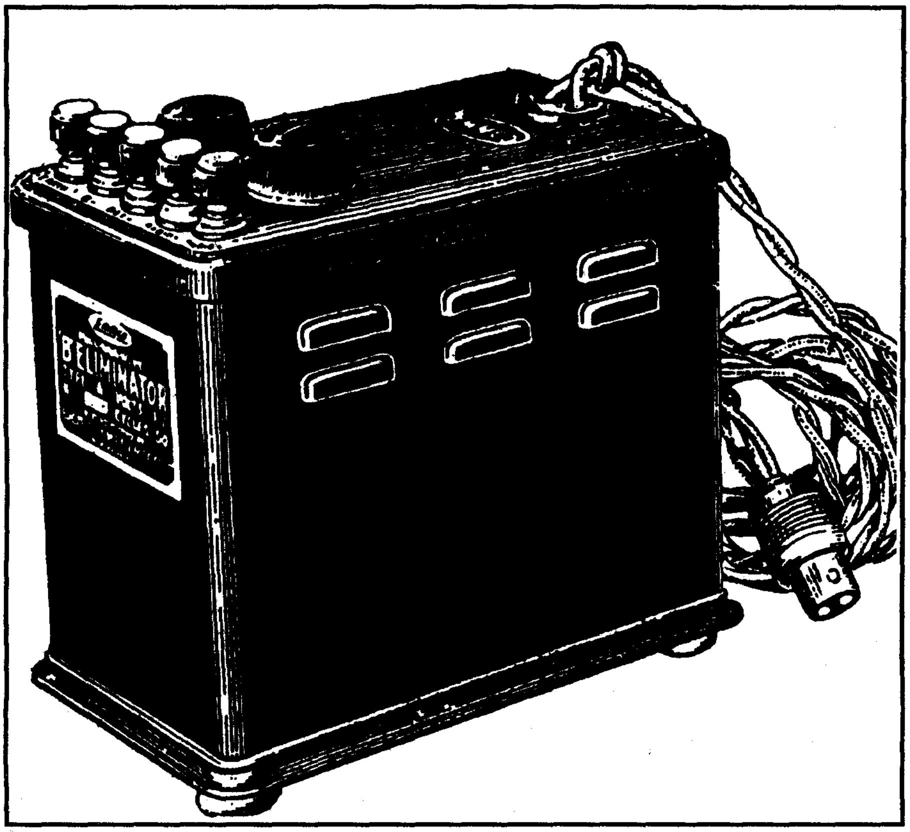


***Fig.5: An Emmco B-battery eliminator, which was advertised for 10 guineas ($21) in 1927 — about three times the price of a set of B-batteries. The terminals and knobs on top provided a selection of semi-adjustable high tension voltages.***

In an effort to find another solution to the filament supply problem, some designers adopted the idea of selecting valves with a similar, low filament current rating and wiring the filaments in series, thereby calling for a much higher voltage but lower current.

A valve which lent itself to this technique was the American type V99 or X99, with a filament rating of 3.0-3.3V at 60-63mA. While easing the filtering problem, however, the string of frail filaments proved rather vulnerable and the technique found only limited application.

## Mains type valves

The salient point that emerged from all this was that battery valves and associated design parameters were not really compatible with mains operation, either technically or in terms of listener expectation in respect to sound output power.

There was an obvious need for valves which could operate with AC on the filament and at more generous anode voltage and current levels — beyond the economic limits of battery supply.

In fact, a solution to the AC filament problem had been identified back in 1921, by Messrs Freeman and Wade of Westinghouse. For the traditional filament, they substituted a narrow tube with an emissive surface, to serve as an electron source or *cathode*. Inside the tube, but insulated from it, they placed a heating element or *heater* which could be fed from a separate supply, most obviously low voltage AC from a step-down transformer winding (Fig.7).

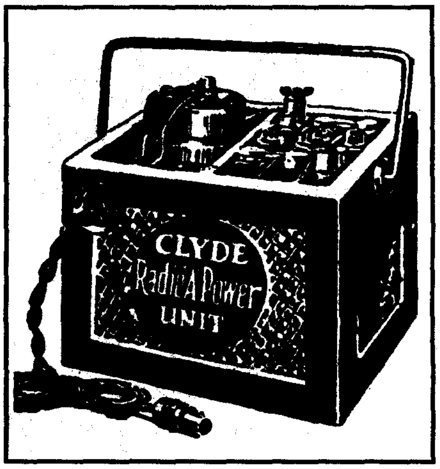


***Fig.6: This Australian 'Radio A-power Unit', advertised by Clyde Batteries in 1927 contained an isolating transformer, an electrolytic ('slop') rectifier and either a 4 or 6 volt battery. It was self-contained and self-regulating.***

Being independent of the electron stream within the valve, the AC could not interact directly with the signal, while the thermal inertia of the heater/cathode assembly would be such as to obviate hum due to temperature variation at the half-cycle rate.

While it subsequently proved to be the logical answer to the problem, the idea was not exploited to any extent until around 1927. One can only assume that the difficulties of devising, patenting, producing and marketing the early generations of battery-based receivers were sufficient, in themselves, to inhibit any radical departure in valve and receiver design!

Even in 1926/7, when RCA released their first manifestly non-battery valve, they still passed over the indirectly heated option. Designated as type 226 (or 26) their first mains type valve was a clear derivative of their 'old faithful' 201-A.

Virtually identical in appearance and with very similar electrical characteristics, its one vital digression was a conventional directly heated filament rated at 1.5V and 1.05A.

The purpose of the stout, heavy-current filament was to provide sufficient thermal inertia to minimise the half-cycle temperature ripple. At the same time, assuming a centre-tap or 'balanced' earth return, the reduced filament voltage would hopefully reduce the level of AC hum injected into the grid bias/signal path.

## So to mains power

The 226 undoubtedly maintained a degree of continuity between the design philosophy of battery powered receivers of the late '20s and their immediate mains powered derivatives — but with one important qualification. By careful null-balancing of the heater earthing, the 226 could indeed be used in all established roles — except that of detector, where the hum level proved totally unacceptable.

It was a limitation that forced manufacturers, at long last, to come up with mass produced valves having an indirectly heated cathode, the best known of which was the 227 (or 27). With a 5-pin base, it was still electrically similar to the ancient 01A — but it was essentially hum-free.

The 27, and valves like it, broke the intellectual log-jam preventing the development of true all-mains receivers. Designers soon expressed a preference for indirectly heated valves for all roles, giving rise to a demand for companion types with more generous performance

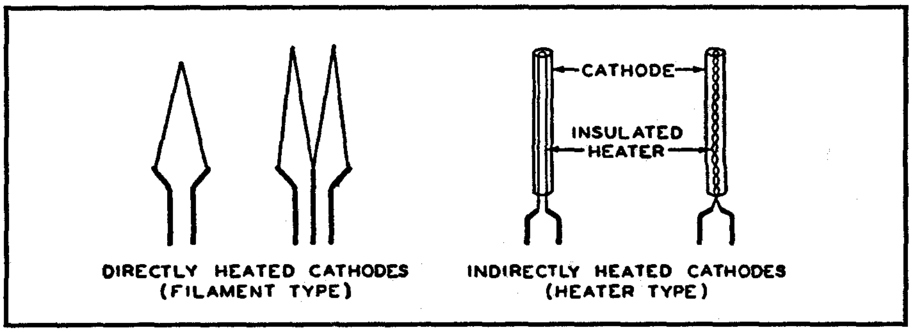


***Fig.7: The indirectly heated cathode (right) was a virtual pre-requisite for AC mains powered receivers. First suggested in 1921, the idea was not adopted for mass-produced valves for another six odd years.***

parameters than could be contemplated with a battery supply.

For their part, valve manufacturers, once they had come to grips with heater/cathode technology, foresaw the emergence of a whole new market area — requiring not just mains powered general-purpose triodes, but power output valves and sundry other types optimised for particular roles in a new generation of receivers.

In fact, the period from about 1928 onwards was marked by a procession of new valve types, as outlined in this 'Think Back' series for May and June 1990 under the sub-heading 'The rise and fall of thermionic valves or tubes'.

There were power output valves like the 45 and 47, rated to deliver 2 watts or thereabouts to the loudspeaker — ten times as much as available from even a loud battery set. There were rectifier valves like the 80, meant to be built right into a mains receiver and supply the necessary high tension voltage and current.

There were screened-grid, tetrode and pentode valves like the 24, 35, 57 and 58 designed for use as RF or superhet IF amplifiers, or for very high gain audio stages.

Thermionic diodes became commonplace, for use as detectors, and so too did complicated valves intended for use as frequency changers in superheterodyne receivers.

In many cases, new valves were introduced to meet urgent demands from the ever-expanding receiver market. In others, they were the result of on-going research in valve laboratories which resulted in new receiver design concepts. Ironically, progress in mains type valve and receiver design generated a demand for parallel technology in battery powered domestic and portable sets and automotive receivers. As a reminder of valves in those categories, readers may care to turn back to the articles mentioned above.

## Assembly and wiring

This same period saw a complete revolution in the methodology of assembling and wiring domestic radio receivers.

Up to and beyond the mid 1920's, most receivers were constructed on a baseboard and panel, which slid into a table-top cabinet with lift-up lid. The major components were designed to mount on the baseboard or panel, with the incoming lead-ends being bent into an eyelet shape and clamped under flat-headed screw terminals or knurled nuts with a concave undersurface. It was very much the 'handyman' approach.

The done thing was to effect the interconnections with bare tinned copper busbar, of *square* cross section and about 1/16" (1.6mm) thick.

This was laid painstakingly in place and bent at strict right-angles, as appropriate, so that every run would be either exactly parallel to the panel and baseboard or at right-angles to them. The resulting 'geometric' style of wiring is well illustrated in Fig.8. Fairly ob-

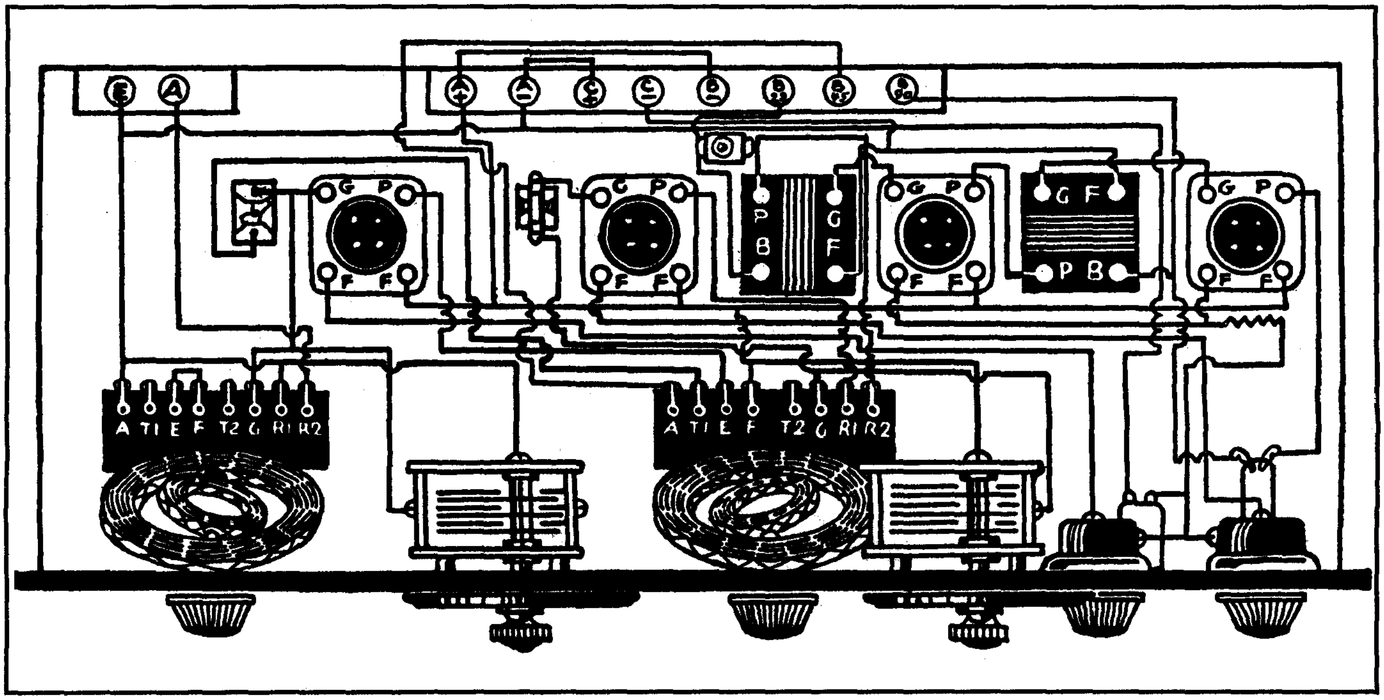


***Fig.8: Originally from 'Wireless Weekly' for August 19, 1927, this shows the suggested wiring pattern for the 'Everyman's Four' receiver. To a handyman, ability to wire a receiver in the approved manner was as much an art form as his wife's embroidery!***

viously, in the two-dimensional drawing, loops have to be used to indicate that various wires cross without touching. In the actual receiver, the busbars would be elevated one above the other, to provide the necessary clearance.

For proud owners of new receivers, the routine was to switch on and demonstrate to visitors how they worked, then explain the purpose of the various knobs, finally lifting the lid to display the working parts — the valves and, of course, the orderly wiring.

I remember my father, responding to an article in a magazine, preparing to make changes in the family Colmovox. He could have used any wire to hand, but that wasn't good enough. He had to equip himself with several lengths of square-section busbar and a pair of long, round-nosed pliers to form eyelets at the end of each run. The job done, it was difficult to tell that the original wiring had ever been tampered with.

In fact, as I recall mentioning elsewhere, he was so proud of his handiwork that he set about making a glass front-panel for the receiver so that visitors, listening to the sound, could also contemplate the internal works!

## A different approach

In due course, however, the industry began to realise that fancy terminals and fussy wiring methods were tedious and costly, without adding anything to the actual performance of the receiver. If you have a copy of the *Wireless Weekly 1927* reprint, take a look at the layout diagrams on pages 35 and 36 for an 8-valve superheterodyne, and imagine the man-hours that would be involved in translating them into a multi-layered pattern of bare busbar.

So it was that geometrically arranged busbar gave place to insulated 'point-to-point' wiring, with tags and soldered joints taking over from terminals and eyelets.

The move to mains operation also had an important bearing on the transition. It was certainly not prudent to have exposed bare wiring or terminations carrying mains potentials, or even the 250-odd volts DC that was commonly applied to the anodes of mains type valves.

The end result was the almost universal adoption of inverted metal dish 'chassies', with the major components mounted on top and the point-to-point insulated wiring and small components underneath, well away from prying fingers.

Apart from safety, the format lent itself to familiar metal working techniques and to assembly line production. If the chassis needed to be made attractive to the prospective purchaser, the external components could be variously embellished with lacquer, enamel, electroplating and labels, all of which were variously exploited in typical Australian receivers.

That was about the way things were when I ceased to be an onlooker and took my first job in a radio factory. I must confess that, against a traditional battery set background, it came as something of a culture shock to learn that the attributes of a capable production wirer were accuracy, speed and the ability to make good soldered joints. Neatness didn't seem to count for much, apart from keeping leads reasonably short and reasonably firm.

After encountering a few early examples of 'new-age' mass-produced chassies, it became evident that, in the matter of neatness, some production supervisers and bench wirers had taken liberty for licence. On top, the chassis and other metalwork may have been 'prettied up' with gold coloured lacquer — but underneath, to compare the wiring with a proverbial 'rat's nest' would have been unfair to rodents!

## How NOT to do it!

Leads ran hither and yon in all directions, trimmed to 'near enough' length, looped around to reach their destination and spot soldered to the appropriate lug. Overlaying the wiring was an assortment of resistors and capacitors, bridging from here to there and supported for the most part by their own roughly trimmed leads.

If that wasn't bad enough, much of the wiring had been done with stranded tinned copper wire, covered in a rubber which had gone 'gooey', interacting with the wire and solder to coat it with a chemical salt of some kind. For a technician, replacing leads or parts in that kind of environment was nothing short of a horror.

When I started at Reliance Radio, it was in a completely virgin situation: my first job, on the first day of a new factory, assembling and wiring the first batch of a completely new line of receivers.

Another novice wirer and I were given the circuit, the wherewithal and a laboratory prototype to follow, and it was more or less up to us to work out the details of how best to arrange the leads and minor components.

Fortunately, my new mate was also methodically inclined and, under the supervision of the designer, we worked out a common wiring routine: short, direct leads for the high frequency connections and methodically grouped runs for the supply leads, anchored to the chassis by clips or other means. A bare tinned copper busbar linked all the earth lugs under isolated mounting nuts, and provided a convenient anchorage for the various earth bypass capacitors.

Once devised, the wiring style was adopted for all models and, in later years, Reliance took to displaying their chassies in radio shows over a 45° mirror, with under-lighting to emphasise the orderly wiring.

In fact, there was more to all this than mere cosmetics. Manufacturers soon realised that underside wiring had to be kept clean and accessable for ease of service, and suitably anchored if it was to survive long delivery journeys by Australian road and rail transportation.

It was a lesson that had to be even more scrupulously applied later in the monochrome television era, with its greatly increased valve and parts count and more complex wiring.

In the next chapter, we will be looking at the evolution of typical mains type TRF and superheterodyne circuits.

*(To be continued)*

# When I Think Back...

by Neville Williams

## Vintage radio receiver design — 3
## Mains supplies usher in a new order

The late 1920's and early 1930's saw the establishment of a vigorous Australian radio industry and the emergence of a large factory-trained workforce, giving rise to a whole new generation of dedicated hobbyists. On the technical front, an initial wave of locally produced mains powered TRF receivers were superseded, in short order, by simplified but efficient superheterodynes.

In the early 1920's, many home handymen had become involved in 'wireless', primarily because it offered access to information, news and entertainment at a time when all three were in short supply — particularly in the country.

With no relevant background and limited back-up in the way of technical literature, such newcomers to the new and unfamiliar technology largely had to learn by trial and error. Fortunately, it was a relatively safe hobby in terms of life and limb.

Operating purely from batteries, receivers of the day posed no threat to unskilled experimenters. The real risk was to the equipment, with beginners all too prone to confuse the battery connections, invoking the ultimate disaster for an impecunious experimenter — 'blown' valves!

However, when the focus later shifted from battery to mains-powered receivers, the supply voltages lurking in the wiring jumped from 135 at most to more then double that figure, plus a decidedly lethal 240V AC direct from the power mains. Rather than the components being at risk, the greater concern was that a chance high-voltage encounter might 'blow' the unwary experimenter!

But while many enthusiasts have experienced salutary 'bites' from mains powered equipment, I'm not aware of any local reader/hobbyist who has paid the ultimate price for their interest in radio.

It may well be that the infusion of academically and/or industry-trained people into the ranks of radio hobbyists fostered an appropriate awareness of the need to be careful with anything connected to the power mains — a point that needs to be borne in mind by the present generation of vintage radio receiver enthusiasts.

### Small AC receivers

As happened in the battery set era, designs for a whole range of elementary mains powered receivers appeared in the technical press, *circa* 1930, intended primarily for home construction. They were welcomed by the rising generation of industry-based enthusiasts who, while handling commercial receivers by day, were frequently too poor, in the shadow of the great depression, to afford anything quite as pretentious.

By courtesy of Mr H.D. Burraston of Murrarundi, NSW, I have to hand a copy of a booklet 'Modern Radio Circuits for AC Operation', issued as a supplement to *EA*'s predecessor *Wireless Weekly* for August 14, 1931. It offers very helpful glimpses of contemporary receiver design.

Fig.1 shows the circuit of the *WW* 'Direct Coupled 2', using a 224 screened-grid tetrode as a regenerative detector feeding a type 245 power triode output valve. The 280 rectifier is not included in the valve count.

(Perhaps I should also mention here that the initial digit, indicating the manufacturer was later dropped from American valve type numbers, so that they became known simply as 24, 45, 80, etc).

Guide notes in the booklet warned that the sensitivity and selectivity of such simple two-stage circuits were limited, and it was recommended only for urban use (I quote): 'within 20 miles or so of the broadcast stations'. Even so, interference between adjacent stations could still be a problem in difficult locations; e.g., close to one or more transmitters.

Compared with an equivalent two-stage battery set, husky valves and a high tension supply voltage in the range 425-450V DC could provide loud reproduction of such signals as the set could successfully tune. In an optimum situation, with an efficient dynamic (moving coil) loudspeaker, the constructor was promised reproduction to rival that available from a much more pretentious design.

### Dynamic loudspeakers

Elsewhere in the booklet, readers were reminded that many existing dynamic loudspeakers were of the 'AC powered' electrodynamic type. Introduced about 1926, a step-down mains transformer and copper-oxide rectifier attached to the housing provided low voltage DC to energise the field coil.

Looking back, I recall that discarded examples of the breed were often picked over by hobbyists, in the forlorn hope that the transformer and rectifier would be in good enough shape to double as a modest home battery charger.

The next generation of electrodynamic loudspeakers (Fig.2) were less cumbersome and generally more efficient. Fitted with field coils of much higher resistance, they were capable of being supplied with current from the receiver's own HT power supply, requiring from 7 to 10 watts for adequate field energisation.

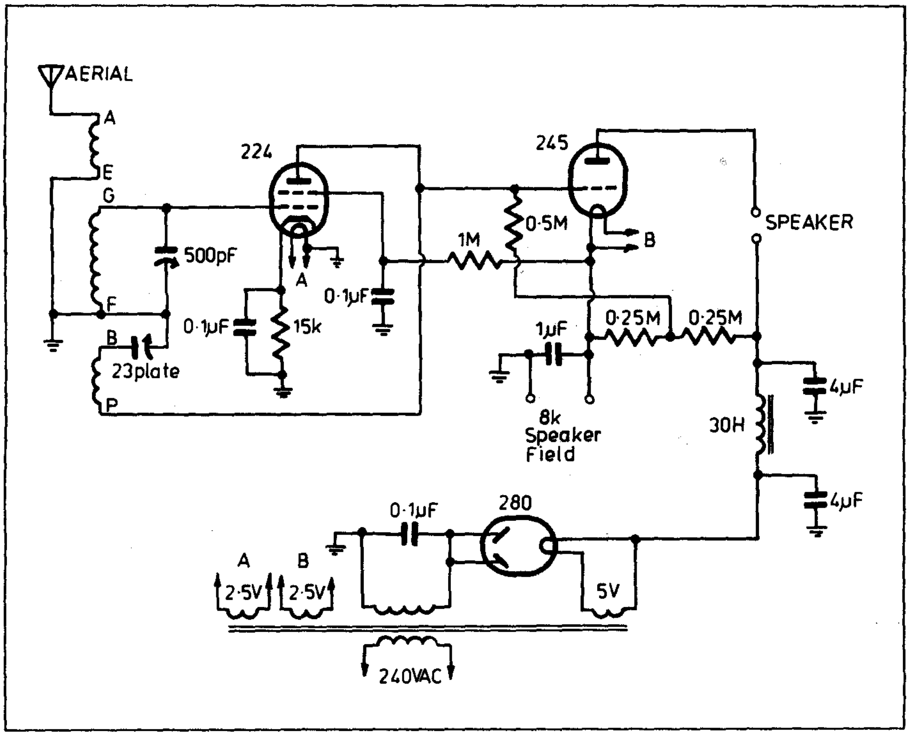


***Fig.1:* Redrawn from a Wireless Weekly booklet issued in August 1931, here is the circuit diagram of the 'Direct Coupled 2", an early and modest mains operated receiver intended for home construction.**

Subsequent generations of Australian-made Amplion, AWA, Rola and Magnavox loudspeakers looked very much like the Jensen pictured. After World War II, field coils gave way to permanent magnets.

With hindsight, various aspects of the 'Direct Coupled 2' circuit reflect the sometimes immature technical reasoning in the transitional period between the technology of the 1920's and 1930's.

