Vintage Radio

By Dr Hugo Holden

The Zenith Royal 500 "Owl Eye" AM Radio

The Zenith Royal 500 radio appeared in 1955, one year after the Regency TR-1 which was the first commercial transistor radio in 1954. Unlike the Regency TR-1 though, by the time that the Zenith Royal 500 was released, the technology had rapidly progressed into the conventional circuitry we know today as the typical "7 transistor AM radio".

The Regency TR-1 was powered by a 22.5V battery to help overcome the effects of the large base-collector junction capacitances of the very early transistor types and it had a low intermediate frequency (IF) of 262.5kHz to help overcome transistor bandwidth limitations. It also had a single Class-A output stage.

However, the Zenith Royal 500 had more advanced transistors, the conventional 455kHz IF and was powered by 6V from four AA cells. It also had a conventional transformer-coupled Class-B push-pull audio output stage.

The styling of the Royal 500 could be said to be distinctive, with the metallic surrounds for the black tuning and volume controls and the metallic speaker grille, so much so that in later years it became known as the "Owl Eye" radio.

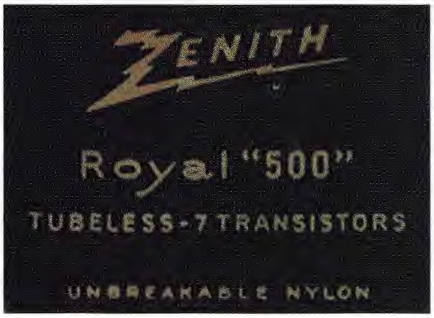
Also of interest was that its case was labelled on the back as "Unbreakable Nylon". That might seem to have been asking for trouble but my sample does appear to have lasted well, with no cracks in the case.

Also on the back and shown in the photo below, the radio is described as "TUBELESS - 7 TRANSISTORS".

Circuit details

The transistors used in the Royal 500are germanium NPN types, as was the case in other very early AM radios, such as the Regency TR-1 (www.siliconchip.com.au/Article/3761, April 2014) and the Sony TR-72 (www.siliconchip.com.au/Article/6938, March 2014).

However, by the early 1960s most manufacturers had changed to germa-



nium PNP types and by the early 1970s there was a general shift to silicon transistors in most new equipment.

As shown in the circuit diagram of Fig.1, while the design of the Royal 500 now looks to be conventional, it represented a very rapid development in solid-state radio technology.

It became the "world standard" for an AM radio, with three IF transformers, a detector diode and a 3-transistor two-transformer audio system with a Class-A driver stage and as already noted, a push-pull output stage.

In one aspect, the circuit was not world standard, in that it has separate oscillator and mixer transistors. Most later radios had a single mixer-oscillator transistor (often referred to as a converter) and saved a transistor by this approach.

Then again, quite a few designs added an audio preamp transistor, so the total transistor count remained the same at seven.

