When 1 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 $^4/_5$V 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-

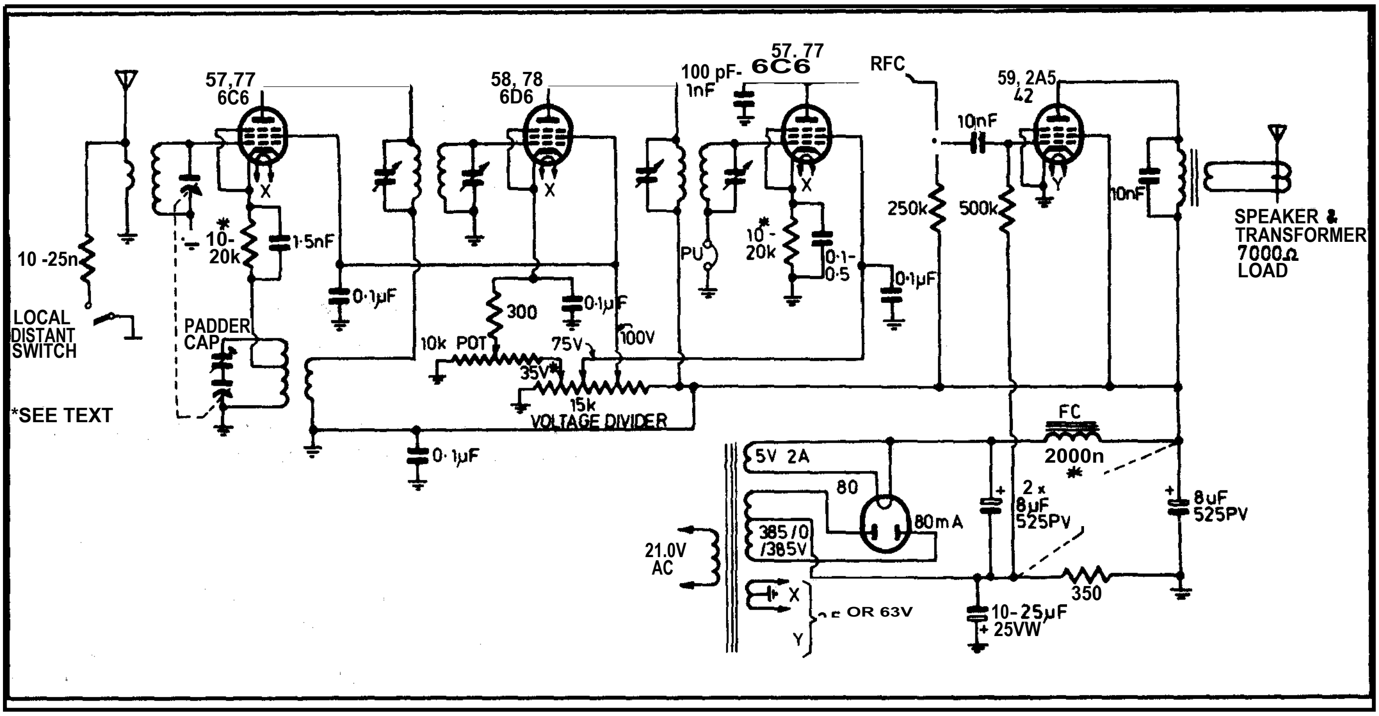

***Fig.1:** A basic circuit fora typical 4/5 valve 465kHz superhet receiver from the early 1930's. Various options are shown and discussed in the text*

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.

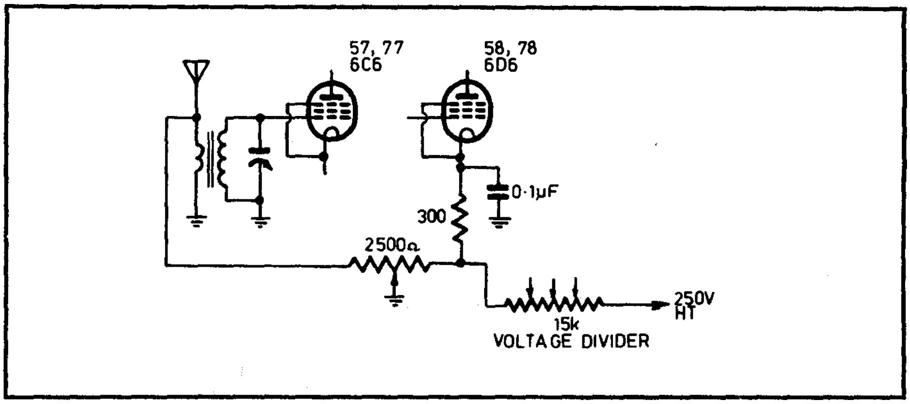

Fig.2: *A method of eliminating the **local/distant** switch, by so **arranging** the gain control that it shorts the antenna to earth in the fully anti-clockwise setting.*

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!