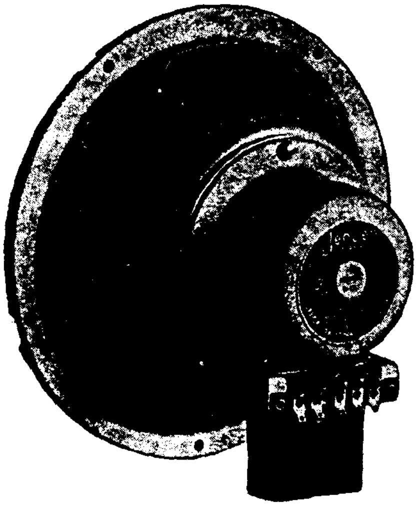


***Fig.2:* A then-current American Jensen dynamic loudspeaker, imported by the International Radio Company Ltd of Sydney. The field magnet is bolted to the rear of the cone, with the cable tagstrip and voice coil matching transformer suspended underneath.**

Thus, while the configuration of the detector is reminiscent of the traditional Reinartz reaction circuit, there is no grid capacitor or 'grid leak' resistor. Instead, the 224 is shown as an over-biased 'anode-bend' detector — an innovation more appropriate to larger receivers, subject to possible detector overload. For a simple receiver, the traditional and reputedly more sensitive 'leaky grid' circuit would normally be a more logical choice.

## The output stage

Again, the output valve is a directly heated type 245, normally requiring the hum to be balanced out by returning the negative feed from the HT supply to a filament circuit centre-tap — apparently overlooked in the circuit diagram. In fairness to the designer, use of the 45 probably has more to do with the valve manufacturers, who clung tenaciously to directly heated output valves long after all other functional mains types had been developed around sleeved cathodes.

But, to me, the most debatable aspect of the design — a carry-over from the much publicised 1920's-style Loftin-White amplifier — is the use of 'direct coupling' to the grid of the output valve from the anode of the preceding stage.

Clearly the designer of the 'Direct-Coupled 2' assumed that omission of the coupling capacitor would effect a noticeable improvement in the overall quality of reproduction.

I subsequently contested this simplistic — but not infrequent — assumption in the very first instalment of 'Let's Buy an Argument' (now 'Forum'), maintaining that the omission of a lone coupling capacitor in a simple non-feedback amplifier merely complicated the rest of the circuitry to no good purpose.

In the circuit of Fig.1, the grid of the output valve is tied to the positive potential at the anode of the 224 detector — a fact that may have influenced the choice of the anode-bend configuration.

For normal class-A operating conditions to apply, the filament of the 245 would need to be about 50V positive with respect to the grid, with the anode supply 250 volts above that again. According to the descriptive text, the design calls for a total supply in the range 425-450V — an incongruous figure for such a small set.

To obtain this voltage, the power transformer/rectifier system has to operate in half-wave mode, as shown. With a ripple frequency of 50Hz and the filtering relying on a nominal 30 henry choke and two 4uF paper capacitors (Fig.3), I do wonder about the residual hum level. (Electrolytic capacitors had yet to emerge as a routine choice for HT filtering.)

I also wonder about the presence of the loudspeaker field coil in the filament/earth return circuit of the output valve. Superficially it might appear to be a neat way of energising the field, but a complex and potentially resonant impedance in a path common to both input and output must introduce random negative current feedback around the output stage, affecting its output impedance. As well it could divert audio power from the voice coil into the field coil.

To invoke an old saying, the complications involved in eliminating one lone coupling capacitor strike me as the technological equivalent of 'straining at a gnat and swallowing a camel'.

## Different approach

Interestingly enough, the same supplement offered readers a quite different 2/3-valve receiver called the 'The Hi-Power Two'. Two separate coils and two ganged capacitors provide band-pass tuning (see Fig.4) ahead of a Mullard 354V indirectly heated triode, operating as a conventional regenerative leaky-grid detector.

As a result and as distinct from the Direct Coupled 2, this alternative design was credited with 'astounding selectivity' (for a small set) and said to be 'at its best when located right in the midst of the powerful local transmitters'.

The detector was transformer coupled to a British-based Mullard PM24A power output pentode — as distinct from the American 24/24A RF tetrode. The specified loudspeaker was again a Jensen dynamic with 8000-ohm field coil but, in this case, wired directly across the DC HT supply.

Requiring only a routine 250-odd volts, the power supply system involved a 280 type rectifier fed from a normal centre-tapped power transformer, plus a couple of filter chokes and the then routine 'Chanex' or 'Hydra' 4uF paper dielectric capacitors.

Also worthy of mention in this otherwise poor man's 2/3 valver is the inclusion of an audio volume control ahead of the output stage, and a top-cut tone control across the anode circuit. Both warrant explanation at this point; first the volume control:

In urban areas, as already indicated, a small mains powered regenerative set could provide quite high output from strong local stations, necessitating some means of reducing the sound to an acceptable level. The seemingly obvious course was simply to back off the regeneration (or 'reaction') control, but this could adversely affect the selectivity, leading to possible interference problems.

By providing a supplementary volume control, the regeneration could be set for maximum detector gain and selectivity, the volume control being adjusted separately to produce the desired sound level. While a routine procedure for a technically inclined listener, the critical manipulation of two knobs, both affecting volume, would have been potentially confusing for other members of the household.

## The tone control

Most receivers up to this point in time had used triode output valves having a characteristically low output (or anode/plate) resistance; e.g., around 1600 ohms for a type 245.

In such a case, the natural frequency response of the system is not greatly affected by the wide variations in impedance which loudspeakers typically exhibit over the audio range. Hence, with a clean signal and a loudspeaker of reasonable quality, the overall sound can be relatively smooth.

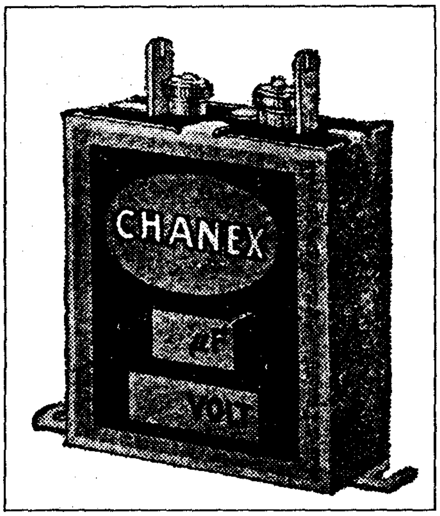


*Fig.3: A typical paper dielectric capacitor, used for HT filtering before the general adoption of the electrolytic can type. Many discarded 'block' capacitors found their way into early home-built amateur station transmitters.*

By contrast, power output tetrodes and pentodes have a much higher output resistance — typically 60,000 ohms in the case of a 247. In consquence, the frequency response tends to vary with the loudspeaker impedance, resulting in a rather 'boomy' quality at the loudspeaker's bass resonance and a pronounced accentuation of the upper treble. The difference between the two was quite noticeable but, while listeners tended to tolerate the extra bass as a novelty, they disliked the strident treble. Designers countered by installing a suitable bypass capacitor across the anode circuit of output pentodes, to attenuate the upper treble response. Indeed, translating a vice into a virtue, they commonly provided a potentiometer in series with the capacitor so that the tone could be varied at will between 'bright' and 'mellow'.

In fact, such 'top-cut' tone controls became a routine fitment on domestic receivers from the early 1930's onward, being commonly left in the 'mellow' setting. As a result generations of listeners became conditioned to 'woolly' music and muffled voices. But back to the original theme.

## Extra stages

As had happened in the early 1920's, small regenerative receivers like the foregoing remained largely the province of hobbyists — of financial necessity and/or because they derived a certain satisfaction from achieving impressive results with a minimum of circuitry.

On the other hand, commercial receivers, intended for family use, were invariably of more ambitious design, less reliant on operator skill and able to cope routinely with a greater range of reception conditions. From the viewpoint of both supplier and customer, the ideal receiver was an affordable model that could be delivered to any ordinary address, connected to an aerial and power point and tuned, forthwith, to the full gamut of stations available in the area.

Fortuitously, the abovementioned *Wireless Weekly* booklet features a range of receiver designs using three, four and five valves plus rectifier — all TRFs, with one, two or three tuned RF stages ahead of the tuned detector. All feature direct coupling to the output stage, which complicates the audio circuitry. But more importantly for our present purpose, the notes document how well the respective front ends coped with the less crowded broadcast scene in 1930/31.

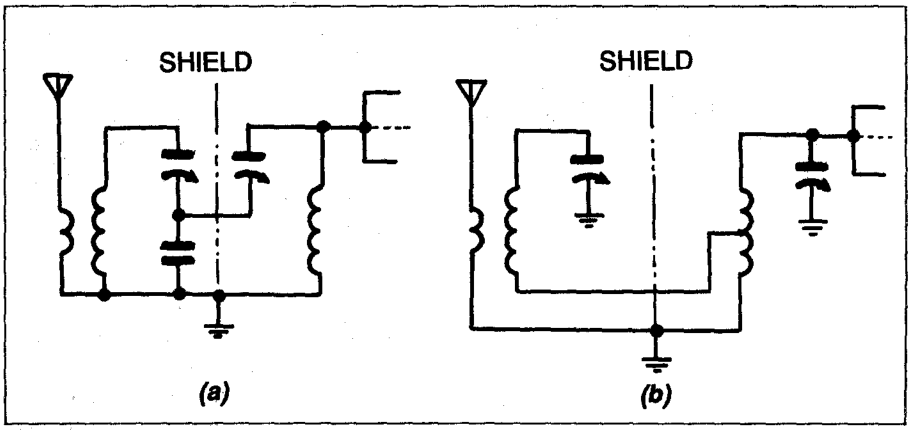


*Fig.4: Double-tuned 'band-pass' circuits were often employed to improve front-end selectivity. Arrangement (b) is the logical choice when the tuning capacitors share a common, earthed frame.*

Again, helpfully, a *Wireless Weekly* 'Call Sign' booklet issued a few months earlier (July 1930) lists the 33 AM broadcast band stations across the Australian continent — compared with a present tally of around 250, crowded into channels only 9kHz apart.

The *Wireless Weekly* 'Midget 3' was so called because it was fitted on to a chassis compact enough to be housed in a table-top cabinet. It used a 224 as a tuned RF amplifier followed by another 224 as a tuned anode-bend detector feeding a 245 power output triode. A 280 rectifier in half-wave mode produced the requisite HT voltage for the direct coupled ouput stage, the 8000-ohm field coil being connected across the HT in series with a 5000-ohm heavy duty resistor.

Using a 224 tetrode in the RF stage ensured much greater amplification of the incoming signal than was normally available with a triode. No less to the point, the presence of a screening electrode between grid and plate, and access to the grid via a top cap connection reduced the grid/plate capacitance by around 100:1.

This obviated the need for neutralising circuitry, the only precaution in the interest of stability being the use of metal shield cans over the 224 valves and the respective coils (Fig.5).

Significantly, the compilers of the booklet classified the 'Midget 3' as the smallest class of receiver which could offer reasonable gain and selectivity without having to rely on the use of regeneration (quote) 'which is considered objectionable by many enthusiasts'.

## 'Most popular' set

The sequence of small receivers leads up to what the booklet presented as the then-current ideal receiver: 'The 1930 Four', whose circuit is shown in Fig.6. It was described as: 'the most outstanding design ever known to the Sydney radio trade', for which 'more kits of parts have been sold ... than any set previously described in Australia'.

Why? Because it had unmatched tone, 'enough volume to fill a small hall' and sufficient range to give excellent interstate reception.

Another TRF design, it used two 224 tetrodes as tuned RF amplifiers, a third as a tuned anode-bend detector, followed by a Philips P443 — a directly-heated high-power output pentode. The rectifier was a high-voltage half-wave 281, fed from a 575V transformer.

The covering article indicates that there had been problems with the design, when first published, with the lower rated output pentode originally specified and with unreliable resistors. Again, with hindsight, I am not surprised when the article goes on to mention that the HT supply voltage provided for the direct-coupled circuitry ended up at around 625-650V!

Notwithstanding this, the fact remains that the two-RF stage configuration, with single-dial triple-gang tuning (C1/C2/C3), won wide acceptance as the best compromise for the reception conditions that obtained in 1930.

Not surprisingly, many contemporary commercial receivers adopted this general approach, with a 3-gang tuning capacitor and two RF stages, followed by a detector, an ordinary capacitance coupled output stage and a conventional 250-odd volt power supply.

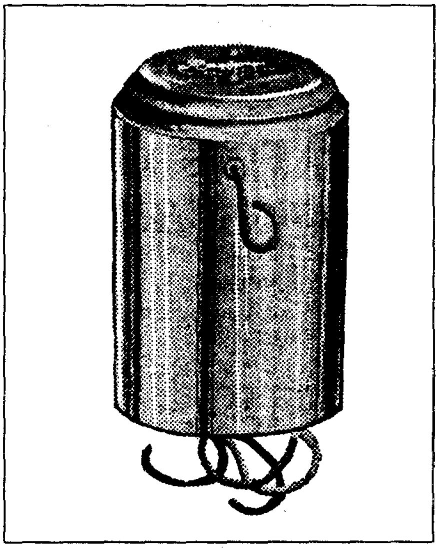


***Fig.5: Manufactured by the Metropolitan Electric Co, Sydney, shielded, matched aerial and RF coils like this were available for TRF receivers, priced at 9/11d (99¢) each.***

## Gain or volume control

One other point about the '1930 Four' warrants special comment, namely the matter of a gain (or 'volume') control.

Because of their high intrinsic gain and consequently low grid bias, RF tetrodes like the 224 could readily exhibit signal overload effects close to one or more broadcast stations, therefore in many urban areas.

A powerful local signal could conceivably penetrate the first tuned circuit and be cross-modulated onto other carriers by the first RF stage. Even though the interfering carrier itself may be rejected by subsequent tuned circuits, its audio component could still break through as spurious modulation on other carriers. Or, again, in a larger receiver, the excessive signal level may be evident as distortion caused by overload of the final RF stage or the detector itself. Either way, a gain control in the audio system is of no help, since the overload has already occurred ahead of where the control can have any effect.

Superficially, the gain of RF tetrode amplifiers can be be reduced by simply increasing the negative grid bias — either directly or by using a wire-wound potentiometer as a variable cathode bias resistor. The problem is that this simultaneously reduces the plate current and further limits the ability of the valve to handle high level signals. Thus, only partial control is possible, with cross-modulation and/or distortion remaining a potential problem.

In the '1930 Four', the designers have opted instead for an 0.2 megohm potentiometer varying the screen voltage of the first two valves. While this was often used at the time, the idea would appear to suffer the same limitations as variable bias.

That it did so is evidenced by the fact that the design specified a 'Local-distant' switch which introduced a low value resistor (typically 10-25 ohms) across the primary winding of the aerial coil. Intended to reduce the level of all incoming signals, the resistor could be switched in or out of circuit, depending on whether or not it provided a cleaner result.

Gain control posed a problem for many medium to large receivers about this time, both TRF and superhets and, while a local-distant switch was a potential source of confusion for non- technical users, it was commonly fitted to both commercial and home-built designs as a matter of necessity.

One other point worthy of mention is the provision of a 'jack' socket (J) in series with the earthy end of the detector grid coil. For the most part ignored, its purpose was to allow a phonograph pickup to be plugged into the grid circuit of the detector so that the phono signal would be fed through the amplifier and loudspeaker.

It could be argued that a detector would not be optimally biased to operate as an straight amplifier, and that there was no provision anyway for an audio control to vary the sound level from discs.

Both observations are legitimate but, at the time, the majority of pickups were relatively crude magnetic types, and fitted with their own loudness potentiometer anyway. Most listeners were aware that electrical phono amplification was possible, but the current emphasis was on broadcast programs. Family radiograms did not really become 'trendy' until around 1935.

## A 'deluxe' TRF

The most ambitious receiver presented in the *Wireless Weekly* booklet is The 'De Luxe Five' — or 'Six', counting the rectifier. An elaboration of the foregoing 4/5 valve receiver, it used *three* tuned RF tetrodes ahead of the 224 anode-bend detector which, in turn, drove a Philips F443 high power output pentode. The rectifier was a half-wave 281, fed with a 600V transformer. As distinct from the smaller receivers, the circuit called for an 'AC Jensen' loudspeaker, providing its own field energisation with an in-built mains transformer and copper-oxide rectifier.

Summing up the receiver, the booklet claimed that, irrespective of valve count, there was nothing that could outperform the De-Luxe Five 'except for some forms of superheterodyne'. It was particularly recommended for use in 'up-country towns' involving a range of several hundred miles, but was not recommended for major cities because 'it picks up all kinds of interference noises and amplifies them to an extent which will make reception unpleasant'.

This is an off-putting statement, to say the least, but probably confirms the fact that, at the relevant time, it was one thing to provide high RF gain but quite another to control it smoothly and effectively.

Relying on screen voltage control for the three 224 RF amplifiers and a drastic local-distant switch, the set may indeed have been unduly vulnerable to front-end overload and mains-borne RF interference in urban areas.

Front-end gain control remained an urgent problem until the introduction of 'super-control' or 'variable-mu' screen grid valves, in mid 1931. The International Radio Company of Sydney announced local release of the National Union variable-mu 235 in *Wireless Weekly* for April 13, 1932.

The variable-mu characteristic was achieved by fitting a special tapered-pitch grid, or by simply snipping selected half-turns from a fixed pitch grid.

The effect was to change the grid control characteristic such that while it appeared quite normal with low values of bias, it required a very high value of bias to cut off the plate current altogether. The abrupt plate current cut-off 'corner' in the characteristic was competely eliminated.

Virtually identical in appearance to the 224, the variable-mu 235 offered essentially the same transconductance — and stage gain — as the 224 at -3V. But whereas the 224 plate current curve cut off sharply at around -6V, the 235 plate current curve trailed out to an ultimate cut-off at around -50V.

In announcing their equivalent valve, the 335 in *QST* for July 1931, Cunningham listed the transconductance as 1.050mA/V at -3V, reducing to 0.015mA/V at -40V — implying a huge potential reduction in stage gain. With that degree of control available and a plate current curve free of abrupt corners, it became much easier for designers to forestall front-end overload with its consequent cross-modulation and distortion.

Had 235 type valves been available in time for the '1930 Four' and the 'De-Luxe Five', the designers could simply have specified them for the RF stages, arranged for variable cathode bias and ended up with much smoother control — minus the local-distant switch.

## Selectivity vs quality

That aside, while receivers such as those above offered predictable gain and selectivity for the listening situation circa 1930, the industry was well aware that, as far as domestic receivers were concerned, such designs epitomised the practical limits of TRF technology. Two and three-gang tuning capacitors were acceptable, four-gangs were manageable but anything beyond that would be too clumsy and too expensive.

In any case, the selectivity curve exhibited by a TRF tuner varied unduly across the broadcast band. According to one set of figures to hand, when tuned to 600kHz, a typical receiver using a three-gang capacitor exhibited a total bandwidth of 100kHz at 60dB down. However, when tuned towards the high frequency end, its bandwidth, as a simple proportion of the resonant frequency, widened to around 250kHz.

Unfortunately selectivity was worst at the very end of the band where it really needed to be at its best — thereby comparing very unfavourably with a superheterodyne, which could provide a narrower passband which was substantially uniform over the whole tuning range. Arguing with as much spirit as characterised their later forays, audio buffs of the period stoutly maintained

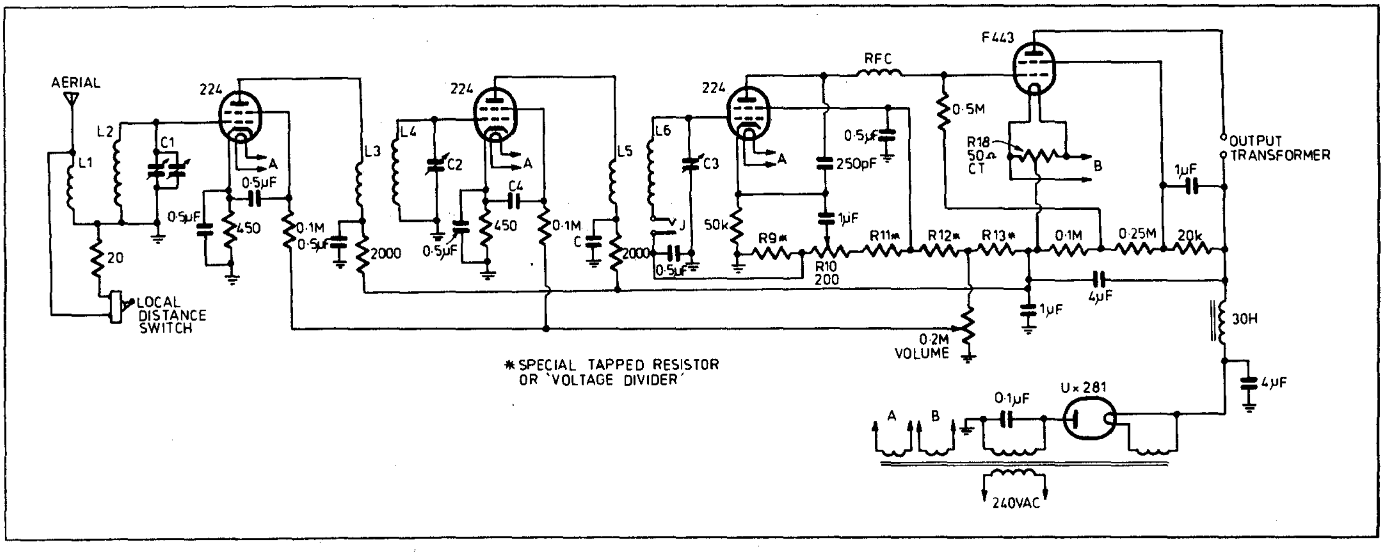


*Fig.6: The '1930 Four', said by Wireless Weekly at the time to be their most popular project to date and considered to be the best current compromise between performance and cost for the average listener.*

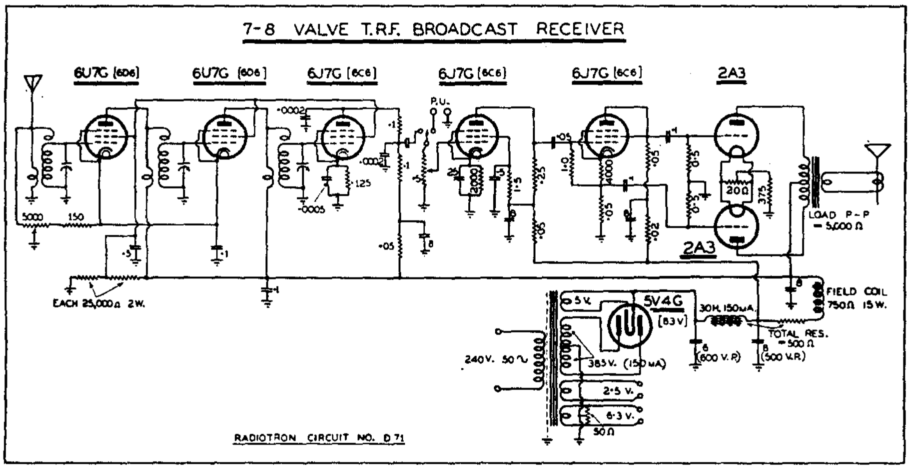


***Fig.7: Designed especially for audio buffs and featured in 'Radiotronics' No.82 (1937), this receiver combined a three-valve TRF tuner with a classical push-pull 2A3 triode amplifier.***

that emphasis on receiver selectivity was inappropriate; that the vast majority of families listened only to their local stations, and that extra selectivity would diminish rather than augment their listening pleasure.

Receivers with a narrower bandwidth had to be tuned with greater accuracy for minimum distortion, they suggested. What's more, they attenuated the high frequency sidebands, diminishing the clarity of voices and robbing music of its natural overtones.

The arguments gave rise to an audio cult which supported TRF receivers on principle, and equated them with 'hifi' radio reception.

In all fairness, it probably has to be admitted that the best sounding receivers of the era *were* TRF tuners with two variable-mu RF stages, an anode-bend detector and a power triode output stage. The modest front-end provided a reasonably balanced signal and the power triode(s) delivered it to the loudspeaker with much less distortion than characterised the louder — and more strident — non-feedback power pentodes.

As we shall see in the next chapter, vital design initiatives enabled the superheterodyne system to capture the mass market from 1930 onwards. But TRF tuners retained lingering support throughout the decade from specialist suppliers and audio buffs.

