VINTAGE RADIO

Reinartz "4-valve" reaction radio

By Fred Lever

I built this simple battery-powered AM radio set using the "Reinartz" tuning principal and early 1930s to 1940s components (well, mostly; I cheated in a couple of places). I did this for a few reasons. One is that it was a learning exercise; I knew that it was possible to build a radio set like this, but I didn't fully understand all the details. Now I do. I also succeeded in turning a load of old junk into a working radio!

Reinartz tuning is also known as reaction tuning, and I was keen to build a radio using this principle. I wanted to build it such that it would appear to be a radio designed and built in the 30s. So I drew up the circuit shown in Fig.1.

I initially toyed with the idea of using battery triodes such as the type 30 or mains-powered tetrodes such as type 24A. But I ended up using two type 57 amplifier pentodes and a type 47 pentode output valve driving the loudspeaker.

I could have used a type 80 rectifier but instead, I used a silicon bridge rectifier hidden in a defunct 5V4. This allowed me to wind the HT secondary on the transformer as a single winding. I also wound on 2.5V heater windings, with centre taps for bias and grounding.

To get to this arrangement, I had to do lots of prototyping different circuits, fabricating of parts and re-thinking and re-designing when my tests failed. This article presents the receiver in its finished state, with a lot of the development detail left out.

Circuit details

Valve V1 is a type 57 pentode which works as a three-grid stage, with tuning, feedback, gain control and AM detection. Each grid of the type 57 has some level of DC bias or signal applied. The combination of the tapped antenna coil and tuning capacitor selects the desired AM signal frequency and this signal is applied, via a grid-leak resistor and capacitor, to the control grid (top cap).