Interestingly, the circuit has an error, because the detector diode X1

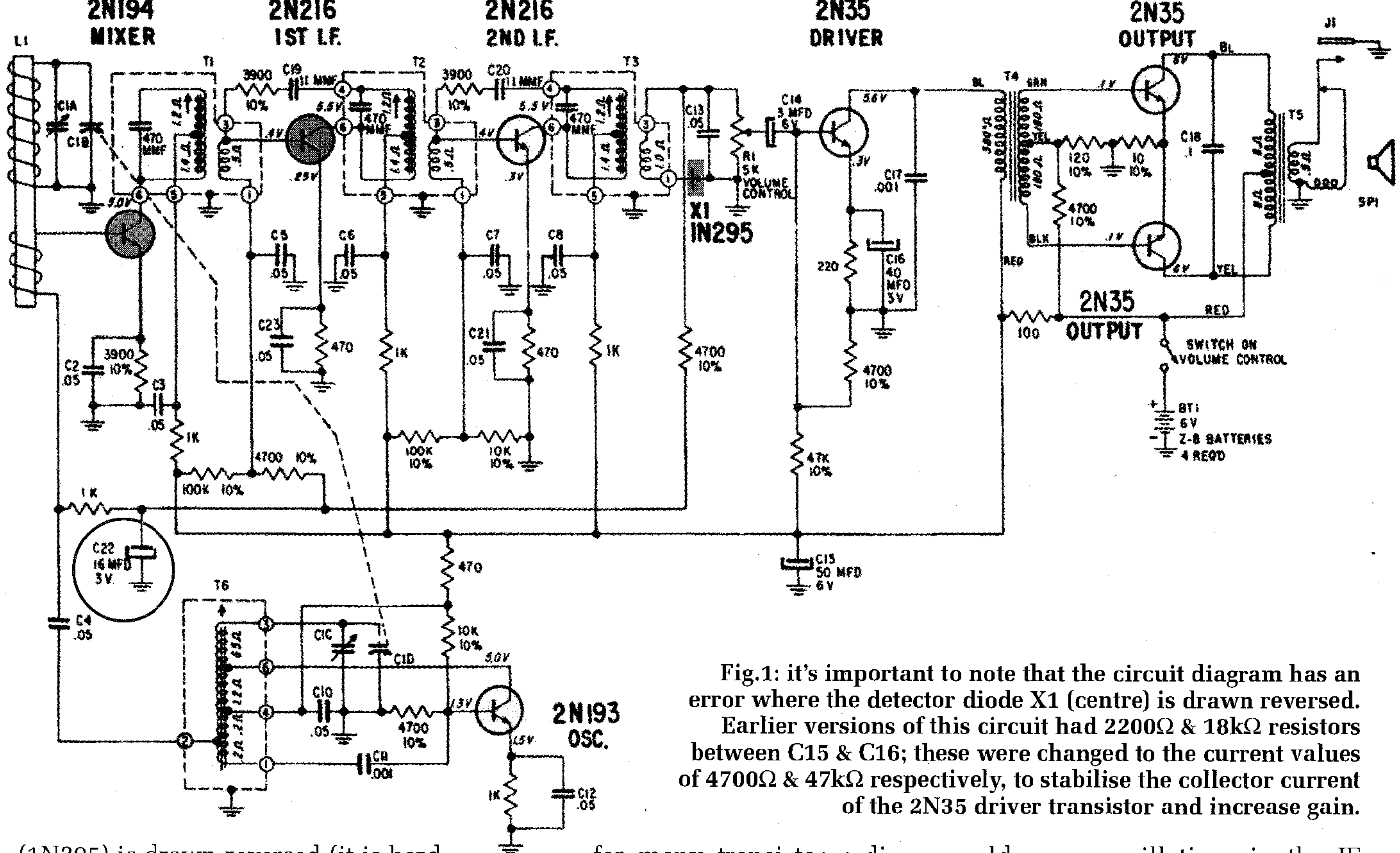


Fig.1: it's important to note that the circuit diagram has an error where the detector diode X1 (centre) is drawn reversed. Earlier versions of this circuit had 2200Ω & 18kΩ resistors between C15 & C16; these were changed to the current values of 4700Ω & 47kΩ respectively, to stabilise the collector current of the 2N35 driver transistor and increase gain.

(1N295) is drawn reversed (it is hard to see and is at the secondary output of the third IF transformer, T3). It is not wired this way in the real radio though, where the diode cathode is returned to ground (negative).

Subsequently there were a number of circuit variations in the Zenith Royal 500, dictated by parts supply, with changes to the AGC design and some versions using PNP transistors too.

The negative-going AGC voltage is developed across C22, a 16μF 3V electrolytic capacitor.

With low signal levels this electrolytic capacitor is subject to a small voltage of the correct polarity from the bias network of the 2N216 and first IF amplifier (the 100kΩ and 4700Ω resistors connected to C22's positive electrode). This also forward-biases the detector diode X1 a little, which helps with detecting low level signals.

However, with most reasonable signal levels from local stations, the AGC voltage on the positive terminal of C22 goes negative with respect to the radio's ground and then C22 is subject to reversed polarity; not good for an electrolytic capacitor.