Fig.7 shows the circuit diagram of a TRF receiver for hifi enthusiasts developed in the Applications Laboratory of the A.W. Valve Company and published in *Radiotronics* No.82, dated December 1937. It used two tuned variable-mu RF amplifiers and a 'reflex' detector — essentially an anode bend detector with a large cathode resistor bypassed only for RF. It did not load the input circuit and had notably low distortion by reason of the cathode negative feedback. Because the design did not lend itself to AVC, the user had to manipulate two manual gain controls — one for the front end, the other for the audio system. High impedance primary windings in all coils and a capacitive coupling loop adjacent to the active end of the respective secondaries helped to equalise the gain across the tuning range. Fitted with a push-pull power triode output stage and an appropriately baffled hifi loudspeaker system, it was very much a receiver/amplifier for hifi enthusiasts of the day.

In May 1941, the Editor of this magazine (by then called *Radio & Hobbies*) the late John Moyle, presented a TRF tuner very like that used in the AWV receiver, with the idea that it could be used with an existing *R&H* amplifier using push-pull 2A3 output triodes. For sound quality, he said, the combination would be 'almost unbeatable'. A year later, in May 1942, I personally described the 'TRF Quality Six' in *Radio & Hobbies*. With parts scarce, due to the war, it was a distinctly different economy design, slanted to take advantage of possible alternative components. Since then, TRFs have been remembered mainly 'in absentia', with hifi-orientated engineers more intent on dreaming up ways and means of creating wideband or variable-selectivity superhets. Only recently, with the arrival of solid-state technology and AM-stereo has such technology come of age.

But that's much too recent to qualify as history. In the next chapter I will be looking at the evolution of 1930's-style superhets.

*(To be continued)* ■

# When I Think Back...

by Neville Williams

## Vintage Radio Receiver Design — 4
## How the superhet was 're-discovered'

In the early 1930s, superheterodyne receiver design was rationalised and simplified to such an extent that it rendered the TRF principle virtually obsolete, for both domestic and professional applications. The progressive developments which brought this about will be examined in this and following articles.

In the Newnes-Butterworths Book *Radio, TV & Audio Technical Reference Book* compiled by S.W. Amos and published in 1977, there is apt reference to the 're-discovery' of the superhet in the early 1930s, and a subsequent period of progressive 'consolidation' that led up to the war years, which saw intensive development of a quite different kind.

Amos does not explain who or what led to the so-called re-discovery around 1930, beyond a brief reference to an unnamed company catering for the home construction market and 'massive' concentration on the subject of receiver design by the technical press.

I, personally, cannot recall ever having seen an article on the subject, but it appeals to me as one holding considerable potential interest as a paper or thesis for anyone having a mind to carry out the appropriate research of patent files and other literature.

In the meantime, I lean to the view that the radio industry worldwide desperately needed a configuration that offered a way around the inherent limitations of the TRF approach in the way of gain and selectivity; that, whatever the 'trigger', sheer competitive commercial pressure maintained the on-going momentum that was evident in the consequent research and development.

In Australia, the motto of the radio industry was 'a set in every home', with individual manufacturers doing their level best to ensure that as many of the sets as possible bore their particular trademark.

However, without getting involved in the exact how, when, where or why, it is possible to nominate various developments which transformed a seemingly involved design concept into receivers that were relatively easy to mass-produce and eminently suitable for use by non-technical listeners.

If Australian manufacturers tended to incorporate similar technology in their respective models, it was because they had to evaluate each new development, irrespective of its source, as soon as it was publicised in trade literature or technical journals.

They simply had to keep abreast of their competitors, or be perceived as 'behind the times'.

### Improvements essential

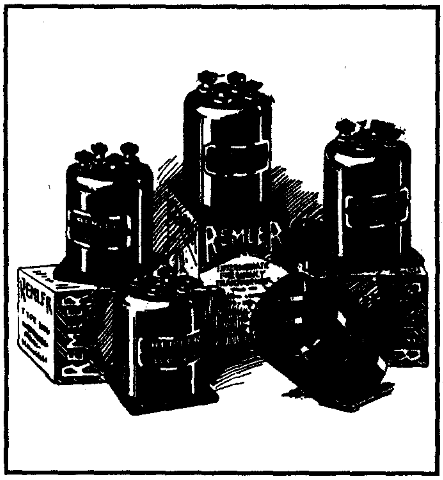
Back in 1925, despite their commendable gain and selectivity, early superhet receivers had peculiarities which, to say the least, were discouraging to potential non-technical buyers.

As explained in the June article, they exhibited double-spot tuning effects, image reception and spurious radiation from the inbuilt oscillator. A few manufacturers persisted with them, but most passed them by.

While the release of mains type screened-grid valves — sharp cutoff and variable-mu — significantly upgraded the design of TRF receivers (see last issue) they were no less a key element in the re-development of the post-1930 superheterodyne. For example, the provision of an RF amplifier stage ahead of the frequency changer became a routine option, isolating the local oscillator from the antenna and providing readily controllable gain, plus up-front selectivity to help deal with image and double-spot tuning effects.

In the frequency changing stage, a single sharp cutoff RF tetrode or pentode could fill a dual role as both mixer and local oscillator. (The so-called 'autodyne' frequency changer is explained later, in connection with Fig.4).

Again, in the IF (intermediate frequency) amplifier section, a single variable-mu tetrode or pentode could provide adequate and controllable gain, feeding into the detector and audio system. For such an approach, only one extra valve would be involved to achieve an order of gain and selectivity that would be unattainable from a comparably priced TRF. But the story does not end there.



***Complete Remler coil kit for a 1920s-style superhet, as advertised in 'Wireless Weekly' (July 29, 1927) by Wiles Wonderful Wireless of Goulburn St, Sydney. The IF transformers carry terminals similar to those of audio transformers.***

## Higher IF

The tuning and radiation problems of the early superhets were compounded by the comparatively low IF (intermediate frequency) then being used — commonly in the region of 50-60kHz. As a manageable supersonic frequency, it was accepted as a natural choice in the quest for high selectivity.

A further consideration was that the early designs had to rely on triode valves, and the intrinsic grid/plate capacitance of these posed less of a problem in the supersonic frequency range, thereby making it easier to secure high, stable gain from a multistage IF channel.

Not surprisingly, perhaps, IF coupling transformers of the period were routinely styled like interstage audio transformers, with connecting terminals for P, B+, G and C- (Fig.1). The prime difference was that, instead of being responsive over the audio range, they were so wound as to be self-resonant at a supersonic frequency — hopefully one that was suitable.

Curiously, advertisements of the period make little or no reference to the *actual* resonant frequency of particular transformers, or to alignment precautions, if any. They simply suggested that constructors be careful to use only a complete matched set of IF transformers designed for the particular receiver.

With the release of screened grid (tetrode and/or pentode) valves, stability and gain ceased to be a problem in the RF and IF channels alike. As a result, engineers had the option of designing superheterodyne receivers around a much higher intermediate frequency, thereby making the image and double-spot tuning problems more manageable.

The first figure to emerge by industry consensus as a new IF standard was 170kHz — subsequently amended to 175kHz — and seen at the time as a radical departure from 50-60kHz. It meant that the oscillator frequency would differ from the signal by 175kHz and that potential tuning 'images' or 'second spots' would be displaced by 2 x 175 or 350kHz. Compared with the previous 2 x 60kHz or 120kHz, the ability of the signal input tuning circuits to reject the unwanted images would be considerably enhanced.

Reasons for agreeing upon a new international industry standard IF included the following:

- The characteristic preference of engineers for an orderly, rather than a random design approach, particularly with an increasing international exchange of technical ideas and information.
- To facilitate the production of compatible coil kits and IF transformers by independent and/or international component suppliers.
- To avoid unnecessary confusion in the radio service industry, with a multiplicity of intermediate frequencies to which different receivers might need to be aligned.

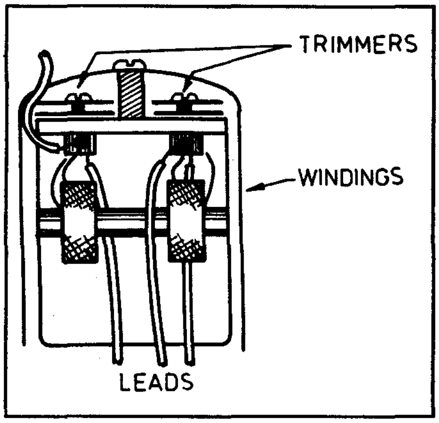


***Fig.2: The construction of an early 1930s-style IF transformer. Two lugs on each of the alignment trimmer capacitors at the top provide rigid anchor points for the fine wires from the coils and for the heavier outgoing insulated leads.***

## Practical IF transformers

If the early 50-60kHz (supersonic) IF coupling transformers were patterned on their audio frequency counterparts, their 175kHz equivalents were unmistakeably envisaged as 'RF' (radio frequency) components, housed in a light-gauge aluminium shield can.

In a few early examples, the primary and secondary windings were simply jumble wound between bakelite cheeks on a common spacer, each being resonated by a separate compression type trimmer capacitor, accessable from outside the can. The two windings would be separated by just the right amount to ensure an appropriate order of signal transfer and selectivity.

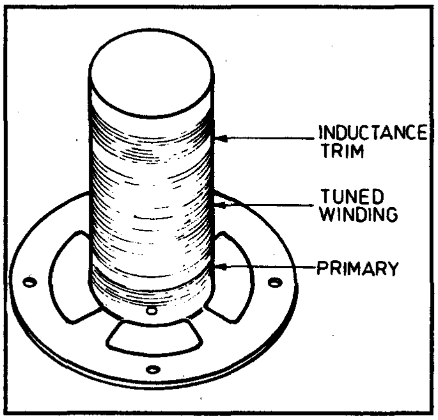


***Fig.3: A simple 'solenoid' style coil wound on an Australian made Lekmek tubular former. The leads were anchored to metal clips fitted into holes around the lower end of the tube.***

More commonly, the coils were honeycomb-wound towards either end of a composition or bakelised cardboard former, and subsequently stabilised by immersion in a low-loss wax or varnish. Mounted inside a common shield can, they were likewise resonated by compression trimmers, with leads running out through the top and/or down through the bottom of the can to the associated circuitry (Fig.2).

With all coils resonated deliberately and precisely to the one frequency — nominally 175kHz — after connection into circuit, the chances are that the selectivity curve would compare favourably with the 1920s-style IF channels, despite the greater complexity and lower frequency of the latter. This was because of the more casual approach to system resonance that was characteristic of the earlier designs.

Certainly, 175kHz superhets earned a reputation in the 1930s for high selectivity — too high, in fact for many listeners, who lamented the loss of upper treble by reason of sideband cutting.

The procedure for aligning the 'new look' superhet receivers, including the IF channel, will be detailed in a future article. In the meantime, one innovation led to another.

## Single-dial tuning

A side-effect of selecting a higher IF was that it increased the discrepancy between the tuning range of the signal frequency and local oscillator circuits. For a broadcast band tuning range of 550kHz to 1600kHz, the frequency ratio was/is 1:2.9. For an IF of 175kHz, the required oscillator tuning range becomes 725 to 1775kHz, with a ratio of only 1:2.45.

To provide single-dial tuning — a prerequisite for family receivers in the 1930s — the designer of a superhet needed to arrange that, for a given rotation of the tuning mechanism, the oscillator would always be 175kHz above the selected incoming signal frequency. In other words, the respective circuits had to 'track' each other, right across the dial. The most obvious approach was to provide a ganged capacitor in which the oscillator tuning section used fewer and/or somewhat smaller plates, so shaped that the oscillator followed the required frequency law. This approach was, in fact, employed fairly commonly overseas, where the cost of designing and producing a customised ganged capacitor could often be absorbed in high-volume production budgets.

Fortunately for smaller production runs, a simpler alternative was devised. This involved the use of a conventional ganged capacitor with identical sections, and a specially selected 'padder' capacitor connected in series with the oscillator tuning section.

The oscillator coil would be designed with deliberately fewer turns such that, at the high frequency end of the band, it could be resonated 175kHz above the signal frequency using the normal alignment trimmer. At the low frequencies, the series 'padder' would reduce the effective maximum value of the tuning capacitor and, by making the padder adjustable in the manner of a compression trimmer, the oscillator frequency could be kept substantially in step with the signal tuning circuit(s) across the entire band.

That the series padder approach was vital in the design of domestic superhets is evidenced by the fact that some 25 engineering papers on this subject were published here and overseas, in the period 1931-41. These explored the principle, the mathematics and the potential accuracy of circuit tracking based on the use of a padder capacitor. It was certainly important in Australia where, for the minor cost of a compression type padder, local manufacturers could use perfectly standard two, three or four-gang capacitors, as might otherwise be used for a TRF.

The tuning dial would be calibrated to suit the brand of gang — Airzone, AWA, Stromberg, or whatever — and adjusted for the correct indication of frequency and/or station call as part of the alignment procedure, to be discussed in a future article.

## Tuning coils

In regard to the associated tuning coils, the aerial input coil could well be identical for either TRF or superhet. With a somewhat higher inductance primary winding, RF coils could also serve in either type of receiver. Whereas, however, a family size TRF might typically use two RF coils, a 175kHz superhet would more commonly use only one, along with a special oscillator coil, as already mentioned.

In the early 1930s, tuning coils were mostly solenoids: wound with enamelled solid wire, single layer on 0.75 to 1.25" diameter cardboard or moulded formers (19-32mm). Depending on the inclination of the designer, primary windings would be wound adjacent to the earthy end of the tuned winding, or overlaying it with woven 'cambric' insulation between.

Normally, the coils would be separately shielded by aluminium cans, of at least double the coil diameter and with similar clearance top and bottom. If the cans were too small this would reduce the inductance and efficiency of the coils; if they were too large they would be unnecessarily cumbersome and costly.

At my first job in Reliance Radio, we used coils wound on Lekmek moulded formers, about 35mm in diameter, with three integral moulded legs supporting the coil above a moulded base mounting ring. The inductance was finely trimmed during manufacture by manually spacing a few turns at the top, after which the winding would be stabilised with wax or varnish (Fig.3).

Lekmek style coils worked well, but they had one unfortunate weakness: they didn't like being bolted down to anything but a dead flat surface. Bolt them too firmly to a chassis with residual curvature and the base ring would crack, leaving the assembler with the option of confessing their aberration or saying nothing and hoping that the fine crack would pass unnoticed.

I/we were much relieved when Reliance went over to coils wound on waxed cardboard formers with metal-lug supports, which were much more tolerant of abuse!

As we shall see later, coils and IF transformers underwent a cycle of changes during the following years, aimed variously at making them more compact, more efficient, more economical to produce and, in some cases more amenable to advertising hype!

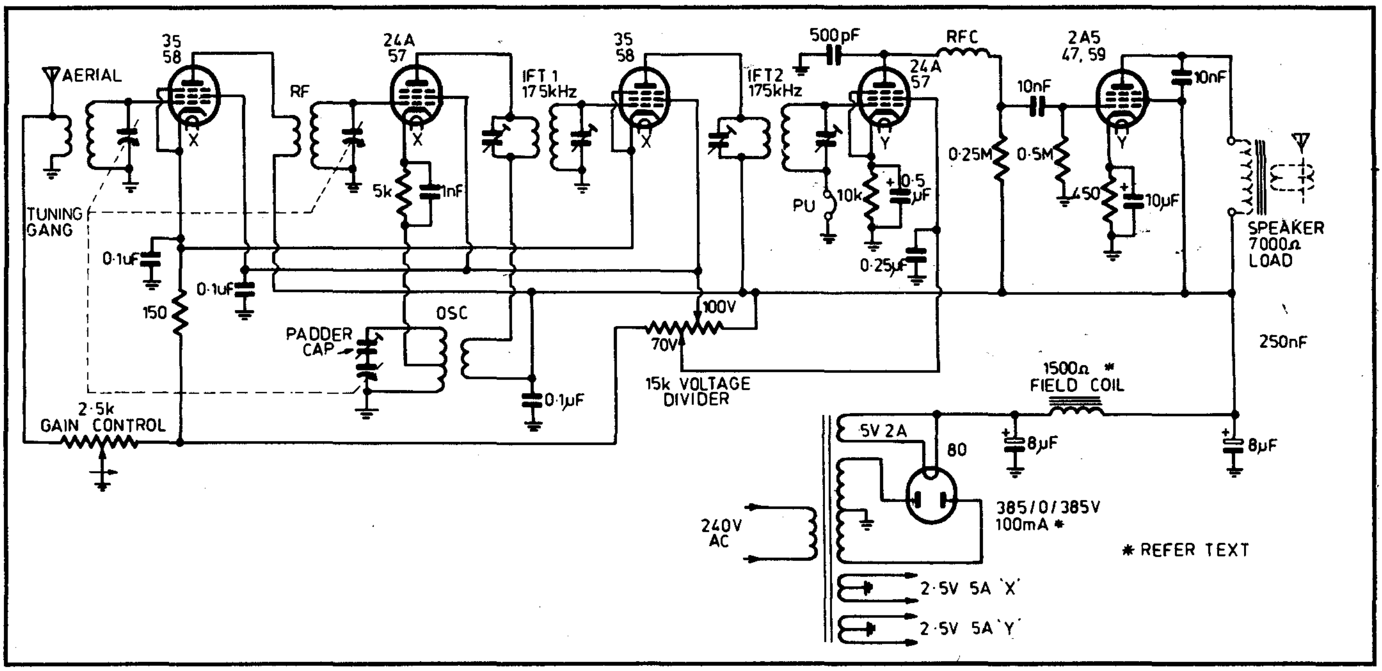


*Fig.4: A circuit typical of five-valve mains powered 175kHz superhets from the early 1930s. Features like special-purpose frequency changing valves, automatic gain control and audio negative feedback had yet to appear.*

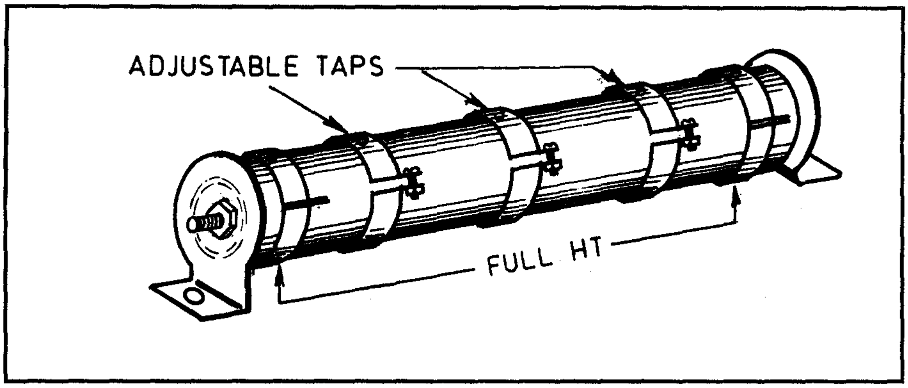


***Fig.5: Commonly used in 1930s-style receivers, voltage dividers were prone to troubles due to loose clips. Treat them gently, to avoid fracturing the fine resistance wire with which they are wound.***

## Typical circuit

To gather together much of the foregoing discussion, Fig.4 suggests a typical circuit for a 5-valve mains powered 175kHz superhet receiver from the early 1930s. It is not a reprint but, rather, one cobbled together from circuit practices of the period, with the front-end configuration very like that of the much publicised *Wireless Weekly* 'Champion'.

Checking through the circuit from the front end, the aerial coil would normally have been of conventional solenoid design, as already mentioned, with a low impedance (e.g., 20-turn) primary adjacent to or overlaying the earthy end of the secondary. As such, it would have been appropriate for direct connection to a conventional outdoor antenna.

In the earliest examples of such a receiver, the RF amplifier valve would have been a type 35 five pin variable-mu tetrode. This was subsequently superseded by the type 58 six pin variable-mu pentode, with its suppressor grid (G3) tied externally, as shown, to the cathode. The cathode and screen feed will be discussed soon.

The RF coil coupling the RF amplifier to the frequency changer would have had a secondary identical to that of the aerial coil, plus a primary winding having at least twice as many turns as the aerial primary to be more compatible with the high anode impedance of the RF valve. Consistent with earlier remarks, the second valve is shown as an 'autodyne' frequency changer — or self-oscillating mixer. In keeping with this dual role, it called for an overbiased, sharp cut-off valve such as the original five pin 24 or 24A, or the later six pin 57. Autodyne circuits could be configured in a number of ways, and a collector of vintage receivers has to be prepared for such variations. The arrangement shown was probably the one preferred by many designers, because the oscillator tuned circuit operated at cathode rather than anode potential.

## Autodyne & IF channel

In this kind of stage the RF input signal is applied to the grid in the normal manner, with the cathode substantially inert at the signal frequency by reason of the cathode bypass and a low impedance tapping on the oscillator coil, which is resonant at an entirely different frequency. At the same time, the valve is operating as a cathode coupled oscillator, at a frequency determined by the oscillator tuned circuit — this time with the grid inert by reason of its own differentially tuned signal circuit. By very nature, the circuit depicted does not provide an inbuilt path for the oscillator signal back towards the antenna.

However, signal and oscillator energy are both present in the actual electron stream and, in consequence, because of the non-linear mixing or intermodulation that takes place, multiple frequencies appear as components in the anode current. These include the oscillator frequency (Fo), the incoming signal frequency (Fs), along with the sum and difference products (Fo+Fs) and (Fo-Fs). In addition, natural harmonics 2Fo, 3Fo etc., and 2Fs, 3Fs and so on are also present, plus their sundry sum and difference components.

Fortunately, the sharply tuned circuits in IFT1 tend to reject all such components except the difference frequency (Fo-Fs) which, by front-end design, is 175kHz. This wanted signal is passed on to the IF amplifier — another 35 or 58 — and thence to the anode bend detector. The screen grid pins of the first three valves are wired together, bypassed to earth by a single 0.1uF capacitor and fed from a 100V tapping on a 15k ohm, so-called 'voltage divider' resistor.

## Voltage dividers

Connected across the HT supply, a voltage divider typically drew about 20mA and dissipated about 5 watts. Years before high wattage vitreous enamel resistors became commonplace, voltage dividers were mostly wound on cardboard formers with lightly insulated resistance wire, slightly turn-spaced, and lacquered to hold the wire in position. However, a narrow strip was masked off during lacquering to expose the wire along the former, the wire thereafter being lightly abraded so that adjustable clips could tap off intermediate voltages between 0 and (say) 270V — see Fig.5.

Voltage dividers served also to place a fixed load on the HT supply, thereby limiting the peak voltage from the directly heated rectifier at switch-on, before the remaining indirectly valves had time to warm up.

Unfortunately, voltage dividers also created their share of service calls — by reason of the generated heat shrinking the cardboard former and cracking the lacquer, causing intermittent contact between the clips and the wire. But in all fairness, fixed resistors in those days did not in themselves offer a very attractive alternative.

If replacement of a voltage divider is necessary in a vintage receiver, the most obvious course nowadays is to substitute a series string of 3W or 5W ceramic resistors, mounted on a tagstrip. Appropriate values, totalling about 15k, can be estimated from the position of the tappings along the original resistance element.

In Fig.4 the low potential end of the voltage divider returns to earth via the 2.5k gain (or volume) control. Depending on the setting of the control, the consequent cathode bias voltage for the RF and IF amplifier valves varies from the requisite minimum of 3V (maximum gain) to about 40V, where the gain of the variable-mu valves would be extremely low.

Furthermore, as the earthed contact in the potentiometer approaches the end remote from the voltage divider, it simultaneously shunts the aerial connection to earth in the manner of a local-distant switch. By specifying a 2.5k potentiometer, the shunting effect on the aerial circuit is less abrupt than it would be with a higher value control.

## The audio system

The anode-bend detector calls for a second sharp cutoff tetrode or pentode — a 24A or 57 — with a modest screen voltage and a deliberately high bias, ensured by the 10k cathode resistor.

Operating close to the cut-off bend in the anode current current characteristic, the instantaneous current can rise with positive-going half-cycles of the RF signal but it cannot react to the same degree to negative half cycles. As a result, rectification takes place, with the valve responding principally to positive- going contours of the amplitude modulated carrier envelope.