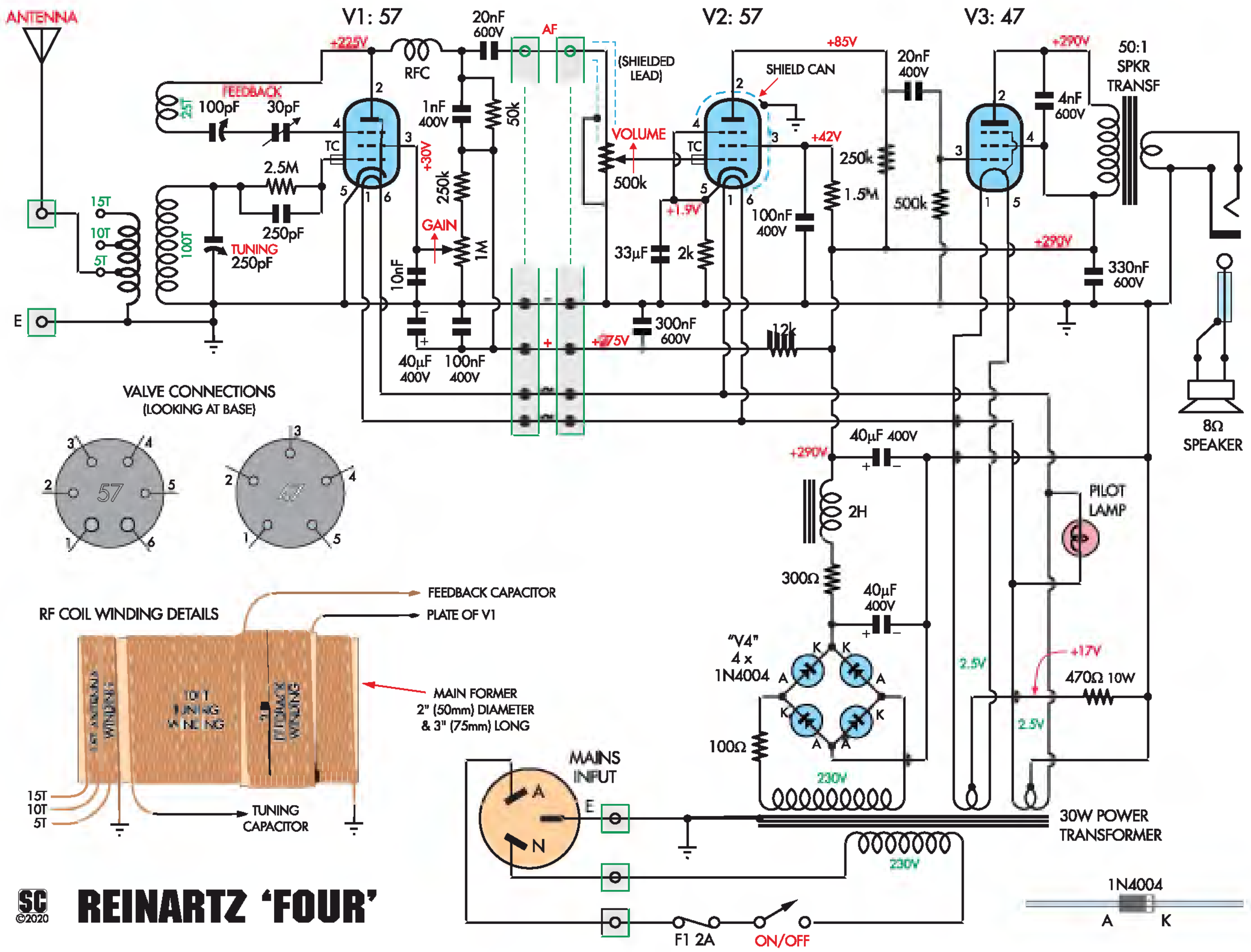


Fig.1: this circuit was built around the principle of reaction ("Reinartz") tuning and designed to imitate a radio from the 1930s, as shown by the use of type 47 & 57 valves from that decade. However, there is an exception in the use of a silicon bridge rectifier for V4 instead of an equivalent valve.

The amplified plate energy is fed back through to the suppressor grid (pin 4) in phase, via the coil connections and varied by the feedback varicap. This sharpens up the selectivity of the tuned circuit with the best operating position just before oscillation.

The screen grid of the valve (pin 3) has a variable DC bias applied, which varies the valve amplification slope, and this is the gain control.

All three controls interact to some degree, so they must be adjusted to get the best reception of the tuned station. The valve also acts as a biased detector with a resultant RF signal at the plate (pin 2) including the audio modulation component.

The coil labelled "RFC" and the following R/C network attenuates the RF component of the signal, leaving only the audio component. How is that for all-in-one circuit operation? And this principle was understood in 1930!

Valve V2

V2 acts as an audio voltage amplifier, as the signal level from V1 is

The chassis in its initial, very dirty state.

fractions of a volt; not enough to drive the output valve directly. The control grid (top cap) of V2 is fed from the volume control potentiometer. The valve is self-biased at the cathode (pin 5).

The suppressor grid (pin 4) is connected to the cathode, and the screen grid (pin 3) is biased at a steady DC level. Valve V2 thus raises the signal level to a few volts at high impedance, suitable for valve V3's control grid.


Two 1930s-vintage power transformers were cleaned and reassembled to act as the power and output transformers.

Valve V3

V3 acts in combination with the output transformer to supply a low impedance drive signal to the loudspeaker, as V2 cannot drive a low-impedance load. Its output impedance is around 50kΩ, so even with an impedance-matching transformer, it just isn't capable.

The signal from V2 is coupled to the control grid of V3 (pin 3) via a 20nF capacitor. V3 acts as a voltage amplifier, but as it operates at a much higher current and from a higher voltage supply, it can drive the speaker transformer primary, which has an impedance of a few thousand ohms.

The transformer steps down the voltage and also the impedance from V3's anode, transferring power to the 8Ω speaker coil. V3 is centre-biased by a resistor in the filament ground lead. This raises its cathode voltage to about +17V, placing it on a linear portion of its operating curve.

The filaments of V1-V3 are powered from separate centre-tapped windings on the mains transformer. For V1 and V2, the tap is Earthed.

"Valve" V4

V4 is the silicon diode bridge rectifier which converts the 230V AC from the HT winding of the power transformer into about 325V DC to power the anodes of V1-V3 via an RLC low-pass filter.

Valve V4 is a cheat, as the diodes are soldered into the base, and the bottle part is disconnected completely. Thus the set looks like it has a rectifier valve, but it has actually gone solid state!

The ~325V DC drops to around 290V after the π filter. You will note a sacrificial 100Ω resistor in one of the AC secondary leads. If the rectifier or one of the filters shorts, this resistor will smoke and be the (cheap) part that burns, if the fuse does not blow first.