This is actually a "classic mistake" in the design of AGC circuits in many, but not all, transistor radios.

In fact, this problem appears to have gone unnoticed for over half a century for many transistor radio designs. The practical remedy today is to fit a bipolar electrolytic AGC filter capacitor instead.

Perhaps not surprisingly, this AGC filter capacitor often does go open-circuit in early transistor radios and C22 was open-circuit in my Zenith radio. The unbypassed feedback causes oscillation of the IF stages.

That turned out to be the case when I first switched on my Zenith radio and it was clear from the heterodyne sounds on tuning stations that the IF was oscillating. It would only weakly receive stations and there was a lot of random noise and static too.

Investigation revealed that the mixer transistor had partially failed and the first IF transistor was noisy. The faulty components are indicated in red on the circuit.

All the other electrolytic capacitors, aside from C22, were normal on test for capacitance, ESR and leakage which surprised me, considering their age. *Editor's note: modern electrolytic capacitors will tolerate a small negative bias voltage (<1.5V) long-term without failure.*

Neutralisation

Vintage transistors such as the 2N916 have fairly high base to collector feedback capacitance and this would cause oscillations in the IF amplifier stages unless neutralisation was employed.

On this circuit, this is effected by the 11pF and 3900Ω feedback components around the two 2N216 IF transistors. Many European-made PNP transistors for IF work such as the OC45 also required neutralisation when used in 455kHz IF stages in typical AM radio circuits.

When it comes to replacing the 2N916 transistors, you need an NPN germanium type with the same feedback capacitance properties or the IF stage will become unstable and oscillate.

The alternative would be to adjust the feedback components to compensate. I couldn't find any 2N194 or 2N216 transistors, however I found some 2N94s which made suitable replacements.

In radios of the mid to late 1960s, germanium transistors with very low feedback capacitances became available, making the need for IF neutralisation unnecessary. These included PNP transistors such as the AF117 or AF127.

Construction

Two photos in this article show the interior of the Zenith radio. Note that all the transistors are in sockets and this feature helped with the fault-finding.

While the tuning dial only lists frequencies up to 1400kHz, the radio can still tune above that frequency (to about 1600kHz).

The electrolytic capacitors are housed in white ceramic tubes with their ends sealed with hard resin. There was no evidence of any physical leakage of electrolyte from any of them and as noted, only one was faulty.

One thing to bear in mind when repairing and testing vintage transistor radios is that they have phenolic PCBs, and the adhesion of the copper tracks to the board is nowhere near as good as with modern fibreglass PCBs. So it pays to avoid soldering if possible and when forced to, use a good temperature-controlled iron with the minimal required heat.

Also, in radios where the transistors are soldered on, they should, if possible, have heat-extracting clips placed on their leads while soldering.

Vintage germanium transistors are far more sensitive to heat damage than modern silicon devices. So the advantage of sockets for transistors is that they do not get exposed to heat from soldering but the disadvantage is that the socket connections can become intermittent.

In any case it is better to do exhaustive tests before concluding that any component in the radio needs removal or desoldering. Fortunately, electrolytic capacitors can be checked in circuit with an ESR (Equivalent Series Resistance) meter.

The first step in fault-finding is to ensure the DC operating conditions and voltages are correct on all the transistors. After that, AC tests with a signal generator and the oscilloscope can be helpful, if available.

The manufacturer's general alignment instructions should be followed. However, if the IF transformers have not been touched and the original transistors are present and working OK, it would be better in most cases not to try adjusting the IF transformers.

In particular, it can be very easy to break the slugs as they can be frozen in after 60 years without being touched. So if the slugs can't be easily adjusted, leave them as they are.

If transistors have been replaced in the IF circuits, then the transformer slugs should be re-adjusted. Or if the IF transformers have been tampered with by another party they will most likely require checking and adjustment.

Any test signal generator should be as loosely coupled in as possible or the generator itself can disturb the tuning conditions of the circuit that it is connected to.