In effect, an amplitude peak at the grid produces an upward surge of plate current and a downward surge of plate voltage. The 500pF bypass and RF choke in the plate circuit together suppress the RF or carrier component, such that the plate current excursions become a pure audio signal suitable for transfer to the output valve. Hence the term 'anode-bend' detector. Note that the lower end of the IFT2 secondary winding returns to earth via two pickup terminals, normally mounted on the rear of the chassis and bridged by a scrap of tinned copper wire. Although not taken all that seriously at the time, it was a facility costing next to nothing that provided a feed point for the rather primitive magnetic gramophone pickups of the day.

In older receivers, the output valve would most likely have been a 47, with a directly heated or filament type cathode. In the absence of a cathode, as such, the bias would have been provided by returning the centre-tap of winding 'Y' to earth through the 450 ohm resistor and 10uF bypass, instead of direct.

Type 47 output valves had the advantage of drawing normal current almost from switch-on, but they were prone to grid current problems — resulting, in many cases, in gross distortion and a limited service life.

Type 59 valves were much better in this respect, but were less rugged than they should have been, suffering more than their fair share of internal shorts. By far and away the best of the three types shown on the circuit was the 2A5, which became the prototype of the popular 6.3V equivalents the 42 and 6F6-G.

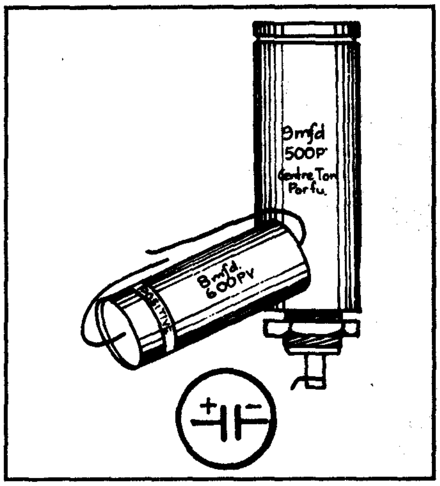


*Fig.6: A traditional can-type electrolytic capacitor and its more recent, smaller gel-type tubular equivalent. If not earthed to the chassis, can types had to be insulated with large fibre washers.*

## Power supply

The power supply shown conforms to a basic configuration which was more or less standard throughout the 1930s and, as such, warrants comment beyond the mere addition of likely component ratings. The power transformer provides the requisite filament/heater windings, plus a centre-tapped high-tension secondary to feed a full-wave valve type rectifier. The pulsed DC output was/is delivered typically to an 8uF liquid or gel-filled can-type electrolytic capacitor and thence to the field coil of an electrodynamic loudspeaker, doubling as a filter choke. This is followed by a second 8uF electrolytic, which provides the final filtering, as well as maintaining the DC supply line at virtual earth potential in respect to audio frequencies. We shall have more to say later about loudspeaker field coils.

In the early 1930s, power transformers were commonly supplied by specialist component manufacturers, who pro,oted selected 'catalog' lines, available from stock at the best price. Receiver manufacturers used them, wholesalers carried them on their shelves, and they were routinely specified in technical journals for home-built equipment.

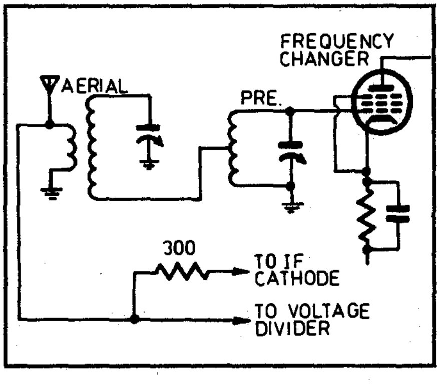


*Fig.7: Pre-selector tuning offers similar selectivity to that of an RF stage, but without the gain or the gain control facility offered by a variable-mu valve.*

For reasons which I can now only surmise, most stock power transformers carried a centre-tapped high tension secondary winding rated at 385-0-385V RMS and variously designed to cope with DC loads of 60, 80, 100 or 125mA, according to the nature of the receiver.

## Voltage/current levels

Contemporary valve curves show that, under no-load (warm-up) conditions, a type 80 rectifier, fed with 385V RMS input, would deliver peak pulses of around 525V to the filter input capacitor.

Since 525 also happened to be the peak voltage (PV) rating of then-practical can-type electrolytic capacitors (Fig.6), it is reasonable to assume that 385 RMS represented the highest secondary voltage which could be countenanced with a capacitor-input filter system.

While can-type electrolytics were said to be tolerant of high peak voltages, the 525PV rating would obviously been exceeded with an over-voltage mains supply. It was certainly not uncommon for liquid-filled electrolytics to 'sizzle' at switch-on, and one might even explode, on occasion, by reason of internal pressure. Perhaps that is why special 600PV types were in high demand for the filter input, when limited supplies ultimately appeared on the market.

In the case of Fig.4, the drain of the voltage divider would lower the peak voltage across the input electrolytic to about 505, leaving a small safety margin. With a directly-heated 47 output valve, also having a similar warm-up time to that of the rectifier, the peak voltage across the first electro would be un-likely to exceed 425V — a very comfortable margin.

Depending on the ultimate DC supply voltage, the valve complement and the setting of the gain control, the DC load current of the receiver illustrated would be around 90mA, suggesting the choice of a power transformer rated at 100mA. At 90mA, the measured voltage across the input filter capacitor would be about 410. By subtracting from this figure the required 270V HT 'rail' voltage (250V + 20V cathode bias) we arrive at a desirable voltage drop across the field coil of 135V. Based on a current drain of 90mA, this works out at about 1500 ohms resistance for the field coil and a field wattage dissipation of just over 12W, which would be appropriate for an everyday 8" (200mm) diameter electrodynamic loudspeaker. These figures have been shown on the circuit as preferred values.

While loudspeakers with 1500-ohm field coils could be obtained from suppliers, they were less common than 2000 ohm or 2500-ohm fields. If, for a vintage receiver as in Fig.4, a collector needs to replace the original electro-dynamic loudspeaker, they may well have to make do with a higher resistance field.

Either of the abovementioned values should work out well enough. For sure, the voltage drop across the field would be increased, but not in direct proportion because, with a reduced supply voltage, the valves will draw significantly less anode and screen current. Based largely on 'guesstimation', I would expect the subsitution of a 2000-ohm field to result in a filtered HT voltage of around 255V at a current level of about 85mA. The field wattage would be something over 13. Repeating the exercise for a 2500-ohm field coil suggests a HT voltage of just under 250V at around 75mA, with a field wattage of just over 14. In short, increasing the field resistance as indicated would reduce the filtered HT supply and, with it, the available output power — but not to the point where it would seriously prejudice the subjective behaviour of the set.

## Cutting costs

While the performance of a receiver along the lines of Fig.4 was outstanding, relative to its cost, it raised the question as to whether there might be scope for an economy version with an adequate performance for non-critical areas. Accepting that it could be housed in a cheaper cabinet and powered from an 80mA transformer by cutting back on the HT current, could such a set also get by without the RF stage?

Superficially the answer was 'no', because reduced front-end selectivity could allow stations across the lower frequency end of the band to be affected by images from stations further up the band by twice 175kHz, or 350kHz.

As a compromise, RCS Radio and other coil manufacturers came up with a preselector coil which, in conjunction with the normal aerial coil, offered adequate up-front selectivity (Fig.7). It still called for a three-gang tuning capacitor, but eliminated the RF valve and the heater/anode load it imposed on the power transformer.

While preselector tuning was a well-known option at the time, receiver manufacturers came up with a preferred alternative which obviated the need for a special coil and a third section on the tuning capacitor: namely a still further increase in the intermediate frequency. How the new configuration evolved will form the subject of a future article.

*(To be continued)* ■

# When I Think Back...

by Neville Williams

## Vintage radio receiver design — 5
## 4/5-valve superhets: the same only different!

**Of the tens of thousands of receivers which found their way into Australian homes during the 'golden age' of radio, by far the greatest number were locally produced 4/5-valve, 465kHz superhets — virtually all of them variations on a common theme. How and why the designs so evolved forms the subject of this present article.**

As indicated in the September issue, a generation of 'new look' Australian-made superheterodyne receivers, designed around screen-grid valves and a 175kHz IF channel, demonstrated just how practical such receivers could be. They were easy to use, and had enough gain and selectivity to perform well in isolated or otherwise difficult areas. No less to the point, they had sufficient range of control to be equally at home in congested urban situations with multiple high-level signals.

Not unduly difficult to produce, they appealed strongly to Australia's fledgling radio manufacturing industry — the more so because of the emergence of a more manageable patents situation.

Their success raised the question as to whether the basic 5/6-valve superhet configuration (September issue, Fig.4) could be simplified to create a more cost-effective product, which would hopefully still be adequate for families in average, non-critical reception areas.

One possible option was mentioned in the September issue, namely omission of the RF amplifier stage and relying on the use of a tuned preselector coil to offset the potential loss of front-end selectivity. As an economy measure, however, preselector tuning fell short of requirements, although it did find occasional application in later years for other reasons.

If the RF stage and its related components were to be eliminated completely, the alternative design option was to select a still higher intermediate frequency, thereby further isolating potential image responses from the wanted signals. (Refer to the September article).

On this premise, one American design adopted in Australia — Philco if I remember rightly — settled for a modest increase in the IF to around 250kHz. I recollect the figure mainly because of occasional reminders to contemporary servicemen that such a receiver existed. I cannot recall ever coming across one of them myself — but who knows what might turn up, these days, in vintage form?

### Standard IF

In planning economy receivers, all other Australian manufacturers that I am aware of settled for what emerged as a new international design standard — 465kHz, or thereabouts.

On the assumption that the oscillator would be tuned 465kHz above the wanted signal, the image problem area would be centred 465kHz above that again — 930kHz away — and hopefully sufficiently remote from the wanted signal to be dealt with by the sole tuned antenna (aerial) coil. Fairly obviously, the higher this coil's intrinsic 'Q' or design merit, the greater would be the image attenuation.

In practice, some manufacturers specified that the intermediate frequency of their receivers be offset, during alignment, from the nominal 465kHz. In suggesting a preferred figure between about 450 and 480kHz, their idea was to dodge incidental heterodyne whistles that had been identified by their regional dealers — affecting, for example, stations transmitting around 930 or 1395kHz, which are direct harmonics of 465kHz.

To quote a case in point, I note from the Historical Radio Society of Australia's *Newsletter No.35* that Tasma specified for their model 180 (1933) an unusually low figure of 445kHz.

These days, the most commonly nominated IF for AM radio receivers is 455kHz — a frequency which is recognised internationally and kept free of deliberate transmissions as a basic precaution against stray interference.

In terms of actual circuitry, an essentially serviceable 4/5-valve 465kHz superhet could be devised from Fig.4 in the September issue, by lifting out the complete RF stage and feeding the tuned antenna circuit directly to the grid of the 24A/57 autodyne frequency changer.

A different oscillator coil and padder would be required for a 465kHz version, along with appropriate IF transformers. The designer might also juggle things a bit (as per the September issue) to get by with an 80mA power transformer. But otherwise, the circuit and layout could — and often did — remain basically similar from one model to the next in a particular manufacturer's range.

### Basic 4/5V superhet

Fig.1, herewith, can be regarded as equally representative of Australian 455kHz superhets manufactured during the early 1930's. While broadly similar to the larger circuit, it does incorporate certain deliberate variations to illustrate other, but nevertheless typical, design approaches.

Following it through, the signal from the antenna input circuit feeds directly to the grid of the autodyne frequency changer. Most early 465kHz superhets used solenoid coils similar to those illustrated in Fig.3 of the Sep-

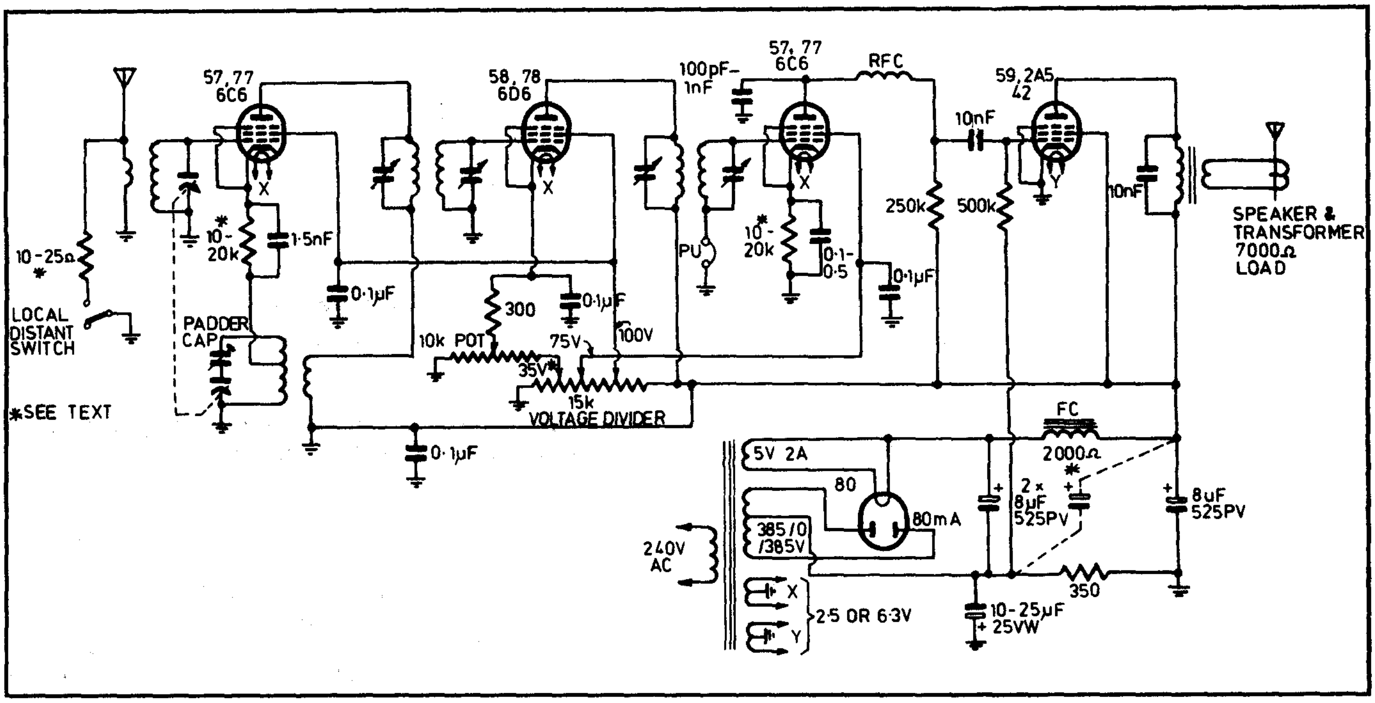


***Fig.1: A basic circuit for a typical 4/5 valve 465kHz superhet receiver from the early 1930's. Various options are shown and discussed in the text.***

tember article, with designers avoiding unduly small formers, small cans and small wire gauges to retain a reasonable 'Q'. In due course, new techniques emerged which made it possible to produce much smaller coils with improved Q-factors. These will be discussed in a future article.

The majority of 4/5-valve superhets produced around 1933/34 were designed around the then new 50-series valves with 2.5V heaters, with the type 57 sharp-cut off pentode being the obvious choice for the autodyne frequency changer. But not for long ...

Within a couple of years, valve manufacturers and stockists began to promote 6.3V versions of the '50' series — mainly because, over and above conventional mains receivers, they were more suitable for use in car radios, vibrator-powered farm receivers and American style AC/DC models.

Being new, they were also trendy and, at the next available model change, most Australian manufacturers switched over to them — a prime example of a concerted response to a common market stimulus!

In the changeover, the 57 was displaced by the 77 and/or the 6C6 — valves that were virtually identical to the 57 except for the heater rating: 6.3V/0.3A instead of 2.5V/1.0A. The 57, along with others in the range, were demoted in short order in the valve catalogs to 'replacement' types.

It should also be mentioned here that, because valves of that era had only limited inbuilt shielding — if any — it was routine practice, as a precaution against stray coupling between adjacent stages, to fit earthed metallic shield cans around the RF amplifier, frequency changer, IF amplifier and detector valves. Rarely indicated in manufacturers' circuit diagrams, this would apply, as a matter of course, to the first three valves in Fig.1.

The autodyne stage is essentially similar to that in the 5/6-valve circuit but, as then indicated, variations were not uncommon in both the overall configuration and in the choice of components.

Values for the cathode resistor typically ranged from 3k to over 10k and for the associated bypass from 1nF to 10nF. Those shown in Fig.1 happen to be the components that I soldered into countless receivers manufactured by Reliance Radio.

With hindsight, the values were not critical and I doubt that combinations within the suggested range would have made any noticeable difference to the performance.

## Gain control

The IF amplifier stage is also essentially similar to the 175kHz version, except that the most likely valve options have been updated to 58, 78 or 6D6 — which were again virtually identical except for the heater rating. One vital factor needs to be considered, however.

Elimination of the RF stage left the IF amplifier as the only one in which the bias can be varied to provide gain control. Application of external variable bias to the autodyne frequency changer might, indeed, have had some effect on its conversion gain — but at some point, the extra bias would inevitably have interrupted the self-oscillation, rendering the receiver abruptly inoperative!

To ensure effective gain control in urban situations, it proved necessary to attenuate the input signal by shunting the antenna terminal to earth in some way. Accordingly, many early model 4/5-valve superhets were fitted with local/distant switches, as shown in Fig.1 (see also the August 1991 instalment).

The shunt resistor was typically a so-called 'non-inductive' type in the range 10-25 ohms, but it was up to designers to select a type and value of resistor which would ensure adequate attenuation relative to the primary winding of their particular antenna coil.

The voltage applied to the gain control via the voltage divider was typically about 35V, but this was again a matter of judgment. With too small a voltage, the gain control might not be sufficiently effective in some areas, even with the antenna switch in the 'local' position. With too large a voltage, unskilled listeners, forgetting all about the local/distant switch, might set the IF stage to near cut off — achieving low volume for sure, but at a very high level of distortion.

An alternative approach, obviating the need for a separate switch, is illustrated in Fig.2. The potentiometer was so wired that turning it anti-clockwise progressively reduced the gain of the IF stage, while simultaneously placing a shunt across the primary of the antenna coil.

Taken from the previously mentioned Tasma 180 receiver, the component valves shown in Fig.2 presumably ensured the right order of control voltage, with the relatively low value potentiometer providing a reasonably tapered shunting action at the low-volume setting.

## Voltages critical

In restoring a receiver conforming to the latter circuit, the same values should be retained if at all possible. A higher value voltage divider would lower the available control voltage; a higher value potentiometer would increase it.

Either way, the substitute component(s) may need to be shunted with a fixed resistor to restore something like the original control characteristic.

Some manufacturers seemed to prefer a configuration more like that shown in Fig.3, possibly because it offered some flexibility in component values and in the exact level of control bias.

In setting it up, it was — and still would be — essential to keep in mind how the circuit is supposed to work, with the potentiometer beginning to shunt the antenna just before the IF amplifier reaches plate current cut off and consequent distortion.

If I seem to be labouring this point, it is because I can still remember the resounding complaints of installers who had to remove, up-end and readjust receivers that had passed muster in the factory but ran into overload problems in suburbs adjacent to high-power transmitters.

At best, it was a matter of readjusting the voltage divider clip; at worst the problem was caused by a potentiometer which failed to achieve a suitably low resistance at the full-off setting.

And, speaking of such matters, it is also worth stressing that, unlike modern audio volume controls, the rotating arm or centre connection in most of the old-type wirewound potentiometers made direct metal-to-metal contact with the mounting bush and locknuts. This didn't matter in circuits like Figs.2 and 3, where the rotating arm was supposed to be earthed, anyway.

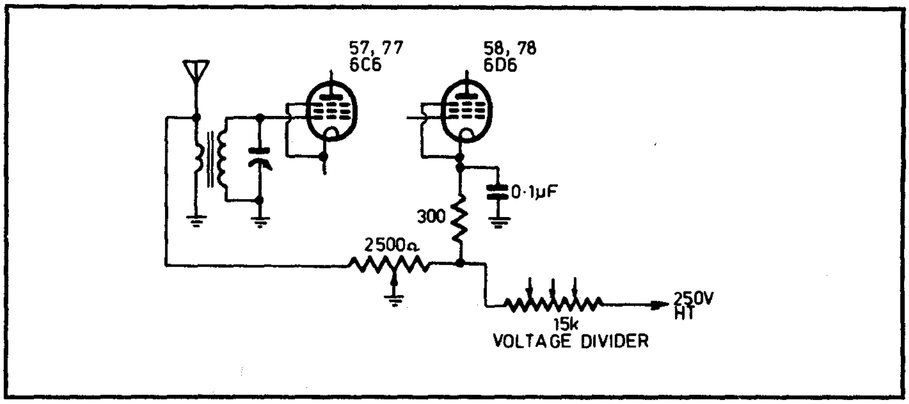


***Fig.2:** A method of eliminating the local/distant switch, by so arranging the gain control that it shorts the antenna to earth in the fully anti-clockwise setting.*

In Fig.1, however, the potentiometer shaft had to be insulated from the chassis — a fiddly job that involved a miniscule tubular sleeve and two larger outer washers, punched from fibre or bakelised cloth.

In those days, pot washers were standard bench oddments; these days, they should be neither overlooked nor mislaid!

## Detector circuit

For the anode-bend detector — another 57, 77 or 6C6 — the component values are again not particularly critical. The cathode resistor has to be large enough, for example, to ensure that the valve operates at near anode current cutoff; anything in the range 10k-20k should serve the purpose.

Whether an individual designer specified 10k, 15k or 20k was probably as much a matter of custom as of deliberation.

The associated bypass needs to be effective for both the intermediate and audio frequencies and, while 0.5uF would have been somewhat more functional at the bass end, most manufacturers settled for the less expensive, smaller and easier-to-mount 0.1uF.

Cheaper, smaller, down-rated components intended for less demanding applications like this were a rarity in those days. Similar remarks apply to the screen bypass, which usually ended up at 0.1uF, even though a case could have been made for 0.25 or 0.5uF. It was unlikely that prospective purchasers would have noticed the difference, anyway.

In the detector anode circuit, the inclusion of an RF choke was a routine carry-over from the past — even though, in my callow youth, I recall one designer suggesting that, for all the good it did, it could well have been replaced by a 10k carbon resistor.

It is sufficient to say that RF chokes in broadcast receivers have traditionally been inexpensive and rather nondescript devices, with (usually) a honeycomb winding or windings comprising as many turns as looked about right!

Suppression of the IF component from the detector output circuit depended mainly on the bypass capacitor, which was most commonly a 100pF unit — sufficient to bypass the IF signal without unduly attenuating the higher audio frequencies. In fact, some designers deliberately opted for values up to about 1nF, on the basis that reduced high frequency response and a more 'mellow' tone might be a good thing!

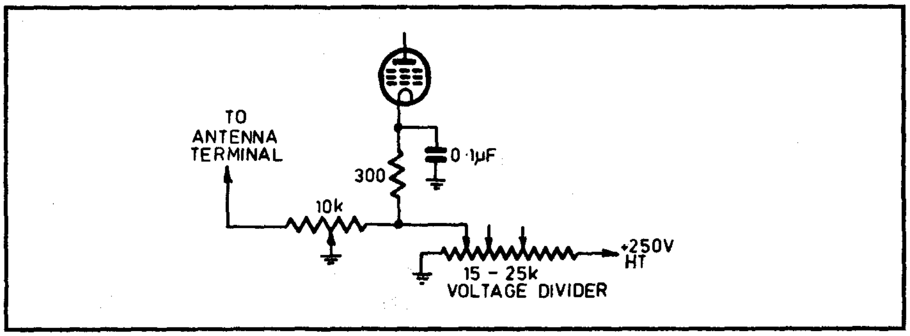


***Fig.3:** When fed from a tapping on the voltage divider, the clip needs to be set to a position which will ensure logical operation of the control, as explained in the text.*

## Output stage

Moving on to the output stage, the first choice was the 59, an impressive valve for the period, housed in a large, domed bulb and with a 'medium' — as distinct from small — ST-16 7- pin base.

With an indirectly heated cathode, it also broke new ground with ratings for operation as a single power pentode (3W output), a single power triode (1.25W), or as a push-pull class B triode stage offering an impressive 20 watts.

Unfortunately, while the 59 was less prone to the grid current problems that plagued the earlier 47, it was also less rugged physically than it should have been, developing more than its fair share of microphonic effects and internal shorts.