The power transformer

I had two circa-1930 transformers in my junk box that looked like they would work as the mains power and audio output transformers. Both had turns ratios of 50:1. I stripped one and found the core size was 25 x 25mm of some poor rusty grade of iron lamination.

I have previously used a value of five turns per volt on one-inch silicon core, so I started with that level of flux excitation. The power required is about 30W (for 4W audio output!), half of which is for the filaments and half for HT.

The primary current would therefore be about 0.125A (30W ÷ 230V). The wire selected has to carry that current; I had some 0.32mm diameter (120mA-rated) wire handy, so I decided to use that for both new primary and secondary HT. Naturally, I added several layers of insulation between the primary and secondary, for safety's sake, and also between each winding.

If I had used a valve rectifier, I would have had to add a 5V winding and double the number of HT turns, with a centre tap, because the valve would only give me a half-bridge. The transformer would then work the iron harder and run hotter with the extra 10W load. So it was nice to leave the rectifier heater winding out and simplify the HT secondary.

The 2.5V secondaries provide the valve filament current. Two are required, and both were made using one layer of 1.2mm diameter (2.3A-rated) wire.

Output transformer

Before stripping the second unit, I felt it might do the audio job as it stood

A 5V4 valve envelope was used as a dummy with 1N4004 diodes installed in its base. This acted as V4 while retaining a 'vintage' appearance.

with the 50:1 ratio and the wire sizes used. For a 4Ω loudspeaker, this makes the reflected load approximately 10kΩ (4Ω x 50^2); a bit higher than V3's rating of 7kΩ.

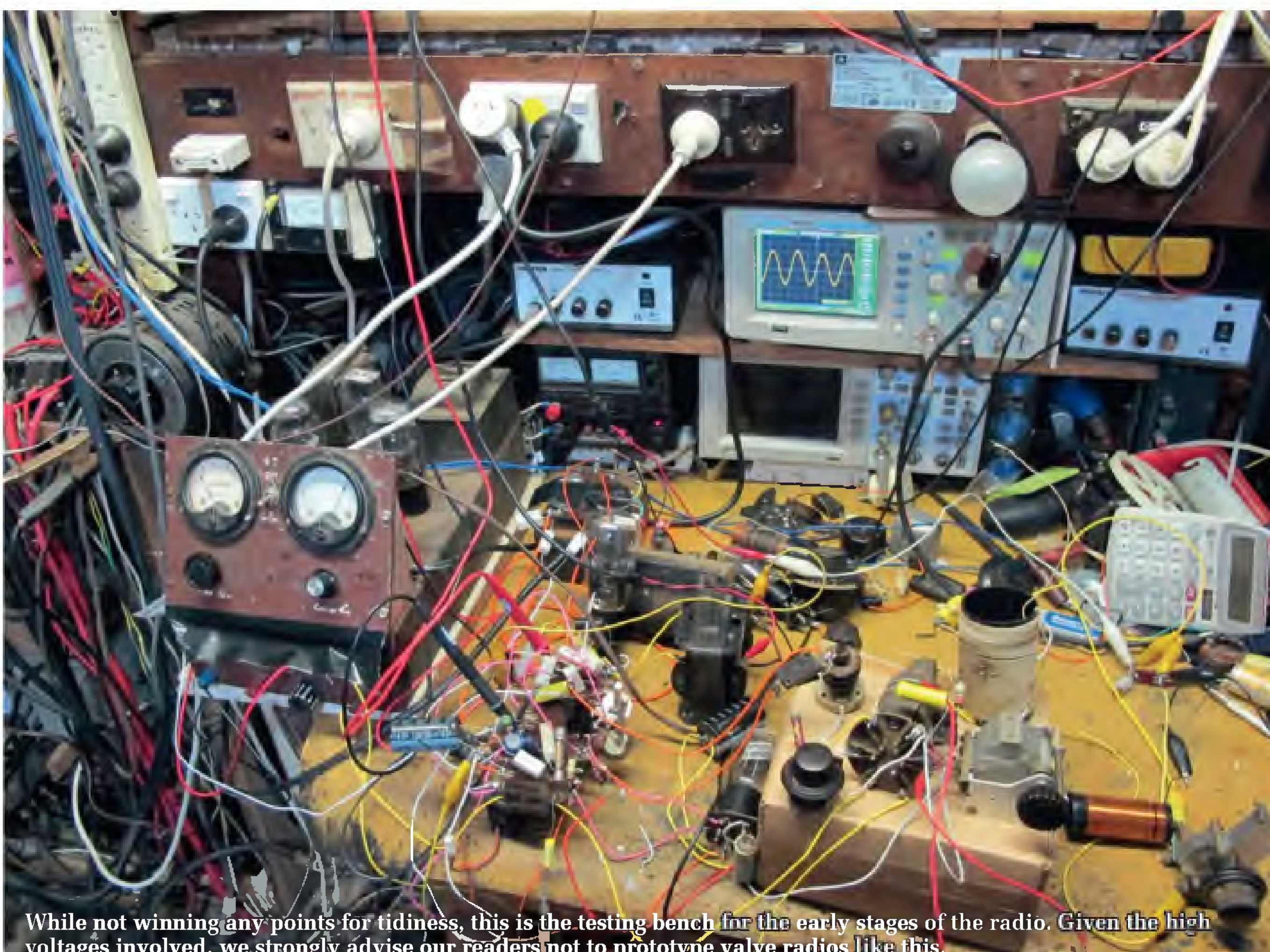
This was borne out by my testing. I wired the transformer across a type 47 valve and loaded its secondary in steps from 2Ω to 16Ω. The transformer has an output response rising from 2Ω, flattening off at 8Ω and remaining constant to 16Ω.