The best way is to simply use one or two turns of wire around the ferrite rod (some early transistor radio alignment instructions did specify a magnetic loop to do it and this was a very wise idea).

Editor's note: the AM Transmitter featured in the March 2018 issue can be modified to tune between 440kHz and 600kHz by replacing a single capacitor. It can then be used as an alignment source at 450 or 455kHz. The details are in the article at: www.siliconchip.com.au/Article/11004

Aligning the IF stages

One useful method to adjust the IF transformers is to temporarily deactivate the local oscillator. In this particular radio it just involved unplugging the oscillator transistor and coupling the signal generator in with a 1-turn loop on the ferrite rod, set for a 1kHz modulated 455KHz carrier.

The detected audio can be seen at the volume control with an oscilloscope, heard in the speaker or measured with an AC millivoltmeter.

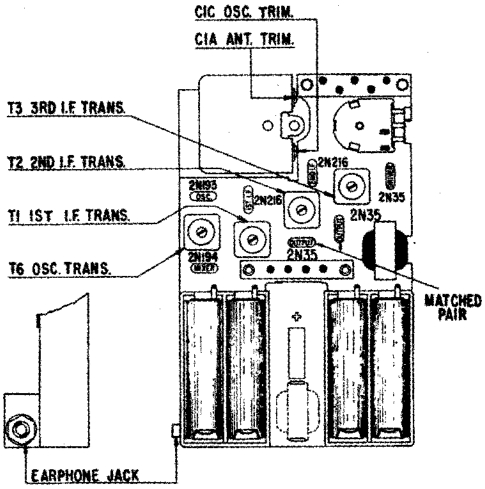
Coupling a 455kHz signal to the ferrite rod still works without deactivating the local oscillator, but a higher signal level will be required to break through the mixer.

In many cases it is of little help sweeping the IF and plotting the response curve, because the IF coils are all tuned to a maximum peak at the same frequency (typically 455kHz). The point being that the IF amplifier band-pass characteristic is largely set by the design of the IF transformers themselves, not by the technician adjusting or "stagger tuning" the IF stages.

Therefore, in my view, an IF sweep generator or "wobbulator" for tuning the IF stages in AM transistor radios has little utility for repairs and adjustments. The opposite is true in correctly adjusting analog television video IF amplifiers though.

Also, generally, it is best to set the IF transformers, or the radio's other adjustments, with a low level modulated RF signal, with the modulation tone just slightly more audible than noise, so that the radio's AGC is just below threshold.

This is because small changes in the observed demodulated audio output voltage amplitude at the detector are suppressed by AGC action which occurs with stronger signals.



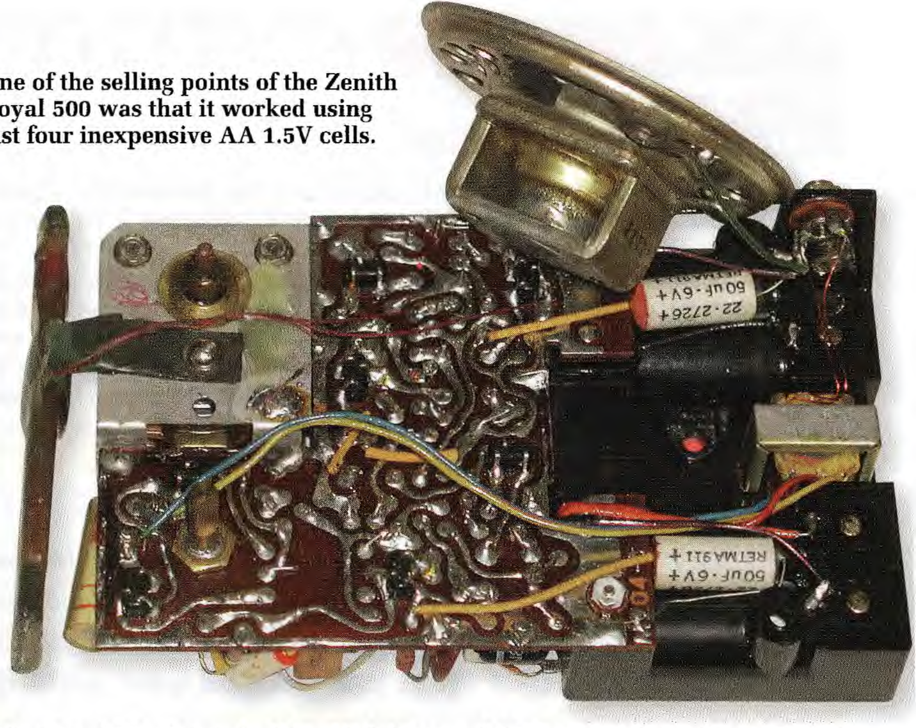
TRANSISTOR & TRIMMER LAYOUT FOR 7XT40 CIRCUIT #2