The 2A5 which succeeded it in fairly short order, and its 6.3V equivalent the 42, specified in Fig.1, were more compact and reliable and adopted by all local manufacturers at the first orportunity.

Valve type notwithstanding, the grid return resistor needed to be higher in value than the detector output load (250k) but not so high as to allow the output valve grid to drift significantly in a positive direction.

With some output valves, the upper limit had to be further restricted if they were operating with 'fixed' bias — signifying a bias that was totally independent of the valve's own cathode current.

Given these constraints, 500k was widely accepted as the logical choice. In fact, when reconditioning old receivers, it is a good idea to disconnect one end of this resistor and check it to ensure that it has not drifted high with the passing years. These days, the obvious replacement would be 470k.

To ensure full bass response with a 500k grid resistor, the associated coupling capacitor should really be 50nF; but most designers at the time settled for 10nF. The reason, very simply, was that paper dielectric capacitors of the era were prone to leakage (with age), which allowed some of of the positive voltage at the detector anode to reach the output valve grid.

The result could be a reduction in the effective bias and increased current through the valve, with the possibility of overheating and reduced valve life.

Designers' reasoning at the time was that a 50nF coupling capacitor could be expected to exhibit five times the leakage of a 10nF unit, and the difference in extreme bass response did not warrant the added risk.

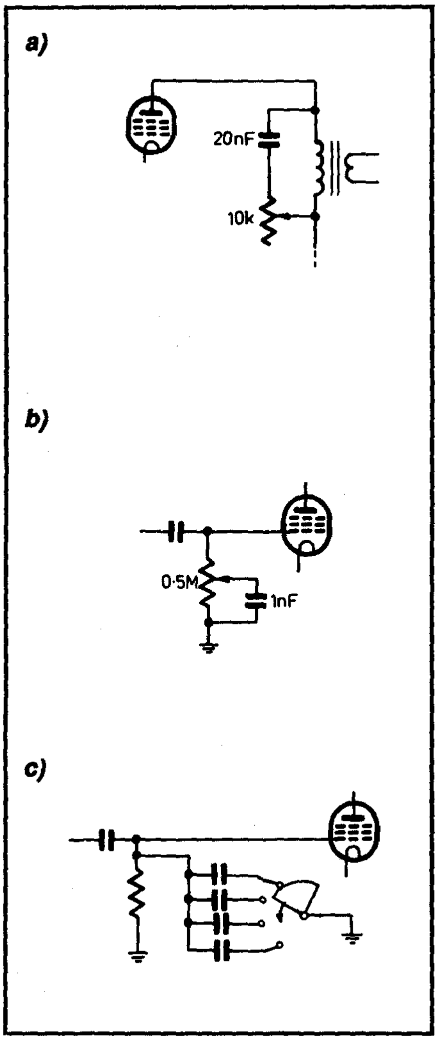


***Fig.4: Three typical methods of providing a top-cut tone control in the early 1930's.***

## Bias method

And that brings us to the so-called 'back-bias' system for the output valve, which was fairly commonly used throughout the valve era. It has been included in Fig.1 as an alternative to the conventional cathode bias depicted in the earlier circuit.

Instead of the centre-tap of the transformer high tension winding being earthed directly, it was returned to chassis through a wirewound resistor of a few hundred ohms, rated to carry the full high-tension current drain.

The resulting voltage drop across it created a negative potential at the transformer CT, which could serve as a negative bias when applied to the lower end of the output valve grid resistor.

Note that, with this arrangement, the negative side of the first filter capacitor must return to the HT centre-tap, rather than the chassis.

This is necessary to prevent the raw 100Hz pulses from the rectifier flowing through the bias resistor and generating a large ripple voltage across it — which would be fed to the output valve grid, producing an audible buzz or hum.

In the days of fluid filled can-type electrolytics, special jumbo-size fibre washers were required to insulate the first capacitor from the chassis.

Old-timers will remember that, when fitting or replacing such electros, it was all too easy to crush the raised centering section of the main washer, allowing the threaded base of the can assembly to short against the chassis.

The final filter capacitor connects between the DC supply line and chassis, with a low voltage electrolytic bridging the bias resistor, positive to earth as per the circuit.

In receivers using an extra filter capacitor to minimise hum, it was commonly connected as shown dotted.

While the back-bias system was used in quite a few 1930's style receivers, the reasons for preferring it to conventional cathode bias were at best tenuous:

- An assumption that output valves operated to better advantage with 'fixed' rather than cathode bias. In class AB and class B push-pull, such may have been the case; but in ordinary single-ended class A stages there was no significant difference between the two methods. With the average cathode current remaining constant in class A, with or without signal, cathode bias was stable or 'fixed' anyway.
- In the negative line, the back-bias resistor could conceivably have offered additional decoupling between the first and final filter capacitors, thereby supplementing the filtering effect. I'd need to be convinced that this was a significant factor.
- With cathode bias, the HT supply line had to be set to about 265V, if the output valve was to operate at an effective 250V plus bias. With back-bias, the HT supply line could be maintained at 250V.

This last point warrants brief comment. In an era when valves and other components were prone to premature failure, the suppliers, when challenged, were likely to claim as excessive a supply voltage greater than 250V — ostensibly the 'natural' voltage limit for the 20 and 50-series valves.

It was an excuse rather than a reason for component failure, but some designers found it easier to anticipate the objection by opting for back-bias.

## Treble response

But back to the circuit. As mentioned in an earlier article (August 1991), pentode output valves had a very high output impedance which resulted in a rising treble response when operating into a reactive load such as a conventional loudspeaker. To correct the resulting rather strident tone, most designers in the early 1930's included a capacitor in the audio chain intended deliberately to attenuate the higher audio frequencies.

One option employed in the Tasma receiver, referred to earlier, was to use a larger than normal bypass on the anode of the detector. Instead of the usual 100pF RF bypass, they used a 1nF, which is large enough to round off the treble response as well. In practice, the capacitor ended up anywhere in the range 100pF - 1nF, depending on the intentions of the designer.

An alternative or supplementary measure was to wire an audio bypass to the anode of the output valve, larger in value by reason of the lower nett impedance of the output circuit. The most common value to give a moderately 'mellow' tone was 10nF, as shown in Fig.1.

Early practice was to wire the capacitor directly between the anode of the output valve and chassis, but this proved to be unwise. Even at zero volume, the capacitor was subjected to a DC voltage of around 250V. At high output levels, the superimposed audio signal could boost this to peaks of double that figure, with a very real risk of breakdown.

This, in turn, would cause a short-circuit current through the output transformer primary, and a heavy load on the rectifier — until either it or the output transformer failed. In the meantime, removal of voltage from the output valve anode would divert electron flow to the output valve screen grid, raising its structure to a bright red heat, with the risk of warping and/or the release of occluded gas. It could all add up to an expensive repair, if the receiver was not switched off promptly after the initial failure.

If you come across a vintage receiver wired this way, the capacitor should be re-connected between anode and B+, as shown. It will be just as effective in limiting treble response, but will reduce the stress on the capacitor and obviate the secondary consequences in the event of a breakdown. If the old capacitor is suspect, replace it with a good quality type rated to at least 400V.

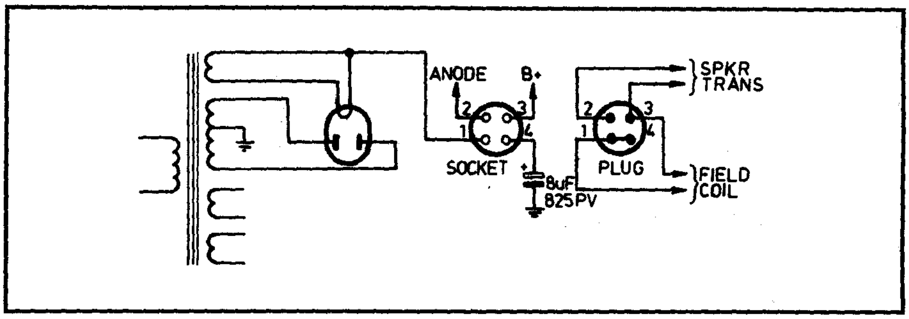


*Fig.5: Wiring a loudspeaker socket and plug as shown above could protect the first filter capacitor from damage in the event of a receiver being switched on without the loudspeaker being plugged in.*

## Top-cut controls

Also mentioned in the August issue was the fact that top-cut (treble) tone controls became a common feature in post-1930 receivers — one idea being to place a potentiometer, typically 10k, in series with the abovementioned treble-cut potentiometer. By selecting a higher than normal capacitance (e.g., 20nF), rotation of the potentiometer would vary the tonal balance from 'bright' to 'mellow'.

Convenient though it may have been, grounding the arm of the potentiometer would have increased the risk of capacitor breakdown, as mentioned. Returning the arm to B-plus as in Fig.4(a) reduced the stress on the capacitor, but called for the use of a self-insulated pot or the provision of insulated washers; this, plus the unpleasant prospect of an exposed control spindle connected internally to the HT line.

Faced with a 'Hobson's choice', many designers opted for a tone control in the grid circuit of the output valve, with or without additional fixed compensation across the output transformer primary.

In the arrangement shown in Fig.4(b), a 500k potentiometer served as the grid resistor, with a capacitor of around 1nF bridging between the moving contact and either (usually the earthy) end. As the moving contact approached the opposite end, the treble response would be progressively reduced.

Convention was to wire the pot so that clockwise rotation increased the treble response and, to ensure a subjectively smooth gradation between the two extremes, designers might specify a linear pot or one with something other than the conventional C-taper used for volume controls.

In a notable example of sideways thinking, one local company came up with a novel form of tone control, which was adopted for a time by some manufacturers. Styled like an ordinary potentiometer, it contained a sequence of interleaved metal shims and mica separators, forming a half-dozen-odd mica capacitors, stacked one upon the other. As the shaft was rotated, a semi-circular vane bridged flexible extensions from the metal shims, progressively increasing or decreasing the effective capacitance as suggested by Fig.4(c).

As I recall, only one version of the control was released, with a nett capacitance to suit the rela-

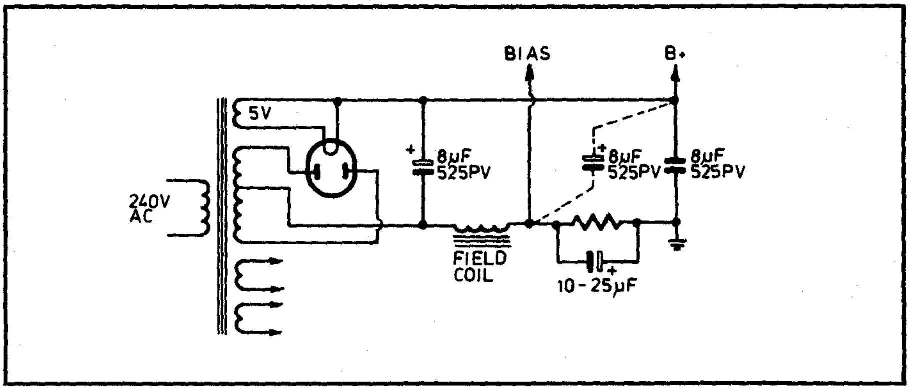


*Fig.6: For reasons best known to themselves, some designers included the loudspeaker field winding, as well as the back-bias resistor in the negative supply lead. It placed about -200V on the exposed shell of the first can type electrolytic!*

tively high impedance of an output valve grid circuit.

## Loudspeaker connections

In 4/5-valve receivers of the period, the output transformer was almost invariably mounted on the loudspeaker, with four leads running back to the receiver — two each for the transformer and the field coil.

Having in mind that one end of each was commonly connected to the B-plus line in the receiver, as per Fig.1, a three-way cable would have been sufficient in many cases.

Common practice was to use either a 4-pin or 5-pin valve socket and matching plug for the loudspeaker connection; but while some brands happened to use a similar pattern of connections, there was certainly no industry standard.

A routine fitment on a serviceman's bench in those days was a 'universal test speaker', with provision to simulate various values of load and field coil and a patch-cord system to set up the appropriate connections.

One of the things one learned, in the old days, was never to switch on a chassis without a suitably wired loudspeaker being plugged in.

With no field coil in circuit, the first filter capacitor could be subjected to 550-odd peak volts, with a high risk of electrical breakdown or, worse still, being blown apart by internal vapour pressure — a nerve-shattering and messy event!

Curiously, one very simple precaution was available, which most manufacturers seemed to ignore: by wiring the loudspeaker socket — 4-pin or 5-pin — so that the input filter capacitor was in circuit only when a matching loudspeaker plug was in place.

Purely as a guide to what to look for, Fig.5 shows how a plug and socket could conceivably be wired to protect the first filter capacitor.

Note that the first capacitor is wired only to pin 4 of the loudspeaker socket. A link in the plug, when inserted, bridges it across to pin 1 and thence to the rectifier filament and one side of the field coil. Pin 3 provides a return path for the field and also a connection to the B+ line in the receiver, while pin 2 provides the connection for the output valve anode.

A 5-pin socket and plug, similarly wired, would leave one pin spare, which could conceivably provide an earth link between the chassis and the loudspeaker frame — a link that is neither essential nor common.

## The power supply

Apart from the use of back-bias, the configuration of the power supply in Fig.1 is straightforward. It shows two 6.3V heater windings, but it was not uncommon to make do with one suitably heavy winding as an economy measure.

In terms of HT current drain, the 59 would draw a nominal 44mA in class A pentode service.

As a detector with a 500k load, the 57 would not draw more than 0.5mA of anode current. The current drawn by the IF amplifier stage would depend on the gain control setting, but a median figure would be 5 milliamps. At a guess, the over-biased autodyne converter would draw about the same.

Allowing 20mA at most for the voltage divider network, the likely drain comes to around 75mA, which was comfortably within the capacity of an 80mA power transformer. To provide the requisite - 18 bias for the 59 output pentode, the back-bias resistor would need to be around 240 ohms — in those days 250 ohms.

To provide the requisite voltage drop, the field coil works out at around 1800 ohms — available in those days 'on order', but with 2000 ohms as the nearest off-the-shelf value.

Substituting the alternative valve types suggested for the RF and IF sections would make no difference whatever to the current drain. In the output stage, there was a slight difference between the 59 and the 6-pin 2A5/42 but, in practice, circuit values nominated for the 59 would have been near enough for the later types.

One variation of the above power supply configuration, which collectors may well encounter, borders on the curious. As shown in Fig.6, it places the field coil in series with the negative rather then the positive supply line.

When I first came across the arrangement, I recall asking the production engineer why it was used. His only response was to assert that it worked fine — didn't it? Perhaps so, but I was offered no reason to believe that it was any better than the conventional hook-up.

One painfully obvious fact was that the first can-type electrolytic, standing boldly erect above the chassis, ran about 200V negative with respect to all the other exposed metalwork — which could hardly have escaped the notice of factory workers required to handle live chasses.

## Chasses that 'bite'!

Indeed, one such operator pointed out that factory 'clowns' sometimes switched a receiver on for few seconds with the loudspeaker unplugged — therefore with no field coil in circuit. As a result, the first electro would be charged to the full peak voltage, with -500V or so on the exposed can. A loud yell and/or expletive was a sure sign that the charge had lingered for long enough to greet the next person to handle the chassis!

Finally, on the subject of chasses with a 'bite', it is appropriate to mention one practice in early mains receivers that was decidedly questionable.

In the early 1930's, domestic mains wiring was comparatively primitive, particularly in regard to appliance earthing arrangements and anti-interference measures. Many homes had only one or, at most, two regulation power points and it was common practice to plug appliances and/or receivers into maverick European or American 2-pin sockets — or, worse still, into light sockets with the aid of 2-way bayonet adaptors.

Fed by indoor aerials in the immediate electrostatic field of the mains wiring, the receivers often suffered more than their fair share of electrical 'snap, crackle and pop'. To make matters worse, the signal strength from metropolitan radio stations was well below what it is today.

In an attempt to attenuate noise interference, many designers adopted the practice of connecting capacitors — usually 10nF tubular types — between each side of the 240V primary winding and chassis.

Whether it was all that effective in the average case is a matter of debate, but it certainly provided an unpleasant 'tingle' to anyone who touched a chassis or an aerial wire that was not earthed in the DC sense. The 'tingle' was due to the natural reactance of the capacitor — 318,000 ohms at 50Hz.

More to the point, breakdown of the capacitor could turn the receiver, the aerial — and/or phono pickup — into a potential 240V death trap.

Granted, manufacturers normally used high quality imported capacitors for the purpose, and I never heard of any actual fatalities. But if you come across a chassis with bypasses on the primary winding of the power transformer, my advice is to remove them once and for all. They're not neccessary, these days, and we can do without the 'tingle' — or most certainly the full 240 volts!

*(To be continued)* ■

# 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.

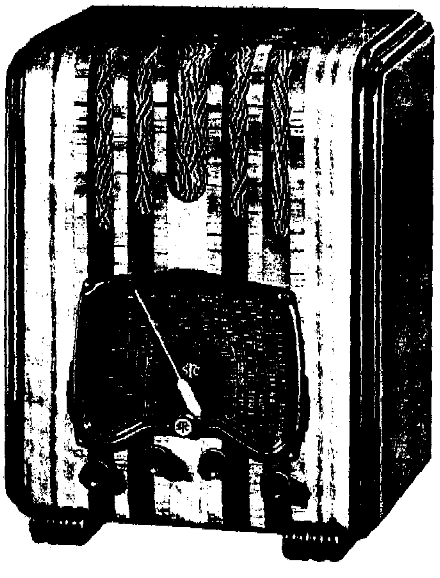
It was left to the valve manufacturers to solve the problem, by the release of special frequency-changer or frequency 'converter' valves which could perform the functions of oscillator and mixer more or less independently. For the Australian radio scene, the most notable such valve was the American designed 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-G, 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 milliamps, 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 G1 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 reason, 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.

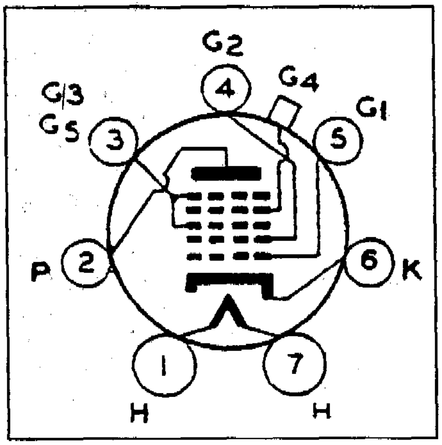


***Fig.1: Pin connections for the 2A7 pentagrid converter, as viewed from the underside. The cathode, G1 and G2 provide the basic triode oscillator.***

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 where 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.

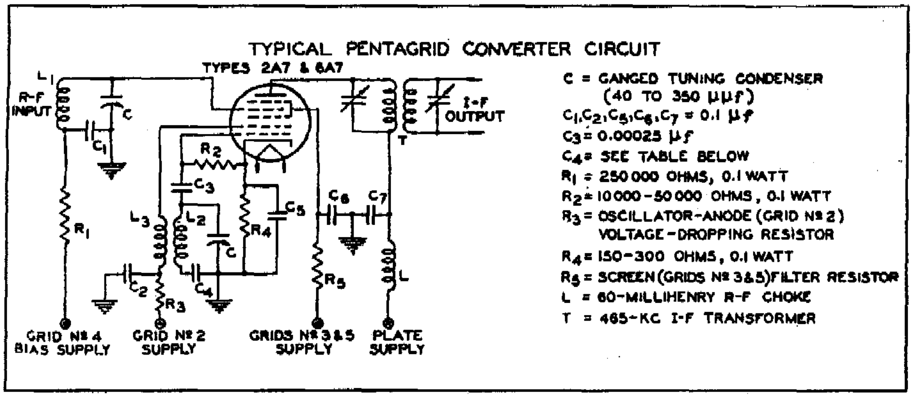


***Fig.2: RCA's typical circuit for the 2A7 pentagrid converter, from an early RCA receiving tube manual. The oscillator circuit (bottom), the RF signal input circuit (left) and the IF output circuit (right) can be readily identified.***

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

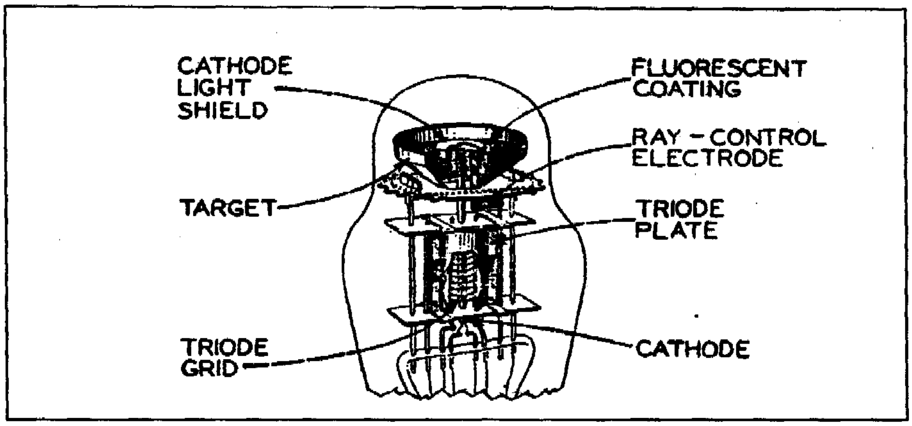


***Fig.3: The electrode structure of the 6E5, taken from RCA literature. It was the first electron ray indicator to be widely adopted in Australia, and was followed by quite a few variants released by RCA and other manufacturers.***

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 6.3V 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.

In 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.

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 era — 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 0.25 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.

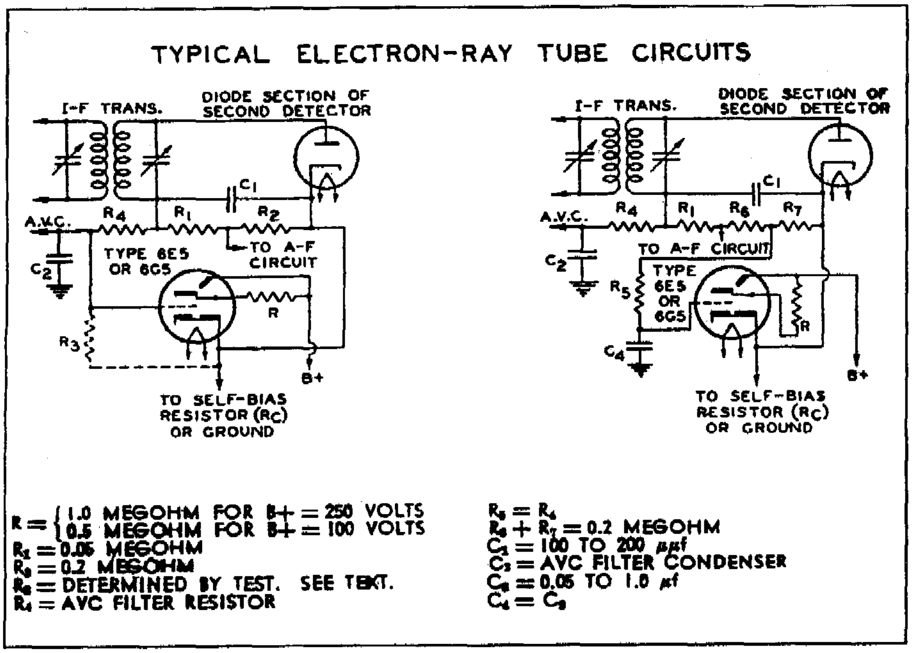


*Fig.4: Typical early tuning indicator circuits published by RCA. The circuits were later refined in various ways, and the 6E5 itself was displaced by other types which offered improved display characteristics.*

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.