There was no real peak, indicating that the valve is very 'soft' in its plate resistance, and the surrounding losses control the power delivered more than the active device.

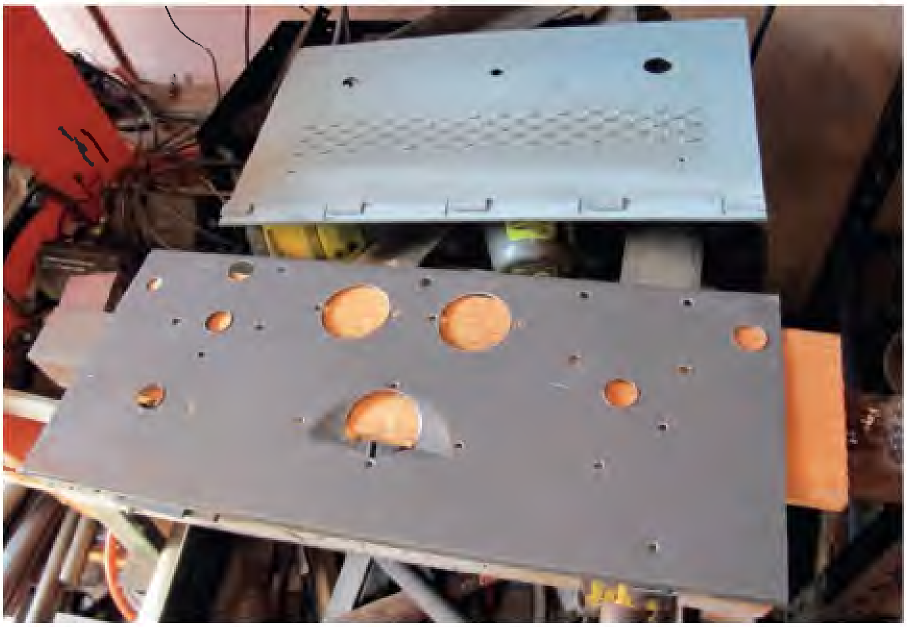
I found the frequency response to be poor below 100Hz but reasonable between 200Hz to 3kHz, then falling off above 5kHz. I thought this was satisfactory, especially for the 1930s level of performance I was after.

So I left the transformer as it was and just dipped it in varnish to seal it up, making it look like its power transformer mate.

The cabinet was based on a two-door utility cabinet that had been left out in a council clean-up. The top shelf would house the RF, tuning and detector sections while the bottom would be for the power supply and audio valves.



While not winning any points for tidiness, this is the testing bench for the early stages of the radio. Given the high voltages involved, we strongly advise our readers not to prototype valve radios like this.