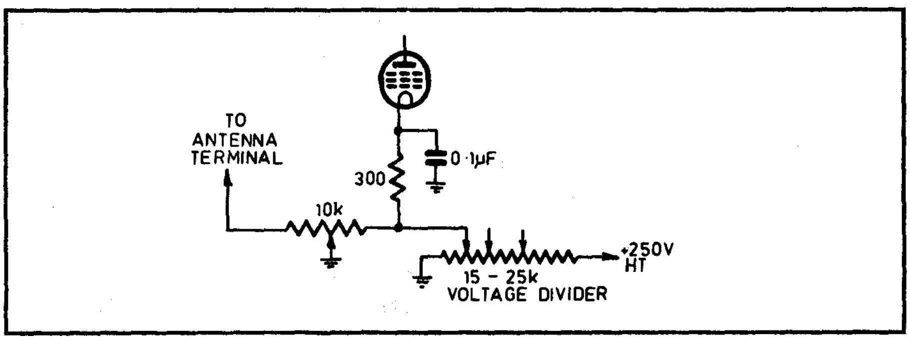

Fig.3: *When fed from a tapping on the voltage divider, the clip needs to be set to a position which will ensure logical operation of the control, as explained in the text.*

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.

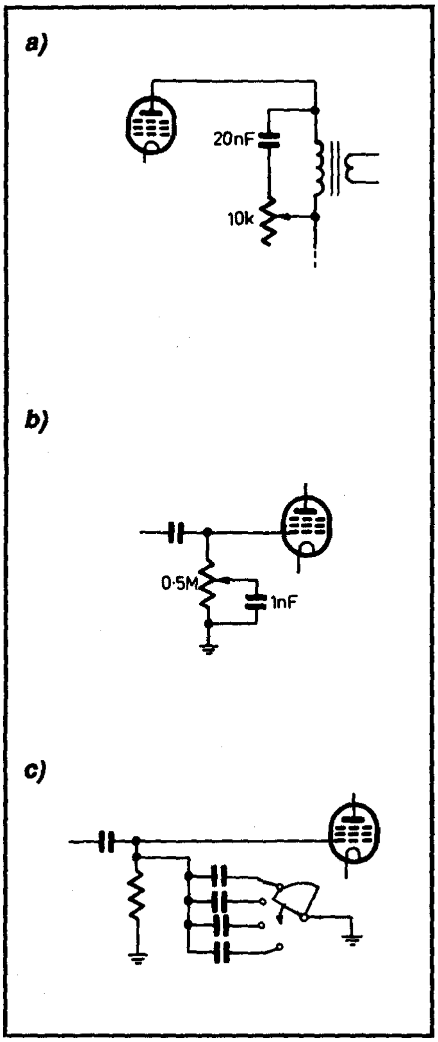

Fig.4: Three typical methods of providing a top-cut tone control In the early 1930's.

Bias method

And that brings us to the so-called tack-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 100, 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.

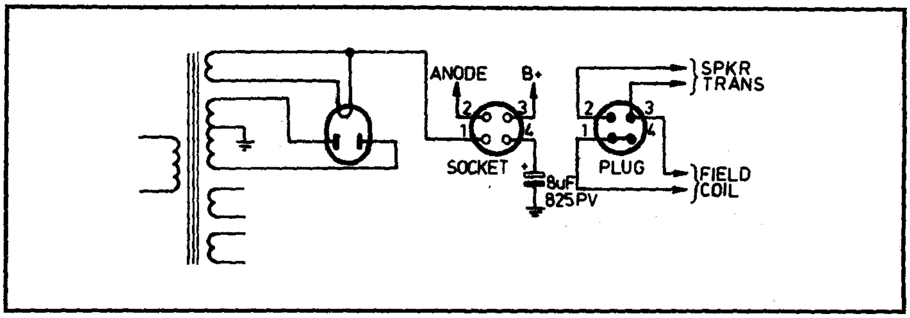

Fig.5: Wiring a loudspeaker socket and plug as shown above could protect the first filter capacitor from damage in the event of a receiver being switched on without the loudspeaker being plugged in.

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., 200), 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-

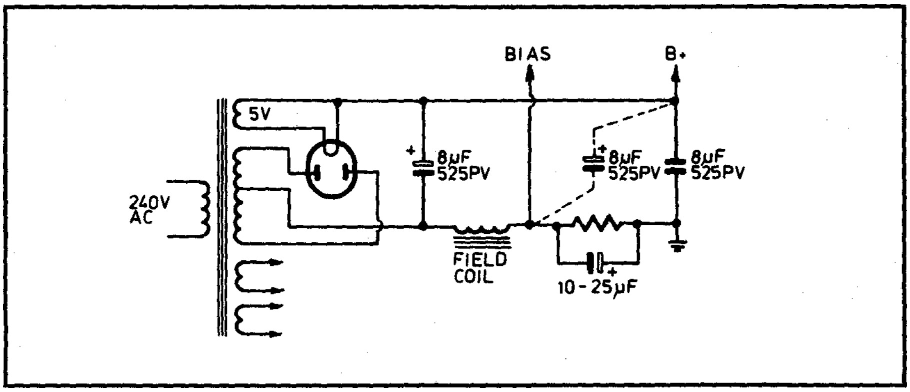

Fig.6: For reasons best known to themselves, some designers Included the loudspeaker field winding, as well as the back-bias resistor in the negative supply lead. it placed about -200V on the exposed shell of the first can type electrolytic!

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 drams.

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 lOnF 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) ■