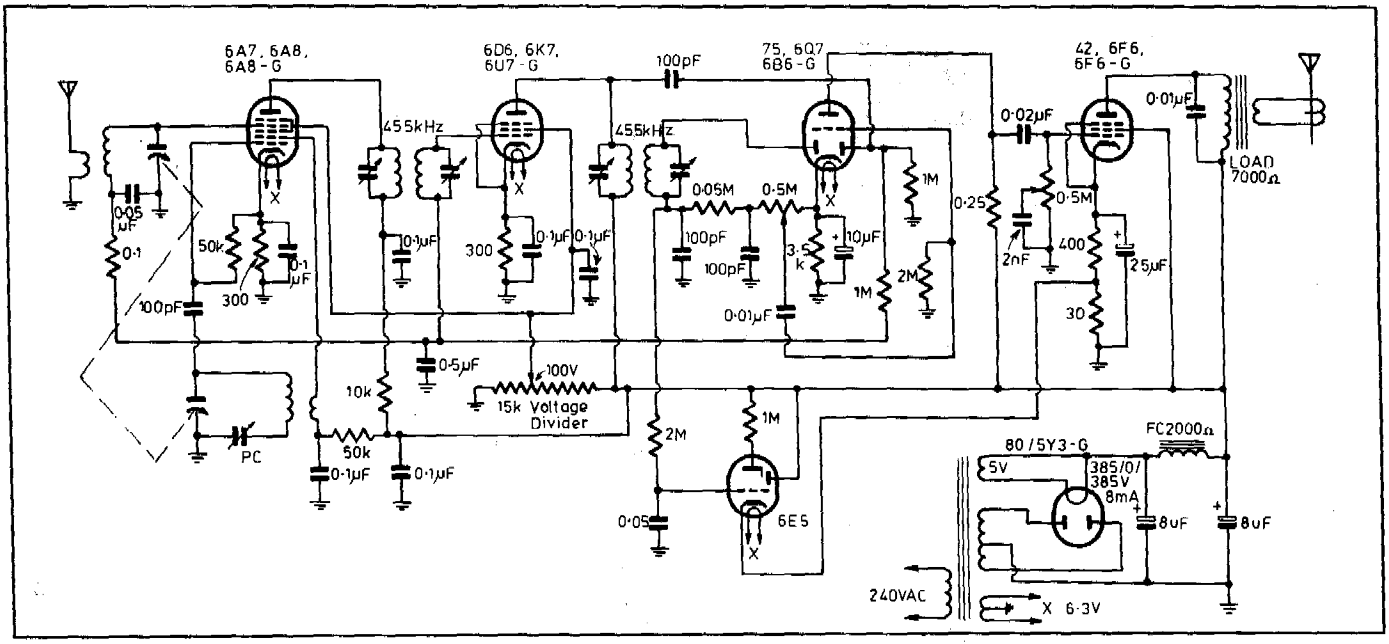


***Fig.5: The incorporation of a pentagrid converter and AGC called for basic changes in the design of 4/5-valve superhet receivers. This circuit is not based on any particular model, but is nevertheless typical of overall Australian practice in the mid 1930's. With rare exceptions the 2.5V valves had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

# When I Think Back...

by Neville Williams

## Vintage radio receiver design — 7
## Enhanced audio, dualwave tuners & frequency changers

During the latter half of the 1930's, the audio systems in Australian radio receivers were upgraded by the adoption of negative feedback — offering better sound for both radio and record reproduction. Up front, dual- or triple-band tuners extended their coverage to the international shortwave bands. Ornate edge-lit glass dials became routine, perhaps in anticipation of the day when they would give place to a video screen.

While these and other developments can be identified with the late 1930's, the sequence in which they appeared is ambiguous. In the pursuit of market share, manufacturers tended to major on different features at different times, with the advantage accruing to those that managed to get it right in terms of sales appeal.

In this present article, it will be more realistic simply to discuss aspects of receiver design which characterised the period from around 1936 to the outbreak of war — an event which was to put domestic radio on hold 'for the duration'.

Fig.5 in the last article typified the design of domestic 4/5-valve mains powered superhets of around 1935/6. Fitted with AGC and magic-eye tuning, and offering acceptable audio quality, they gave their owners little cause for complaint. In a laboratory situation, however, limitations were still evident — which posed an ongoing challenge to design engineers.

So it was that while the 2A6/75/6B6 series of hi-mu diode-triodes appeared to meet the immediate need, engineers knew that they were lacking in treble response because of the so-called *Miller effect*. Incoming signals were being 'shunted' by the valves' intrinsic grid-anode capacitance, rendered the more serious by the fact that the anode was not simply an inert electrode but one that carried an amplified version of the signal — in opposite phase to the grid input.

The end effect, according to J.M. Miller of the US Bureau of Standards, was as if the grid-anode capacitance was (M+1) times its actual value, where M represented the voltage gain of the stage. The *Radiotron Designer's Handbook* (1940) quotes the 75 as having an inherent grid-anode capacitance of 1.7pF so that, allowing for a gain of 60, this translated into a dynamic (Miller effect) input capacitance of 105pF.

### Duo-diode pentodes

While it could be argued that this was less of a liability than the audio bypass capacitors included elsewhere in the circuitry, engineers saw it as a needless treble loss of original signal that should be avoided, even if only on principle.

Valve manufacturers responded to their dilemma with the 2B7/6B7/6B8 series of duo-diode general purpose pentodes. As an R-C coupled audio amplifier, these offered a potential stage gain of 100 but, with a static grid-anode capacitance of only 0.007pF, the Miller effect capacitance amounted to less than 1pF — compared to 105!

Not surprisingly, for the cost of a screen feed resistor and bypass capacitors, many engineers opted for the diode-pentode rather than the diode-triode.

Alert to a still further design option, Australia's Amalgamated Wireless Valve Co (AWV) devised a special variant of the 6B7, the 6B7S, followed by its octal-based equivalent the 6G8-G. Whereas the original 6B7/6B8 had been classified as 'remote cut-off' pentodes, the 6B7S and 6G8-G were redesigned with a full variable-mu characteristic, cutting off at -43V — about twice the figure for the original types.

AWV engineers reckoned that the 6B7S/6G8-G could still serve as plug-in alternatives for the original types in most audio applications.

However, the full variable-mu characteristic should enable them to be used with variable bias and the valve(s) did, in fact, find limited use as gain-controlled audio amplifiers, supplementing normal front-end AGC systems.

In practice, however, they found their widest application as IF amplifiers in place of the traditional variable-mu 78/5D6/6K7 pentodes — the difference being that the IF output could be fed to the 6B7S/6G8-G's own diodes for detection and AGC voltage. By so doing, the entire tuner could be standardised around two valves, with an antenna feeding into one end and an audio lead coming out the other (see Fig.2).

The audio system could then likewise be self-contained, ranging from a single high-gain valve for an 'el cheapo' mantel set, to something more pretentious for standard or up-market models.

It may seem like a small point, but it fitted in with the emerging philosophy of regarding the audio system as an audio amplifier in its own right, rather than extra stages stuck on the rear end of a radio set!

### Power pentodes

Back in 1936, the greatest single limitation on audio quality in 4/5-valve receivers had to do with the power output pentode.

With their high output impedance, these exhibited an exaggerated treble response and exaggerated harmonic distortion, when operating into the highly reactive load presented by a loudspeaker. They also imposed very little electrical damping on the cone, resulting in an unnaturally resonant or 'boomy' kind of bass.

As noted in earlier articles, designers sought to counteract these effects by wiring a tubular capacitor (e.g., 10nF or 0.01uF) across the loudspeaker transformer primary, and/or resorting to treble-cut elsewhere. It sufficed as an interim measure, but the need to find a more fundamental solution to the problem was hastened by the release of the high-power 6L6 beam tetrode, which could generate high frequency transients across a loudspeaker load of quite startling — and destructive — proportions.

In *Radiotronics* No.71 (December 1936), AWV published a circuit which proposed the most radical approach of all to the overall problem, namely to replace the output pentode with a 2A3 filament type power triode.

Adequate drive to the 2A3 involved the use of a 6C6 resistance-coupled pentode, preceded in the tuner by a 6A7 and a 6B7S. In this so-called 'fidelity' design, the highest level of overall distortion at any signal level, any modulation percentage and/or any condition of loudspeaker load was said to be 7%.

If this seems high by present standards, similar tests on a contemporary receiver using an output pentode yielded a figure of 30%!

Despite this evidence, and to the best of my knowledge, the idea was taken up only by a few hobbyists. Manufacturers presumably looked with disfavour on the marginally larger and more awkward power transformer that would be required, and the potentially less rugged output valve. In addition, a new scaled-down beam power tetrode was on the horizon (the 6V6), which would make for good sales promotion — even if it didn't amount to much in practice!

## Negative feedback

As it happened, the same issue of *Radiotronics* was cautiously optimistic about the idea of using *negative feedback* with pentode (or tetrode) output valves — for the reason that, while preserving their efficiency in terms of current drain, it could artifically reduce their output impedance to approach that of a power triode. As a result, frequency response would be flatter, distortion drastically reduced and loudspeaker damping greatly improved.

Negative feedback involved diverting a small proportion of the output voltage from the power stage back to an earlier point in the audio signal chain, such that it would be out of phase with the input signal at that point.

Inevitably, in counteracting or partially cancelling the original signal — hence the description 'negative' or 'inverse' feedback — it would reduce the apparent gain of the system and necessitate a larger input signal. It offered a vital bonus, however.

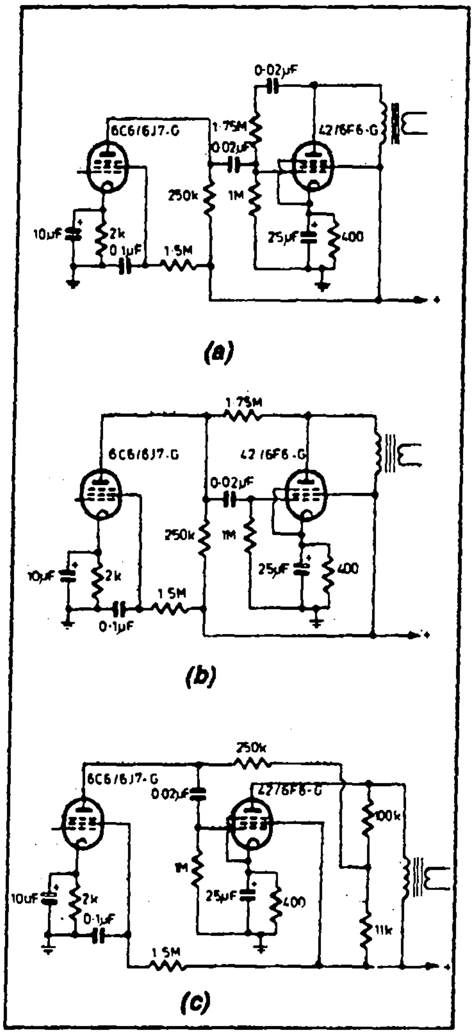


***Fig.1: Typical circuit configurations for applying negative feedback around the output stage of ordinary receivers. Such circuits normally remain valid after replacement of the output transformer or even the complete loudspeaker.***

If the amplifier gain within the feedback loop tended to rise for any reason, over any part of the frequency spectrum, the output signal would increase accordingly. But so also would the sample fed back via the feedback path — thereby increasing the degree of cancellation and further reducing the system gain.

By such means, negative feedback would tend to counteract variations in stage gain, either up or down, so that the overall frequency response would be made smoother.

Similarly, if the stage(s) within the feedback loop generated spurious harmonics, they would be fed back to the input along with the legitimate signal. Being then amplified in reverse phase, internally generated harmonics would tend to cancel themselves, effectively reducing the level of distortion.

Again, if the loudspeaker cone tended to prolong sonic vibrations of its own accord, the mechanically generated wave trains would be fed back to the input of the amplifier in reverse phase, and serve ultimately to counteract the spurious cone movements which gave rise to them in the first place.

Research in Australia and elsewhere established that a voltage gain reduction of around 3:1 or 4:1 (10 to 12dB of negative voltage feedback) was sufficient to impart triode-like characteristics to a power pentode output stage, in respect to the vital parameters mentioned above. In particular, the new and more economical 6V6-G could be expected to behave like a 2A3!

## Simple circuits

Since the deficiences in the audio end of a typical 4/5-valve receiver related to the disparate characteristics of a power output pentode (or tetrode) and the complex anode load presented by a loudspeaker, an effective negative feedback path could most simply be provided between the anode and grid of the output valve.

Fig.1 shows a number of possible configurations, which appeared in literature of the period. Diagram (a), from *Radiotronics* 71, is probably the most obvious way of placing a feedback loop around the output valve, with a DC blocking capacitor and a series resistor simply strung from the anode back to the grid. With the grid shunted to virtual earth through its own 1M resistor and by the 250k anode supply resistor and the anode resistance of the 6C6/6J7-G, slightly less than 10% of the anode signal swing would be effective in the grid circuit.

At full output, on the basis of 3.1W into a 7000-ohm load, the signal voltage at the anode would be about 150V RMS or 212V peak.

Of this, about 10% or 21V peak would be fed back to the grid — so that instead of the rated figure of 16.5V peak, the required drive with feedback would become (16.5 + 21), or 37.5V peak. This would be equivalent to a gain reduction of just under 2.3 times or 7dB — a rather

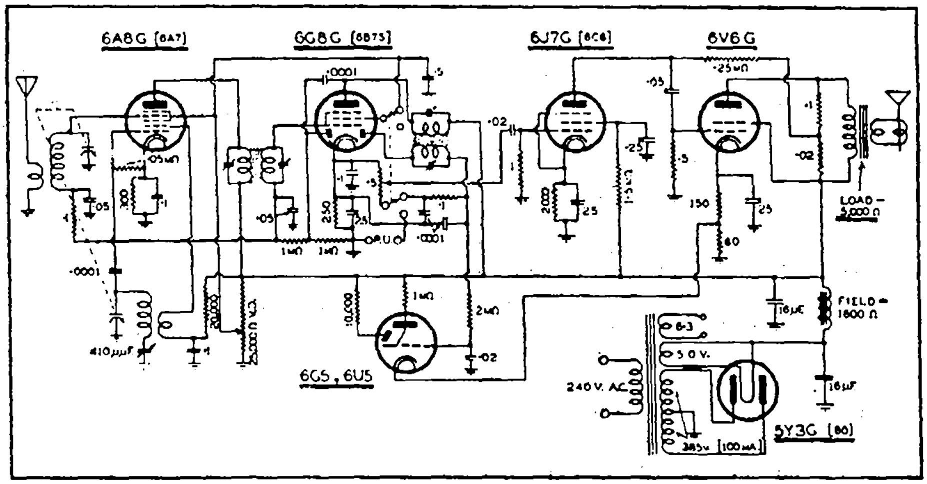


*Fig.2: Circuit practice in the later 1930's, as exemplified in Radiotronics 81, published in November 1937. The choice of a 6G8-G in the IF stage allowed a 6J7-G pentode to be used as a driver ahead of the then-new 6V6G beam tetrode output valve. The circuit also assumes the use of ferrite-cored IF transformers, as indicated by the dotted area between windings.*

cautious figure in terms of audio feedback design.

The figures indicate, however, why AWV encouraged engineers to provide a capable audio driver ahead of a feedback output stage — to ensure that adequate gain would still be available, along with a distortion-free drive voltage.

Fig.1(b) is/was very similar to (a), except that the blocking capacitor was omitted, with the resistor connecting to the anode of the voltage amplifier.

With the values shown, the gain reduction would be identical to that of 1(a) — although in practice, the values could conceivably have been juggled slightly to maintain the effective DC anode feed resistance to the 6C6/6J7-G at the then-recommended level of 250k.

Fig.1(c) emerged as the most popular configuration of the day, probably because the feedback percentage was determined by a resistive divider wired directly across the output transformer primary.

With the constants shown, the basic divider was set for 10% — although only four-fifths of this, or 8%, would be effective at the grid because of the secondary divider formed by the feedback/load and grid resistors.

Again, some juggling of the divider could well have been justified to get the gain reduction closer to the desirable 3:1 or 10dB.

Such details aside, most 4/5-valve receivers employing negative feedback used a simple configuration along the general lines indicated in Fig.1 — and for this we can be duly thankful. Such circuits are inherently stable, and failed components can be replaced with equivalent values without apprehension.

This applies even to a faulty output transformer and, provided the replacement is a functional approximation of the original, the negative feedback will continue to ameliorate possible problems with frequency response, distortion and damping.

The same cannot be said of the more complex audio systems found in contemporary up-market receivers or stand-alone audio amplifiers. In such equipment it was common practice to mount the output transformer on the chassis, rather than on the loudspeaker, running the feedback loop from the secondary of the output transformer to a point relatively early in the audio chain. The design objective was to combat possible aberrations not just in the output stage, but also elsewhere in the audio chain.

In such circuits, the polarity of the transformer connections are critical, determining whether the feedback is negative or positive — in the latter case rendering the amplifier hopelessly unstable.

## Voice coil feedback

If you have occasion to change the output transformer in such equipment, the appropriate procedure is to wire the primary in the most convenient manner, effecting the necessary connections to B-plus and the anode — or anodes in the case of a push-pull output stage.

However, the leads from the secondary winding should be spot soldered in a temporary fashion to the loudspeaker socket, one lead being usually earthed while the other feeds the other end of the voice coil and the negative feedback circuitry.

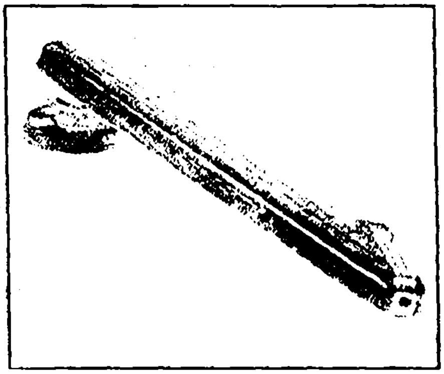


*Fig.3: The earliest Astatic crystal pickups had a straight, rectangular metal arm. This then-new 0-7 model, featured in our December 1939 issue, had a more ornate moulded arm with offset head to counteract tracing error.*

Unsolder this feedback lead and leave it disconnected for the next step. Connect the loudspeaker, switch the amplifier on and feed any available signal through it at a low volume setting.

Now, keeping your hands clear of high voltage leads, touch the feedback wire on to the point from which it had been removed. If the volume level increases or, more likely, if the amplifier emits a loud shriek or begins to 'motorboat', it is a pretty sure sign that the feedback is now positive.

In this case switch off, reverse the connections from the transformer secondary winding and try again. This time, reconnecting the feedback lead should reduce the sound level from the loudspeaker, indicating that the feedback is now negative, as it should be.

A problem with multi-stage feedback loops is that the phase of the feedback can still rotate at supersonic frequencies, to produce a degree of instability which may or may not compromise the behaviour of the system in the audible range.

Ideally, this should be checked after an output transformer has been changed — a procedure which calls for a high-performance AF/RF signal generator, square-wave generator and a wide-band oscilloscope.

But this assumes another level of expertise and is really outside the scope of this present article. Domestic 4/5-valve receivers rarely used voice coil feedback, if only because the output transformer was conventionally treated as part of the loudspeaker, rather than of the chassis.

## Typical circuit

It fell to my lot to draft the circuit shown in Fig.2, which was devised by AWV Applications Engineer R.H. (Dick) Errey. Published in *Radiotronics* 81 (November 1937), it was intended to epitomise appropriate circuit practices for contemporary 4/5-valve superhets.

The tuner was concentrated around a 6A8-G and 6G8-G — in the latter case for reasons outlined earlier. (A separate article in the same issue of *Radiotronics* explains why a high performance pentode should be provided for in feedback circuits such as those illustrated in Fig.1).

The circuitry to do with detection and AGC broadly follows recommendations discussed in the last article, as also does that involving the 6G5/6U5 remote cut-off 'magic eye' tuning indicator.

Series resistors in the HT supply to G2 of the 6A8-G and 6G5/6U5 target are intended to provide a self-compensating effect, particularly if the HT supply voltage should rise above 250V as a result of mains fluctuations.

By way of further explanation, the article says that investigation of early complaints about unduly short life of tuning indicators reveals that it had commonly been due to excessive target current — leading, in some cases, to the target structure becoming red hot!

It is also noteworthy that the circuit provides for Radio-Phono switching, with one switch pole to select the desired input and the other to silence the tuner by interrupting the supply to the 6G8-G screen grid. The latter provision was to prevent possible break-through of noise interference or powerful radio signals when playing records.

It was about this time, as I remember, that crystal pickups (Fig.3) were making an initial impact on the market. While the early Astatic piezo models were rather clumsy compared with their postwar lightweight counterparts, they had more output and a much fuller sound than typical 1930-style magnetics. They contributed significantly to the mid-1930's swing to combination 'radiograms'.

The beam tetrode output valve is referred to in *Radiotronics* as 'the new 6V6-G' — of potential interest to set makers because it represented new technology, offered a marginal increase in sensitivity and an extra watt of power output, albeit at about 10 milliamps extra current drain.

Note that the feedback circuit follows Fig.1(c), but with an increased ratio of 20% — which according to *Radiotronics* ends up as an effective 10% at the 6V6-G grid.

## Emphasis on feedback

In effect, AWV chose to divert the extra sensitivity of the 6J7/6V6 combination to the negative feedback, to provide a further contribution to quality rather than to gain — an indication of the emerging design philosophy of the day.

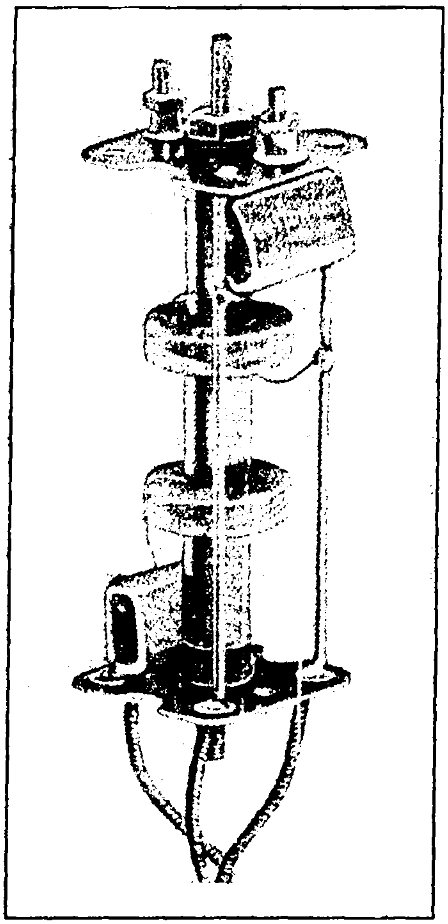


***Fig.4: From the April 1941 issue of R&H, this Britannic IF transformer, minus its shield can, uses litz pie-wound coils, fixed tuning capacitors and adjustable ferrite slugs for alignment.***

So too, perhaps, was the tacit acceptance of a 100mA power transformer and the specification of 16uF filter capacitors, presumably to ensure adequate filtering with the somewhat reduced value of field coil impedance.

On the subject of gain, AWV suggests that the sensitivity should still be adequate for the reception of interstate broadcast stations or for use on the shortwave bands.

The addition of an RF stage, they say, would result in a high performance receiver with ample gain and good quality reproduction from both radio and records. As such, the design would become the 1937 counterpart of the high-performance 175kHz circuit featured earlier in this series.

A point of note is that a pattern of dots between the windings of the IF transformers seeks to convey the idea that each of the relevant coils has a central ferromagnetic core — normally slugs of powdered iron or oxide, moulded with an insulating binder and cemented inside the former on which the coils were wound.

As pointed out in the last chapter, the merit or Q-factor of IF transformers had already been boosted by winding the coils with litz wire, which offered a significant reduction in their RF resistance. It transpired that insertion of a suitably formulated ferrite core through the centre of each winding could provide the required inductance with fewer turns, therefore with less wire and a still further reduction in RF resistance.

This, plus the use of low-loss moulded formers (e.g., Trolitul) and Trolitul-based varnish pushed the Q-factor of 465kHz IF transformers to the point where designers, once again, had to balance selectivity against loss of treble due to sideband cutting.

(The emergence of Trolitul was featured in the very first issue of our predecessor *Radio & Hobbies* — April 1939 — in a feature article and in an RCS advertisement.

The same issue contained a contemporary discussion of selectivity by R.H. Errey, mentioned earlier. Further articles on selectivity and coil design appeared in the June, July and October 1939 issues, written by Eric M. Fanker — chief engineer of Thom & Smith, makers of 'Tasma' receivers).

The use of litz wire and ferrite cores became so routine from then on that they were taken for granted, and not necessarily designated in circuit diagrams.