The chassis was made from an old computer case and holes were marked and drilled for the various component locations.

The cabinet

Having settled on the major components and after proving that each circuit section would work using breadboard lash-ups, I turned my thoughts to the cabinet.

I looked around the workshop for some timber or a box of some sort, and spied the perfect thing. It was a two-door utility cabinet left over from a council clean-up; just the ant's pants to house my radio, I thought, although I realise that others may not share my enthusiasm.

After measuring it, I concluded that the top section had enough room to fit the RF valve, tuning and detector circuits, with the power supply and audio valves at the bottom. That way, on the front panel, the three tuning controls (tuning, reaction and gain) would be up top with the volume knob, power switch and pilot lamp below.

Making the chassis

I cut some metal from old computer cases and mocked up the front panels for both sections. That looked promising, so I made the front-end chassis by riveting the flat steel sheets together in an "L" shape. The valve socket is spaced off the bottom with a square Perspex insulating sheet. The tuning controls bolt onto the metal front panel.

I used as many very old components as I could, favouring parts that had ceramic or Bakelite in them. I used a six-wire connecting cord to join the front-end and power supply sections. This carries the filament and HT supplies, plus the audio feed.

The power supply has a deep chassis section, allowing most of the modern parts to be hidden out of view underneath. The resistors and capacitors were fitted onto tag strips with only the valves and transformers showing on top.

The volume control, power switch and a big lamp bolt onto the front panel. The metal panels I took from the computer case have stiffeners and some important-looking vent holes, so I arranged the parts around to make it look like they were meant to be there.

Painting the chassis & cabinet

When the metal cutting was finished, I grabbed some spray cans and experimented with getting some different textures on the metal. First I degreased the metalwork, washed it and dried it. I then sanded back the front panels with 80 grit emery paper so they were matte grey, with straight scratches in a horizontal flow line, like brushed aluminium.

I then sprayed on a thick coat of black, and watched as it soaked into the scratches and then dimpled up with a mottled look. Next, I sprayed a thick coat of gloss over the top to fix the dimpling in position.

I also sprayed the back and top of the chassis with a light coat of black, followed with a misted spray of aluminium silver that "pooled" slightly upon landing on the wet black, mimicking the old baked enamel "stove" finish. I let that harden and sprayed a couple of layers of clear coat over to fix it. I left the underside of the supply chassis in the basic light-grey PC colour.

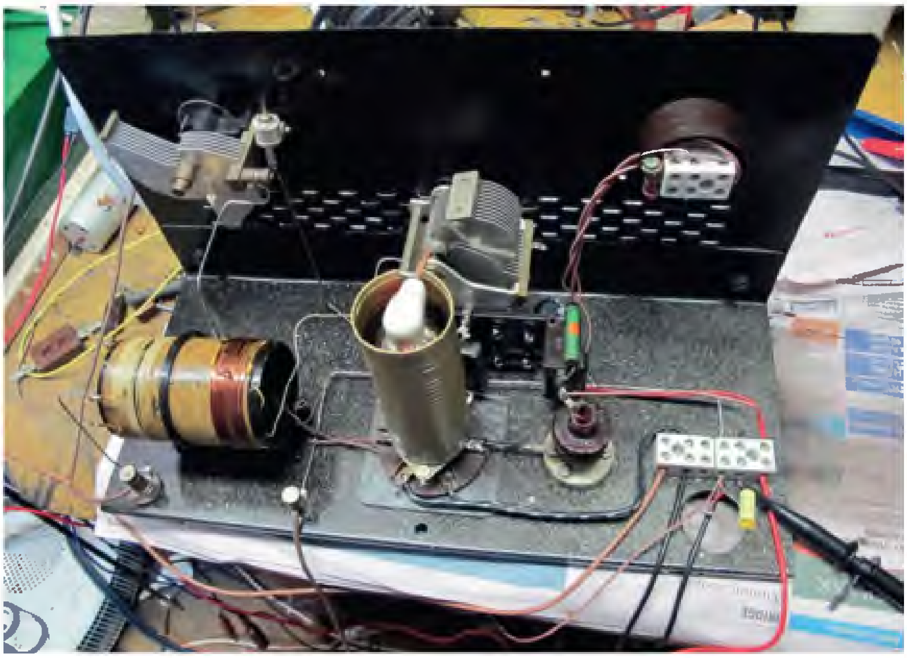
Next, I power sanded all the timber cabinet surfaces to get rid of the shine and grease, then transitioned it from white to brown.

As the first step, I gave it a coat of black as a base, and when that was tacky, added a coat of mission brown all over. When that had hardened, I filled in some of the inset panels and beading with gold paint as a contrast, then sealed the lot with coats of clear gloss.

Front panel appearance

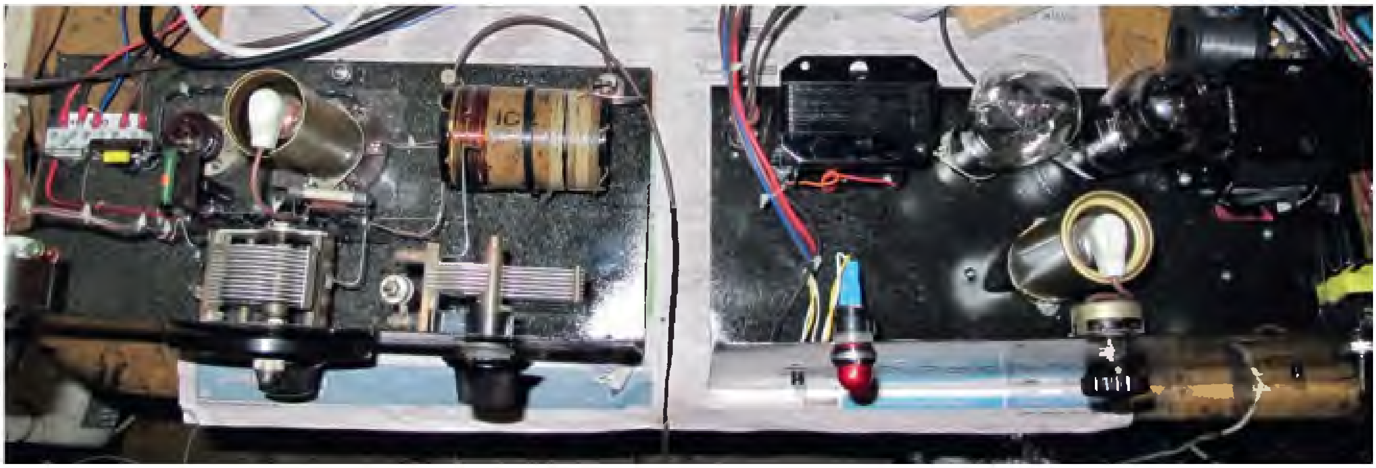
I thought the front panels might look good with screw-on nameplates over the controls. In the old days, we used to make labels from "Traffolyte" black-on-white sheet and mark them with an engraving machine.

I don't have access to an engraving machine or a Traffolyte supply, so I



The top section of the radio encompasses the tuner arrangement.

The bottom section of the radio handles the power supply **and audio.**



Both chassis are shown here connected together for further testing. The chassis were de-greased, sanded and cleaned before being painted with a finish similar to an old stove.

◀ The completed tuner arrangement section of the radio mounted in the cabinet. The tuning coil is a two-inch air-core solenoid winding without ferrite. Originally this was mounted vertically, but mounting it parallel to the chassis helped reduce interference. Many of the leads were also replaced with stiff copper wire to prevent de-tuning and varying feedback levels.

The finished audio and power supply section of the radio. The type 57 valve (V2) also needed shielding to prevent it coupling to the output valve and transformer. ▶

The front view of the finished radio chassis and cabinet. The front panel uses screw-on nameplates, which were made using thick cardboard pieces sprayed with lacquer. A low-powered laser engraver along with some nice timber would also work well if you have one.

fudged it by printing up thick cardboard pieces, spraying them with lacquer and mounting them with 5/32in screws.

Making the RF stages work

Once I'd finished assembling the RF and audio stages, I powered them up using bench supplies. Despite having proven that individual circuit sections worked earlier, I struck some interesting problems. This is where I learnt more about 1930s radio design and reaction circuits.

After a safety check for shorts, I powered the tuner section up, temporarily hooked to an external audio amplifier.