It also became routine to mould cores and formers with a matching thread, so that IF transformers and tuning coils could be aligned by positioning cores in the formers, thereby reducing reliance on trimmer capacitors (Fig.4).

This subject will be discussed in detail in a later article, to do with receiver alignment.

## Shortwave coverage

What triggered consumer interest in shortwave listening in the 1930's is open to speculation, although *EA*'s shortwave listening columnist Arthur Cushen may have offered an inadvertent clue in his recent mention of the commencement of the BBC's World Service from Daventry, UK, in 1932.

Perhaps it was also due in part to diminishing interest in ordinary long distance reception. With 'me too' programming and the increasing use of transcription discs, distant Australian stations no longer sounded all that different from the locals.

By contrast, periodic re-broadcasts of overseas stations often highlighted news, sport and events from countries that were still weeks away by steamship, and equally remote in terms of culture. With more and more overseas broadcasts penetrating Australian airwaves, it was intriguing to discover that they could be accessed with an otherwise normal receiver equipped to cover the shortwave bands.

For listeners in rural areas, shortwave reception offered a further bonus in that shortwave transmissions, both overseas and local, could often be heard at times when atmospheric conditions had obliterated broadcast band reception.

Appearing on the market from about the mid-1930's, shortwave coverage began almost as a fad, but attracted attention as the overseas political situation edged towards war.

Most of the resulting receivers were D/W (dual wave) types, with coverage from about 16-51 metres (19-6MHz) in addition to the normal broadcast band. More pretentious receivers often boasted two shortwave bands in addition to the broadcast band, covering 13-39 metres (23-7.7MHz) and 35-105 metres (8.6-2.9MHz) — the latter taking in both the 40m and 80m amateur bands.

Because shortwave signals were commonly weaker than local broadcasters, adequate receiver sensitivity was essential. But a normal 4/5-valve D/W superhet, with the ability to log interstate stations, was usually capable of a useful performance on short waves. The 5/6-valve circuits with an RF stage were invariably better, in terms both of sensitivity and signal/noise ratio. Even a few 3/4-valve mantel sets boasted shortwave coverage, although with strictly limited performance.

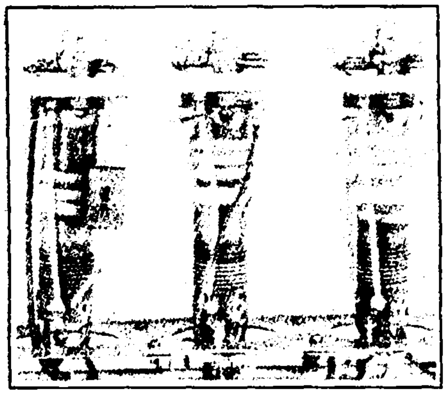


*Fig.5: A sub-assembly of (presumably) Tasma coils from the late 1930's, ready to be bolted into a chassis and fitted with cans. Alignment trimmers are at the top, normally accessable through holes in their respective cans.*

## Coils and switches

Technically, shortwave coverage involved the provision of an alternative set of tuning coils, with provision to switch from the normal broadcast coils to their shortwave counterparts — the latter usually being solenoids comprising a dozen or so turns of enamelled wire, space wound on a former 19mm or so in diameter.

As often as not, published circuits did not indicate the switching in detail, if at all. It was assumed that technical personnel would understand that a rotary switch would establish contact with the active end of each winding, as required, the 'earthy' ends being permanently wired into circuit.

For dual-wave receivers, common practice by the major manufacturers was to use formers and cans long enough and tall enough to accommodate pairs of coils in each can. The shortwave coil was normally at the lower end of the former, to ensure the shortest possible connections and be far enough away from the broadcast winding to minimise undesirable coupling effects.

Fig.5 is repeated from an article on contemporary coil design by Eric M. Fanker, in *R & H* for October 1939. It depicts a sub-assembly of dual-wave coils — oscillator, RF and antenna — presumably as used in an up-market Tasma receiver.

Alignment trimmers, one for each winding, are so positioned as to be accessible through the top of the individual cans. In the accompanying article, Eric Fanker explains the role of ferrite cores in the broadcast coils but says that, at higher signal frequencies, core losses would tend to overtake anticipated benefits, rendering them of little value.

Normal layout practice was to mount the coils alongside the tuning gang, with the decks of a rotary bandswitch immediately below and the relevant frequency changer — and possibly RF amplifier — valves nearby.

For each model, bench wirers were required to adhere strictly to a predetermined wiring pattern, to ensure the shortest possible signal paths on the high frequency band(s) and to minimise possible stray coupling between them.

The first rotary bandchange switch that I can recall was a dubious device with a separate, rather cumbersome wafer mechanism for each pole, supported by side-rods and spacers. The common contact on each wafer was a plated semi-circular strip, the other half-sector accommodating an arc of rounded brass rivets, each provided with a solder tag.

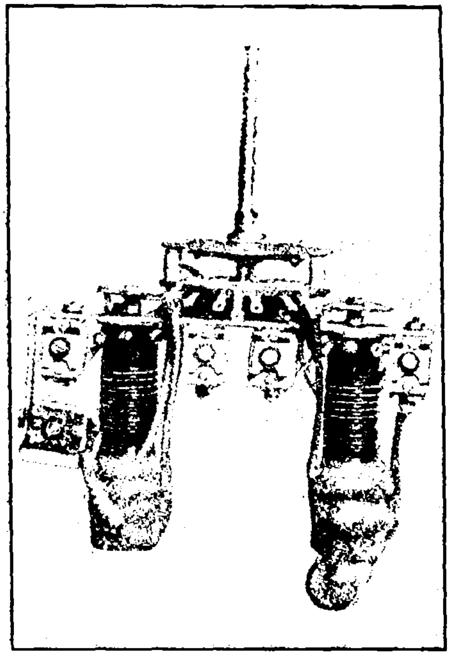


*Fig.6: A Britannic pre-assembled dual-wave coil unit advertised in the April 1941 issue of R&H. Mounted on a bracket attached to a Yaxley switch, it is typical of units often used in home-built or small production-run 4/5-valve superhets.*

Contact between strip and rivets on each wafer depended on a springy wiper blade, supported on a central rotatable shaft by moulded spacers.

One end of each wiper rested on the relevant contact strip; the other end was so shaped, with a hole or dimple, that it would mount and drop over the selected stud, establishing the desired circuit connection.

At best, the mechanism had a rather stiff and imprecise action, rendered so by the need to disengage and re-locate each wiper on a new stud in the somewhat flexible assembly. At worst, it was necessary to 'wiggle' the knob each time it was moved to ensure adequate contact.

If a collector should come across a vintage receiver with a switch answering this description, you will be looking at an historical relic — but a potentially troublesome one!

Fortunately, before many such receivers were produced, 'Yaxley' brand switches appeared on the market — followed, some years later, by a look-alike which was marketed locally under the

AWA/Oak banner. Both used a front clicker plate to provide positive indexing, and wafers able to accommodate multiple poles. These employed small, low-drag, silver-plated contacts.

Notably trouble-free, YaxleyOak inspired rotary switches are still with us decades later, and used for a variety of purposes.

## Prefab coil units

In the major factories, it was possible to use separate coils, switches, capacitors and valves because the optimum placement for every component and every lead could be determined in factory prototypes and duplicated, as a mandatory requirement, by production line assemblers and wirers.

But in the realm of hobbyists and kit suppliers, cottage industry assemblers and even small factories, rigid control of wiring was less practical and shortwave performance could suffer as a consequence.

Reacting to the situation, component suppliers made available a variety of pre-wired sub-assemblies which could be mounted in otherwise complete chassis, and installed by connecting up a few external leads.

The least pretentious of such sub-assemblies comprised a Yaxley or Oak switch on a bracket, on which was mounted two antenna coils and two oscillator coils, as for a 4/5-valve superhet.

The assembly was often held in place by the lock-nut on the switch shaft and wired up according to the maker's instructions. (See Fig.6).

At the other extreme were complete and much more expensive tuner sub-assemblies carrying the tuning gang and even the sockets for the frequency changer — and possibly RF — valves, all pre-wired and pre-tested.

Bolted into a suitable space in the host chassis, such units largely obviated any uncertainty about 'will it work?' Any number of variants between these two extremes may turn up in reclaimed valve receivers.

## Frequency changers

At this point it had been planned to include a few paragraphs about the associated dial mechanisms and the problem of locating and tuning shortwave stations, but for space reasons, this has had to be held over until the next article.

It is appropriate, however, to round off this present discussion with a few relevant observations about frequency changer valves.

Throughout the mid-1930's, most mains powered receivers had used a pentagrid converter in the 2A7/6A7/6A8-G series. These had done a useful job on both the broadcast and shortwave bands, although limitations had become apparent in the 20MHz region when changing conditions heightened interest in the 13-metre (22MHz) band.

At this frequency, the somewhat makeshift triode oscillator in the pentagrid series tended to become unreliable with ageing valves or reduced supply voltages, as well as exhibiting frequency shift with fluctuating AGC or other voltages affecting the mixer section. The resultant detuning tended to exaggerate the effect of signal fading.

In *Radiotronics* 84 (March 1936), AWV announced the pending release of two new frequency changer valves to replace the 6A8 series: the 6K8-G and 6J8-G. These would use the same base and socket connections but could offer improved performance, given minor changes in the associated circuitry.

As I recall, the 6K8-G was the first to become available in quantity, possibly because it had greater support on the American market.

Described as a triode-hexode, the triode was a separate structure, with a transconductance of 3mS (3mA/V) — being a very willing oscillator as a result!

In the mixer section, G1 was the remote cut-off signal input grid, and G2 a screen grid; G3 was tied internally to the triode grid for oscillator injection, with G4 tied to G2 to provide further screening.

The input and output impedances of the mixer were higher than those of the 6A8-G, offering the designer improved performance by increasing the dynamic resistance of the input and output tuned circuits and optimising the oscillator grid current.

Compared to the pentagrid series, oscillator frequency shift due to applied voltages was said to be reduced by about 10:1.

The 6J8-G, described as a triode heptode, also featured a separate triode but differed from the 6K8-G in having a supressor grid, G5, in the mixer. This was tied internally to the cathode.

It had slightly lower oscillator and conversion conductance than the 6K8-G but, as I recall, was credited with higher output impedance, even better oscillator stability and a better signal/noise ratio. In Australia, at least, it ultimately became the more popular of the two types.

Other frequency changers appeared in Australian receivers in the 1930's, such as the Philips/Mullard octodes. But while they had their supporters, they were very much in the commercial minority.

*(To be continued)* ◆

# When I Think Back...

by Neville Williams

## Vintage radio receiver design — 8: The evolution of table and mantel models

**The majority of Australian mains powered receivers in the 1930's were 4/5-valve floor model superhets as already discussed, but the 'second set' concept generated a supplementary demand for 3/4-valve 'table' and 'mantel' models. These shared much the same basic technology, but were subject to quite different design objectives.**

Before embarking upon this further dimension of receiver design, it may be appropriate to 'clear the decks' by commenting on an aspect of domestic dual-wave sets, large or small, which had to be held over from the last article. I refer to tuning systems of the day, and the frequent difficulty in locating and/or identifying individual short-wave stations.

In place of the humble 0-100 celluloid vernier dials that characterised console receivers in the early 1930's, the models that followed later in that decade were commonly fitted with comparatively large, edge-lit glass dials that offered a more striking and informative display. Blue/green sailing ships seemed to be the preferred motif, surrounded by an array of local and interstate station callsigns.

As well, multiband sets carried shortwave calibrations in metres and kilocycles, plus the odd overseas transmitting centre: London, Paris, Rome, New York, etc.

Unfortunately, and despite the sometimes pretentious graphics, the shortwave calibrations indicated, at best, where overseas stations would most likely be found — and then only by careful and attentive tuning! Virtually all domestic shortwave receivers suffered from this same limitation, for which there was a compelling technical reason:

To take in the broadcast band, multiband receivers had to be fitted with a standard tuning gang of about 415pF maximum, in order to cover from around 550 to 1600kHz — a ratio of about 3:1, embracing a total bandwidth of about 1000kHz.

On a typical dial scale, a local AM broadcast band station might spread over 6mm or more, making it relatively easy to identify and to tune for the best sound.

When switched for shortwave coverage, the same tuning gang would still span a ratio of 3:1 (e.g., 13.5 - 40.5 metres), which represented a useful segment of the shortwave spectrum. But this was/is equivalent to 22 - 7.4MHz, embracing a total bandwidth of over 14,000kHz — fourteen times that of the broadcast band.

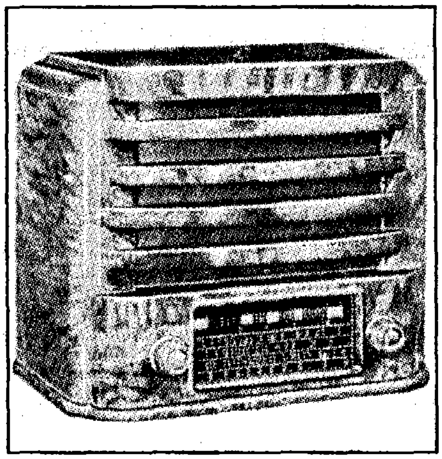


*Fig.1: A Kriesler 'compact' D/W receiver, as advertised in our November 1939 issue. In a moulded cabinet, with a choice of five colours, it retailed for around £13 ($26).*

Since an AM shortwave station occupies only the same 20kHz-odd of bandwidth as an AM broadcast transmitter, it follows that with such a tuning range it will occupy only about one fourteenth of the dial space — even for a strong signal.

That amounts to only about one-half millimetre, or the thickness of a pointer or calibration mark.

To make matters worse, neither the circuitry nor the mechanics of an ordinary analog (tunable) domestic receiver could/can be held to an accuracy equivalent to the width of a line on a large dial. So a shortwave station of specified frequency will rarely coincide with the dial calibration — and even if one goes searching for a particular signal, it will be less than a millimetre wide, and therefore very easy to overlook.

It helps if the dial mechanism can be made as smooth as possible and free from backlash but, at best, it is difficult to locate and identify shortwave stations relying purely on dial markings. A few models featured double-vernier drive knobs and/or supplementary 'band-spread' pointers, but they could offer only very limited assistance with what remains a fundamental limitation of ordinary tunable domestic multiband receivers.

Now to take up the main theme of this present article:

### Smaller, simpler, cheaper?

Scaled-down superhet receivers, using mostly three valves and a rectifier, were an integral part of the world radio scene for so long that, like the proverbial poor, they seemed always to have been with us. However, when I began to reflect on the matter, I realised that such was not the case. They had had a belated marketing timetable in Australia, and a design philosophy all of their own.

With hindsight, it became evident that, when mains-powered 4/5-valve superhets won acceptance in the early 1930's

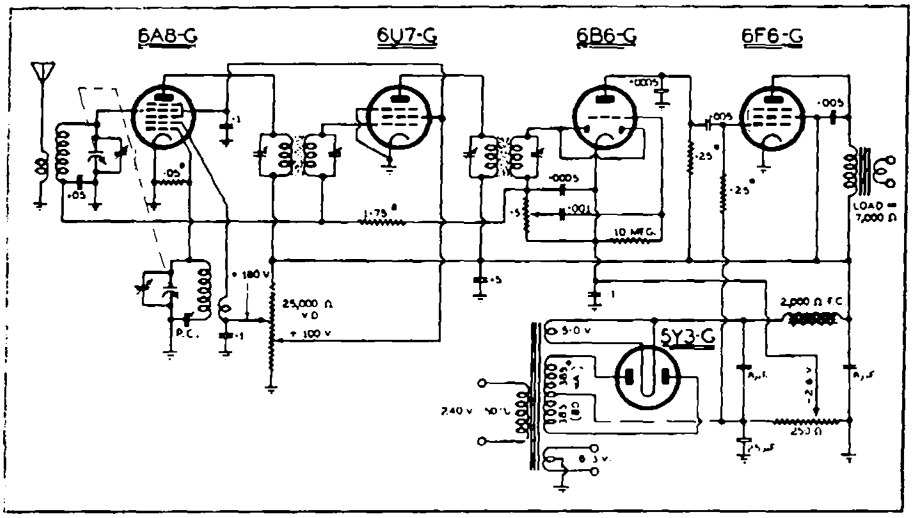


**Fig.2: From Radiotronics 99 (July 1939), this circuit suggests the ultimate in simplicity for a 4/5-valve superhet. To that point in time, AWV had not encouraged the idea of dropping the first audio stage, possibly because they lacked a high-gain output valve.**

as the optimum design for an average Australian home, polished plywood console cabinets were entrenched along with them, free-standing against the living room wall. Perhaps I should add: with or without in-built record playing facilities, which became increasingly popular from the mid 1930's onwards.

To use a modern 'buzz' phrase, such receivers assumed the role of the 'entertainment centre', around which Australian families would gather each evening to enjoy their favourite serial, quiz show or drama. Anything less pretentious than a full-sized cabinet, bedecked with ornament or family photograph, would have lacked credibility!

That compact models had not been totally overlooked, however, is evidenced by a letter from Ray Brown, an old-timer from North Haven, NSW. Ray remembers having constructed what *Wireless Weekly* presented in the early 1930's as the first so-called 'midget' superhet — a 5-valve design (57 autodyne, 58, 57, 2A5 and 80) in a 'boxy' cabinet measuring a mere 11 x 7 x 6 inches (28 x 18 x 15cm).

This was followed by a 3/4-valve version using a 57, 57, 2A5 and 80 combination — the 58 IF amplifier having been omitted, along with one IF transformer. To compensate for the loss of gain, a reaction winding was added to the remaining IF transformer, so that the second 57 could function as a regenerative detector at 465kHz.

A padder-type compression capacitor served as a semi-fixed reaction control. It was an interesting combination of old and new technology, which Ray Brown says worked well. In its day, the idea of a regenerative superhet, where the reaction could be preset, held a certain fascination for experimenters. But to the best of my knowledge, the circuit found little practical application.

By chance, discussing the same era, a friend from the Blue Mountains area of NSW mentioned that his neighbour had owned an Astor 'Mickey Mouse' receiver. He can't remember much about it, except that the sound level seemed remarkable for the size of the set.

## 'Table' model sets

Another reader/correspondent, Ted Baker of Bathurst, sent me an historic photostat showing the 'Airmaster' range of broadcast band receivers as marketed in 1935. At the economy end was a 3/4-valve superhet which was offered in two cabinet styles: a slim and presumably inexpensive free-standing console and a lone, relatively bulky table-top model, which I would estimate to have been about 20 inches (51cm) tall.

I worked at Reliance Radio until about 1936. A small company, it could readily have diversified into pint-sized models, but the management presumably felt that the demand for them was limited — or at best patchy.

The only economy model Reliance produced at the time, over and above their normal manufacturer-to-you range, was identified as the 'Series 14-B'. Adapted from their standard 'Series 14' 4/5-valve superhet, it used a more compact chassis, admitted to the odd economy measure and assumed the use of a cheaper cabinet. While available as a table-top model, its main appeal, as I recall, was as an economy domestic console — with much the same valve complement and circuitry as the higher priced model.

After leaving Reliance, I worked for about three months in a factory at Redfern, Sydney, producing receivers for the Emmco/NST/Wilkes organisation(s). Again, the output comprised predominantly console models.

Lest I was being mislead by non-typical examples, I checked through my file of *Radiotronics* promotional bulletins, issued by the AWV Applications Lab. Their job — and my job when I sub-

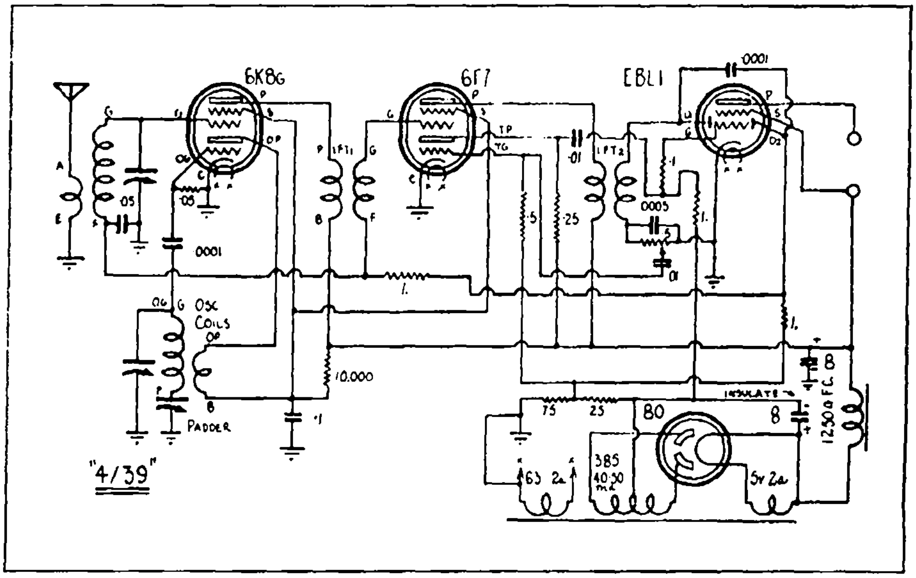


**Fig.3: Described for home construction in the August 1939 issue of R&H, the '4/39' was noteworthy because it duplicated the stages of a 4/5-valve superhet using one less valve. It perpetuated the assumption that even small sets should be able to receive interstate and overseas stations.**

sequently joined the AWV team — was to identify designers' priorities Australia-wide, and to complement them with technical information about the Company's inventory.

In my *Radiotronics* file, which covers from late 1935 to October 1941, there were several typical circuits for 4/5-valve superhets, circuits for up-market receivers using an RF stage and/or a more elaborate audio system, and a sequence of fairly ambitious battery powered receivers for country listeners.

But there was litle or no mention of physically small receivers or designs with fewer stages. Either the Valve Company Lab team had been remiss, or there was indeed very little local interest in scaled-down domestic receivers.

That they were in production, however, even if in limited numbers, is evidenced by an advertisement in the November 1939 issue of *R & H* for what Kriesler called their 'Dual Wave World Range Compact' receiver. Illustrated in Fig.1, it came in a walnut or black moulded cabinet and retailed in NSW for £12/19/6 ($26), or slightly more in other states and/or in cream, green or marble.

## Only just cheaper!

The one deliberately simplified circuit I encountered in *Radiotronics* is shown in Fig.2. Taken from *Radiotronics 99* (July 1939), it minimises the number of components and uses five economically priced valves.

In practice the cost advantage would not have been great and, as in the case of the Reliance series 14-B, any substantial savings in the end price would have had to come from the cabinet, the dial and loudspeaker.

Because of the special nature of the circuit, however, it may be appropriate to interrupt the main theme of the article to comment on the compromises which were deemed acceptable by the Valve Company engineers for an economy broadcast band receiver.

The usual 100pF oscillator grid coupling capacitor was omitted, the circuit being so configured that the normal tuning capacitors blocked any direct path to earth for the grid current. The performance of the 6A8-G was not adversely affected by the omission.

The use of a back-bias resistor with adjustable tapping allowed three of the four cathodes to be directly earthed, and that of the 6B6-G to be bypassed only with an 0.1uF.

Simple AGC was specified, with a 1.75M isolating resistor to minimise loading on the diode detector. Nowadays, 2.2M would be a logical substitute.

The circuit also exploited the novel idea of operating the 6B6-G (or other similar high-mu triode) with a 10M grid resistor and zero nominal bias. In fact, grid current through the unusually high value resistor (accentuated by rectified IF, noise and audio signal components) would generate sufficient bias to allow the high-mu triode to operate normally, presenting a nett input impedance of half that of the 10M resistor. This high figure explains the use of a 0.001uF (1nF) input coupling capacitor.

An 0.25M grid resistor for the 6F6-G was mandatory by reason of the back-bias, the .005uF (5nF) coupling capacitor being admittedly smaller than optimum. A .02uF (20nF) would be a better choice if the bass response was open to question. The 25uF electrolytic across the back-bias resistor could likewise be omitted, if a slight loss of bass and slight increase in hum could be tolerated.