The tuner screamed and made blurting motorboat noises, and only faintly allowed radio 2RPH through. The feedback gang did nothing, and the screen gain control only worked like a switch, all or nothing! The tuning control only vaguely worked, and the whole thing was worse than a dud crystal set. Oh dear.

I disconnected the coil feedback paths and ran it as a straight TRF detector, and found the coil then tuned in stations over the broadcast band normally, but with low gain and poor selectivity.

Whenever I tried to put a feedback wire back on the coil, I got uncontrolled instability. On close inspection, I found that I had reversed the ground and grid wire ends of the main tuning coil – a simple goof. Thus, the plate feedback winding was always adjacent and uncontrollably coupled to the control grid by leakage capacitance.

Reversing the tuning winding wires swapped the feedback coil back to the Earthy end of the tuning coil, and allowed me to connect the feedback wires minus the screaming. The coil then worked, but with it standing vertical on the steel chassis, it performed poorly compared to the prototype on timber breadboard.

Flux fields

The tuning coil is just a plain 2-inch air-core solenoid winding with no ferrite to concentrate the flux field. The flux field is therefore a toroid coming out of the winding ends and linking end-to-end down the length of the solenoid. Nearby metal will interfere with this flux field.

The solution was to mount the coil with its axis parallel to the chassis, high enough off the metal surface to avoid any damping, as you can see in my photo at upper left. Also, I found that moving some of the leads de-tuned the station or changed the feedback level. I replaced those sensitive wire runs with stiff tinned copper wire.

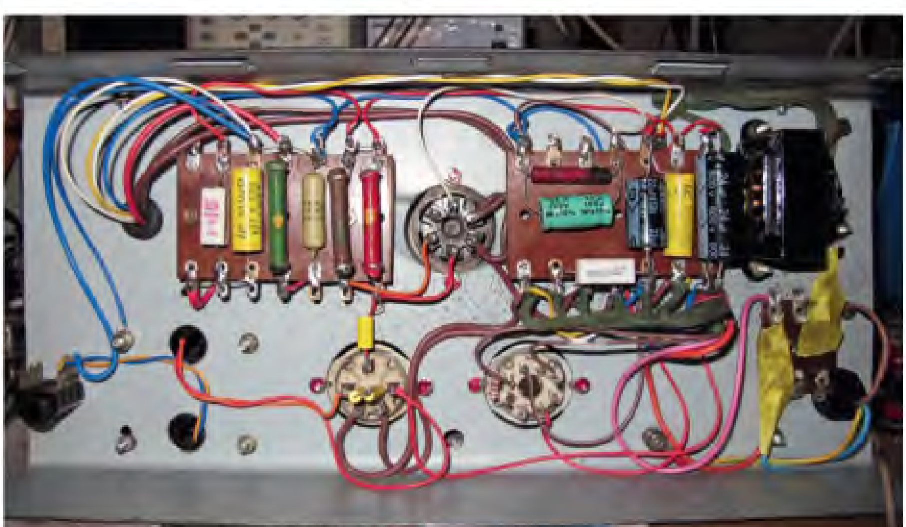
The whole thing then settled down and became reliable, stable and worked as in my prototype tests. Stations could be tuned in and lifted clear of adjacent stations with appropriate settings of the gain and feedback controls.

Finishing the power supply

In building this section, I wanted to put all the parts onto tag strips, but I did not fuss too much about using all 1930s components.

Some of the capacitors are brand new but being out of sight, don't detract from the look of the chassis. I fitted the clunky-looking old school parts on the top where they could be seen.

I wound the smoothing choke on a 15mm core with about 600 turns of the same gauge wire as used on the power transformer. The resulting choke measured about 2H and with the 40µF filter caps, it's good enough to remove most of the hum. See the photo adjacent for an underside view.



The underside view of the chassis that houses the power supply section.

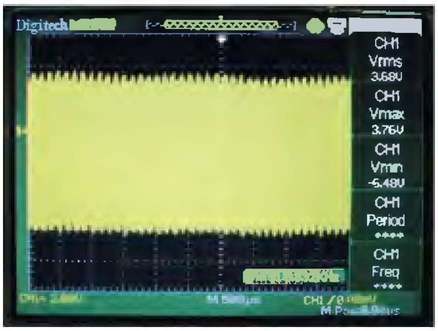


Fig.2: the detector plate (V1) was fed with a 915kHz sinewave, showing just the carrier signal.

Fig.3: this carrier signal was then modulated at 450Hz, but note this isn't a 'typical' modulated waveform, as the valve is already affecting it.

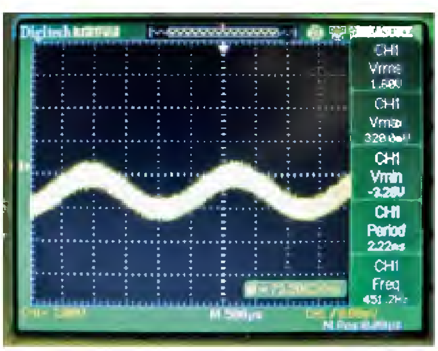


Fig.4: at the tuner's output the choke and stray capacitances have rolled off the RF carrier to nearly zero.

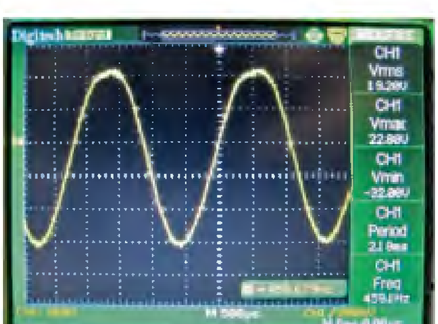


Fig.5: the audio at the amplifier valve's plate (V2) before being sent to the grid of V3.

True to form, once I'd finished everything, plugged in the speaker and powered it up, there was more screaming instability and wall-to-wall 50/100Hz hum that was not there before!

The 50Hz and 100Hz components were mainly due to the negative HT and signal rails not being bonded to chassis ground.

Another minor source of hum and instability was not having the speaker secondary grounded. With those problems cleared up, I was left with oscillation when the volume control was turned up.

The reason was simple. There is no way you can have an unshielded valve like a type 57 adjacent to the output valve and transformer and not get coupling through the air. Just placing a hand between the two valves removed the instability. I fitted a shield over the type 57 valve, and that was all that was needed.

The tabletop speaker

I wanted something that looked the part and once more, dipped into the junk box looking for inspiration. This speaker was made from a kitchen colander, a monitor stand and a discarded car speaker driver (as shown in the photo at upper right). I sprayed it the same mission brown as the set, and it plugs into the audio chassis via a jack plug.

The result may make the purists wince a bit, but I was quite pleased with the finished product.

It works!

To my joy, the whole radio then worked as expected. With a 10m external aerial, at Springwood in the NSW Blue Mountains, I could tune in all the Sydney stations plus a hint of others down in the hiss and crackle.

The feedback and gain controls worked as before, varying the gain and selectivity. With an output of only a couple of watts, the speaker delivers a comfortable listening level.

Detector wave shapes

I took some scope screen grabs of the wave shapes around the detector. They are a bit different from those of a receiver with clear-cut RF stages with separate diode detectors.

Feeding the detector with a 915kHz sinewave gave the waveform shown in Fig.2 at the detector plate. This shows a carrier with some small, unknown modulation at about 9kHz. Perhaps this is a beat frequency from an adjacent carrier, or some form of low-frequency self-oscillation.

The completed tabletop speaker. It consists of a computer monitor stand, colander, and an old car speaker. Like the rest of the design, it's a hodge-podge of parts.

I then modulated the carrier at 450Hz and the plate signal, shown in Fig.3, illustrates the valve 'detecting' the signal in its own way.

At the output point of the tuner, the audio signal has most of the carrier (and the odd 9kHz signal) removed by the radio-frequency choke (RFC), acting as a low-pass filter (Fig.4). Valve V2 then amplifies the audio, providing plenty of voltage for the grid of V3 (Fig.5).

The whole story

For those interested, I've written a series of articles with much more detail on the design and construction of this set. The complete saga has all the gritty of design failures and goof-ups.

I've posted it on the "Vintage Radio" website hosted by Brad Leet. You can read all these details at the following links:

https://vintage-radio.com.au/default.asp?f=12&th=30

https://vintage-radio.com.au/default.asp?f=12&th=44 SC