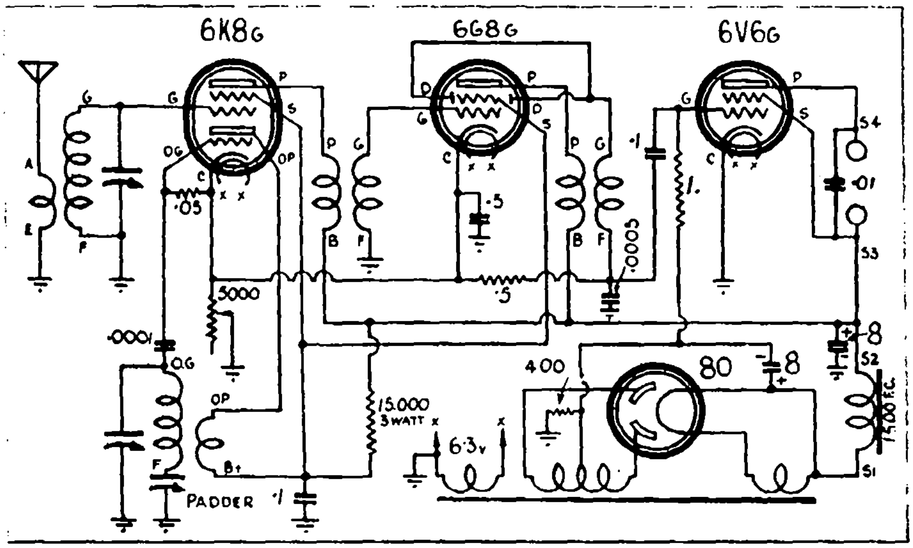


*Fig.4: The original 'Little General' circuit from the April 1940 issue of R&H. Thousands of them were built by readers. To assist experimenters, options like fitting a dual-wave bracket or a loop antenna were detailed in subsequent issues.*

The circuit was deemed unsuitable for the application of negative feedback around the output stage, but the combination of .0005uF (500pF) capacitors on the grid and anode of the 6B6-G and that of 0.005uF (5nF) on the anode of the 6F6-G was sufficient to suppress the residual IF component and smooth out the treble response for routine listening.

As an exercise in cutting corners, circuit No.RD44, which carries my initials, was out of character for the AWV Lab; but it may provide a handy resource for vintage enthusiasts. It would hold good for 1930's-style equivalent valve types as under:

6A8-G/6A7/2A7;
6U7-G/6K7/6D6/58;
6B6-G/6Q7/75/2A6;
6F6-G/42/2A5;
5Y3-G/80.

So back to the original theme:

## Early *R & H* Issues?

It might be argued that valve manufacturers could scarcely have been expected to promote designs calling for a reduced valve complement. With this in mind, I also thumbed through volume one of this magazine, first published monthly in April 1939 under the title *Radio & Hobbies* ('*R & H*'). It was produced by the experienced *Wireless Weekly* team, who should certainly have been able to identify the dominant interests of prospective readers.

In fact, the initial four issues contained constructional articles on up-market receivers using six or more valves, plus a number of elementary battery sets for beginners. It was not until issue five (August 1939) that they got around to a 'midget' mains operated receiver for everyday use: the dual-wave '4/39', described by (the late) John Moyle.

To my mind, that receiver and the designs which followed over the next 20-odd years epitomised the thinking behind a succession of valve-based Australian 'mantel' radios, as distinct from the earlier and more bulky 'table' models — or scaled-down consoles.

In his introductory remarks about the '4/39', John Moyle explained that 'baby' receivers were already very popular overseas. Some were even mass produced, at prices so low that it was cheaper to replace them when they failed, than to have them repaired.

By contrast, John said, while local demand for small receivers was rising, Australian listeners had become conditioned to conventional receivers in large cabinets — so much so that most would find it both 'amusing and interesting to hear music and speech coming from a small box only a few inches either way'.

*Wireless Weekly*, he said, had featured the '4/38' mantel receiver during the previous year, reducing the usual 4/5-valve complement by omitting the voltage amplifier and driving the output pentode directly from the detector. As some local manufacturers had found, the resulting gain was sufficient for day-to-day broadcast reception but insufficient for use on the short waves. This time around, *R & H* wanted to do better than that.

In a quest for higher gain, the editorial team had considered resorting to a reflexed IF/audio stage, but were deterred by the difficulties that others had encountered with the idea. (Reflexing was discussed on pages 38-39 of our June 1991 issue).

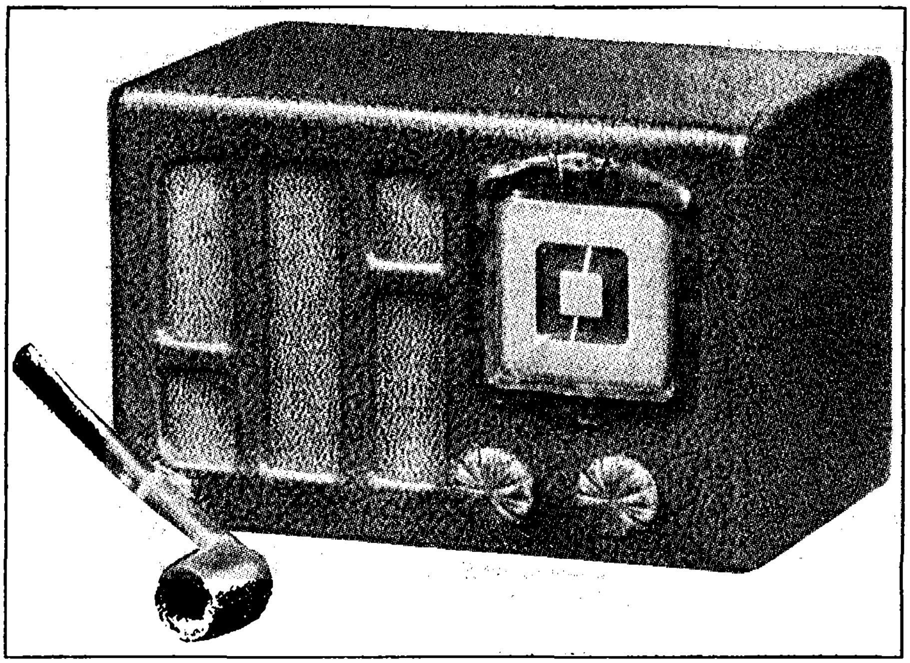


*Fig.5: The original 'Little General', in its inexpensive leatherette covered cabinet. The one-piece escutcheon and dial scale pushed in from the front, the 'pointer' being a white line on a drive drum fixed to the shaft of the tuning gang.*

## A little 'big' set!

As it turned out, the *R & H* team came up with an ambitious 3/4-valve circuit, as shown in Fig.3, which provided the same sequence of stages as a normal 4/5-valve superhet. In short, it met what they saw, at the time, as a minimum requirement for any Australian family receiver — be it large or small. The circuit is interesting in its own right.

A 6K8-G served as the frequency changer, with a common feed resistor for the screen and oscillator anode — a configuration which (in the case of the 6K8) was said to counteract the effect of supply voltage variations, minimising oscillator frequency shift and the associated risk of 'motorboating'. Shortwave coverage could be provided by replacing the single coils shown in the circuit with a readily available dual-wave coil bracket.

From the frequency changer, the signal passed to a 6F7, an imported American double valve containing a triode and a variable-mu pentode section, independent except for a common cathode. With pentode characteristics very like those of a 6B7S/6G8-G, the 6F7 could serve as a normal IF amplifier stage, with AGC control.

After IF amplification, the signal passed to twin diodes in a European duo-diode output pentode — a valve with about twice the transconductance — and therefore power gain — of the 6V6. Its intended role was for use in 3/4-valve superhets, operating directly from the detector output.

In the 4/39, however, the signal was passed back through the 6F7 triode section for prior amplification. With an amplication factor of 8, similar to that of the early type 27 triode, the stage gain was quite low. However, when feeding an EBL1, and in the absence of negative feedback, the overall audio gain would not have seemed all that different to the user from a conventional 4/5-valve superhet.

An interesting aspect of the circuit was that it used back-bias for all stages, including the AGC system. Without going into details, this allowed all cathodes to be grounded, thereby avoiding the complications which might have arisen in providing self-bias for the multi-purpose cathodes in the 6F7 and EBL1. The bias levels were set to keep the current drain within the capabilities of the specified 40mA power transformer.

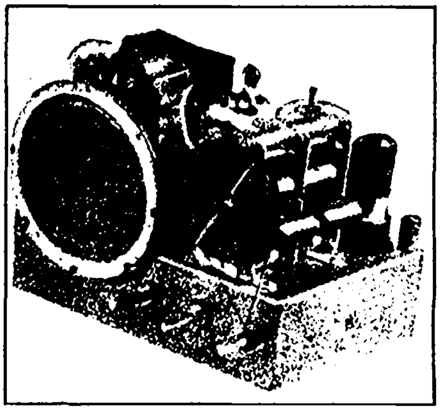


*Fig.6: The completed chassis of the 1946 'Little General'. It differed from the original mainly by the inclusion of one of the options, the fitting of a dual-wave bracket, accounting for the extra (central) control shaft.*

Superlatives were not spared in describing the appeal and performance of the 4/39: at 10W x 7D x 8H inches (25 x 18 x 20cm), it was 'small enough to take with you on holidays'.

Again: 'on the broadcast band there appears to be nothing that it cannot tune in'. And: 'if there is anything on the shortwave bands worth listening to, you will hear it at excellent strength'.

## 'A new star arrives'

Despite the apparent enthusiasm, less than a year had passed (April 1940) before John Moyle was waxing equally eloquent about a new midget receiver which the *R & H* staff had developed in the meantime.

It would appear that a few month's experience with 4/39 had confirmed the appeal of a receiver that could be carried at will into the kitchen, the sewing room, the workshop or the kids' bedroom for music, news, race results or whatever. But what had also become abundantly clear was that the set was rarely if ever tuned to interstate or overseas stations. For the role of a personal or 'second' set, the 4/39 had clearly been over-designed.

So the emphasis in the new receiver (Fig.4) was on portability, simplicity and low cost. Gone was the dual-wave bracket and AGC, the 6F7 and the EBL1, to be replaced by ordinary coils, a 6K8-G frequency changer, a conventional 6G8-G IF amplifier and diode detector, and a 6V6-G biased to limit the total drain to 40mA.

Under the banner 'A new star arrives', the simplified design was presented as the 'The Little General Mantel Receiver' — a title that someone has suggested was intended to catch the eye of hobbyists in uniform.

Yes, said John Moyle, the Little General will still receive the main interstate stations at listenable volume, but its main role is to provide intimate personal listening to the local stations — without a hint of the audio noise and hum that can all too easily be audible in small receivers used close-up at low volume.

Fig.5 shows the prototype, photographed for size comparison with John Moyle's perennial pipe. The cabinet was produced at low cost by numerous cabinet makers, but it was well within the capabilities of a handyman.

Assembled from off-cuts of plywood, composition board or softwood, the basic box was first sanded smooth, with rounded corners. After a generous coating of carpenter's glue, it was overlaid with figured 'leatherette', with a scrap of decorative cloth backing the loudspeaker grille.

## Phenomenal response

The Little General certainly 'hit the spot' with *R & H* readers. Backnumbers of the April 1940 issue were rapidly exhausted and, thereafter, a constant stream of requests for copies of the circuit arrived through the *R & H* 'Shilling Query Service'.

Before wartime restrictions put a brake on the marketing of new components, it was evident that the sale of key items by the various suppliers had run into five figures. How many of them were absorbed by 'backyard' factories we will never know.

Even without firm statistics, it is difficult to escape the conclusion that the *R & H* 1940 'Little General' played a major role in focusing the attention of the industry and listeners alike on mantel model receivers for personal listening. Even during the war years, the Little General's very simplicity made it an obvious choice for anyone who wanted to 'knock up a set' from oddments.

During this same period, follow-up articles suggested ways in which experimenters could increase the gain (April 1940), or provide a loop antenna (June 1941), or fit a dual-wave bracket into the original chassis (December 1941).

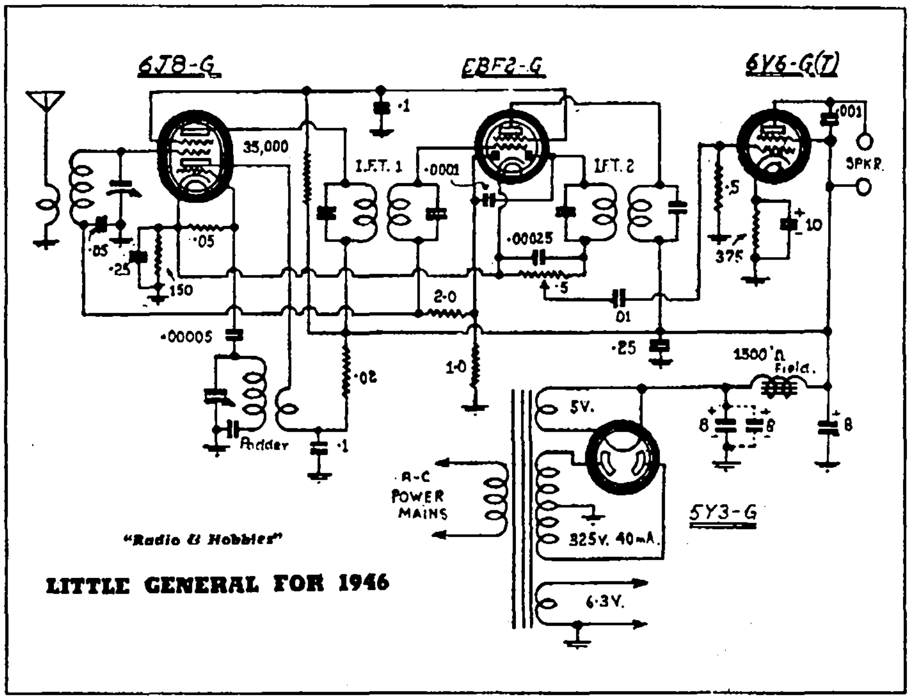


***Fig.7: The circuit of the 1946 'Little General', which suggested using the new 6JB-G converter, reverted to automatic gain control and encouraged the use of a lower voltage power transformer.***

I recall also that someone discovered that a quite healthy sound could be obtained by feeding the signal from a high output standard groove crystal pickup to the grid of the output pentode.

Besides seeing a few Little Generals end up as mini-radiograms, the idea also gave birth to a one-valve phono player — which was novel, to say the least.

## Post-war Little General

In January 1946, as Technical Editor, I made my own contribution to the Little General saga with an update of the earlier articles — which had long since gone out

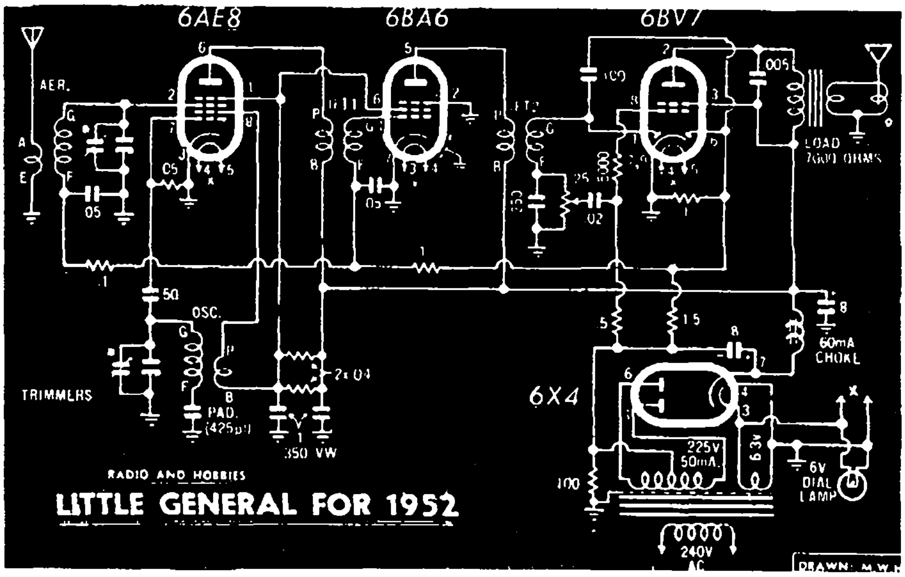


***Fig.8: Breaking with tradition, the 1952 'Little General' specified the use of all-glass miniature valves and matching miniature coils and IF transformers. It also saw the adoption of a permag. dynamic loudspeaker and a more energy efficient power supply — all typical of contemporary commercial mantel receivers.***

of print. (In those days, office photostat copiers were still 30-odd years down the track).

I explained in the preamble that, while smaller valves and components were on the horizon, the most realistic course as at January 1946 was to retain the chassis, layout and cabinet of the original Little General, adapting the circuit and parts list to accommodate the components most likely to be accessable in this immediate postwar period.

Fig.6 shows the completed chassis, which looked essentially similar to the original version. The dial kit, probably from RCS Radio, involved a moulded drum, which attached to the gang shaft, a knob spindle with a tight-fitting rubber grommet and a length of woven drive cord with tension spring. The matching escutcheon and dial scale fitted through a cutout in the front of the leatherette covered cabinet.

The recommended circuit (Fig.7) showed a 6J8-G as the preferred frequency changer, but other valves such as the 6K8-G, 6A8-G or 6A7, which might be on hand, were suggested as legitimate alternatives.

Following the convention of the magazine at the time, the circuit showed only a single set of coils, and in fact constructors had the option of installing a set of broadcast coils underneath the chassis.

However, the presence of three controls confirms that the prototype carried a dual-wave bracket instead, on the basis that it involved so little extra effort and outlay that we had decided to do it that way, that time around.

An octal-based EBF2-G was nominated as the preferred IF amplifier/detector although, again, there were other options in the way of the P-based version, or the 6G8-G or 6B7S.

My choice at the time was to revert to the use of AGC rather than manual gain control, the detector and delayed AGC circuitry being exactly as might be found in the front end of a full-size 4/5-valve superhet. Output from the detector was fed directly to a 6V6-G or 6V6-GT — valves that by then were so plentiful that alternatives were not even discussed.

In the power supply, a point of note was that a definite effort was being made to discourage the use of a traditional 385/0/385V secondary and to promote a 325/0/325V rating for small receivers, to avoid needlessly high voltages and heat dissipation.

After several years of wartime shortages and uncertainties, the article was very obviously intended to re-position the 'Little General' as an important and on-going feature in the *R & H* repertoire of do-it-yourself projects. To borrow John Moyle's phrase, it was a clear indication that Australians were becoming accustomed to hearing music and speech coming from a small box!

According to *EA*'s old valve receiver master index, which Jim Rowe kindly looked up for me, the Little General popped up again in August 1947 and July 1951, with a totally new version presented by Raymond Howe in September 1952.

## 'Modern' valves

Climaxing the trend set in the previous year, the 1952 version (Fig.8) discarded once and for all the option of using conventionally based valves and specified a new chassis to accommodate only the new all-glass miniature valves, along with proportionately smaller coils and IF transformers.

Using the same size chassis and cabinet as previously, there was room above the chassis for all the major components and also for a modern edge-lit glass dial, leaving ample space underneath for uncluttered wiring. Noteworthy also was the use of a dynamic loudspeaker with a permanent magnet rather than an electromagnetic field coil — a spin-off from wartime technology.

Despite their much reduced dimensions, the new miniature valves were well ahead of the older types in terms of gain and efficiency. The 6AE8 triode-hexode converter had about twice the conversion gain of the older types, the 6BA6 offered two to three times the transconductance of earlier IF amplifiers, while the 6BV7 was way ahead of the 6V6-G and even more sensitive than the EBL1 — once the pride and joy of the Philips/Mullard range.

With overall back-bias and delayed AGC, the 1952 circuit invites obvious comparison with those discussed earlier. But allowing for a gain advantage of around 2:1 per stage, the overall sensitivity could be expected to be well up on the earlier 3-stage versions. A further point of note is that, with the use of a relatively low-resistance choke in place of the loudspeaker field coil, HT voltage drop in the filter system was less.

In addition, the indirectly heated 6X4 miniature rectifier was much more efficient than the old 5Y3/80, offering the further advantage that it did not call for a separate 5-volt filament winding. It permitted the use of a simpler power transformer delivering much lower voltage, but with a higher current rating.

Since all of the valves shown were Australian-made, along with virtually all the other components, the Little General for 1952 had a lot in common with postwar mantel receivers offered by Australian manufacturers. Some even used leatherette-covered cabinets; but in line with overseas trends, those who could cope with the initial expense came up with a variety of moulded plastic designs.

Occasionally, much to the delight of home constructors, production over-runs of such mouldings turned up later in surplus clearance dealers, giving enthusiasts the chance to accommodate their handiwork in a decidedly 'non-handyman' cabinet.

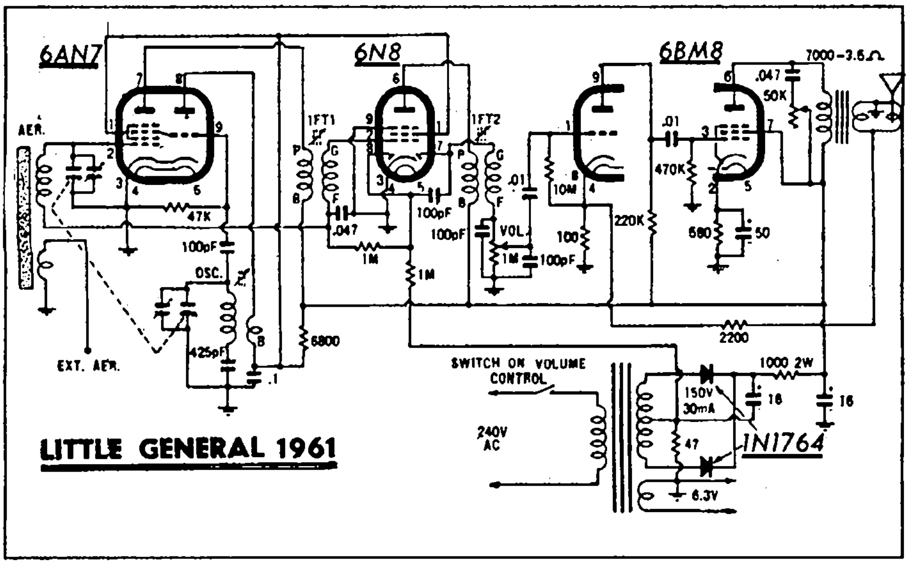


*Fig.9: The last of the 'Little General' series, using what was virtually the last generation of mass produced valves. This series also featured widely in Australian monochrome television receivers, before giving place to solid-state devices.*

*Continued on page 83*

# WHEN I THINK BACK

*Continued from page 37*

## The final chapter

A detailed sequence of articles in the issues June-September described the construction of the 1956 version, with the 1957 version appearing in April of that year. By that time, the situation had changed. TV broadcasting had commenced in Australia, and it was obvious that radio would no longer dominate family entertainment. A TV set would in future take the place that had been occupied for so long by the radio console.

For sure, radio would still have a place for casual listening — provided the set didn't take up too much room and could be moved around, as required. Quite suddenly, from being a second set, the 'Little General' type of radio had become the only one that most families needed.

The final chapter in the 'Little General' saga came in a series of articles by Alan Nutt (March-June 1961), culminating in the design shown in Fig.9. Ironically, it reverted to the basic design which had set the ball rolling in 1939: a four-stage circuit using three valves — this time Philips all-glass 9-pin miniatures, manufactured in Australia and equally popular with commercial manufacturers.

A 6AN7 triode-hexode converter was fed from a ferrite-rod loopstick, in lieu of an antenna and antenna coil. This was followed by a 6N8 duo-diode pentode, doing the job of a 6G8-G/6B7S, but much more efficiently. Last but not least, the 6BM8 provided a high-gain triode audio stage and a high-gain output pentode, expressly intended for that role.

The valve rectifier had disappeared, to be replaced by a pair of semiconductor power diodes — the first step to what was soon to follow, with all valves being replaced by solid-state devices.

In the meantime, what happened to the negative feedback, which was featured in the later 4/5-valve and larger receivers? In brief, negative feedback was/is fine if: (1) There is gain to spare; (2) The circuit is amenable to its use; and (3) The loudspeaker and baffle system is of sufficient quality to justify it. Faced with these prerequisites, most small-set designers said: 'Forget it!'

Within a few years, anyway, Australian valve/mantel sets would be rendered obsolete by imported transistor portables featuring optional mains/battery operation and multiband reception — not in response to Australian demands, but because they were universal designs intended for world markets! ◆