While obscured in the photos, the Royal 500 does have a separate mono earphone jack (J1 on Fig.1).
***Source:* www.transistor-repairs.com/schematics.html**

Operation	Input signal frequency	Connect inner conductor from oscillator to	Connect outer shield conductor from oscillator to	Set dial at	Trimmers	Purpose
1	455kHz		Chassis	600kHz	Adjust T1-T3 for maximum output	For IF alignment
2	1620kHz	One turn loosely coupled to wavemagnet		Gang wide open	C1C	Set oscillator to dial scale
3	1260kHz			1260kHz	C1A	Align loop antenna
4	535kHz			Gang closed	Adjust slug in T6	Set oscillator to dial scale
5	Repeat steps 2, 3 and 4					

All alignment steps for the Royal 500. Check www.transistor-repairs.com/schematics.html for a great listing of schematic diagrams on Zenith radios.

One of the selling points of the Zenith Royal 500 was that it worked using just four inexpensive AA 1.5V cells.



The Royal 500 shown in this article is a model B. It was released in 1956 and used the PCB shown above, instead of being hand-wired. The transistors are all mounted in plug-in sockets, which makes it easy to remove and replace them. While this version of the Royal 500 used NPN transistors, later models made the switch to PNP transistors as they became more common.

Setting the local oscillator

The oscillator coil slug is set to calibrate the pointer with the dial (or set the lowest tuning frequency with the variable capacitor fully meshed) at the low end of the band.

The oscillator trimmer capacitor is then set at the high end of the dial to make sure the tuning range and dial pointer are correct.

The general rule is that the inductances set the low end of the band and the trimmer capacitors on the tuning gang set the high end.

The exception to this rule is when there is an adjustable padder capacitor in series with the oscillator section of the tuning gang. This sets the low end of the band.

Ideally the frequencies that the local oscillator tunes over should be set according to the manufacturer's instructions to ensure the dial scale calibration is as good as possible. This also requires that the IF centre frequency is correctly set.

The antenna circuit is tuned (near the high end of the band) for maximum signal, by adjusting the trimmer capacitor on the relevant section of the tuning gang.

In the case of the Zenith Royal, the manufacturer's instructions specified a test frequency of 1260kHz.

If a radio station sits near to this frequency, and in the absence of good test generators, it is better used as the signal source for this adjustment as there are no generator loading issues to consider. In Sydney, station 2SM at 1269kHz would be ideal.

Often the ferrite rod antenna tuning cannot be easily set for a peak at the low end of the band, because it requires sliding the antenna coil on the ferrite rod to adjust the inductance. But often the coil is held in place with wax and it is better to leave it alone.

Mechanical considerations

On the mechanical side of things, a small amount of lubricant can be added to the moving metal surfaces such as the variable capacitor shaft and bearings.

In this radio there is a ball bearing epicyclic reduction system where the centre tuning knob rotates at a greater rate than the dial pointer shell surrounding it; this aids fine tuning. Cleaning and lubrication of the on-off switch and volume control is often required.

In this radio, there was corrosion and a white oxide on the transistor bodies. This was carefully removed without affecting the labels or logos and the transistors bodies wiped with a small amount of WD40 to help protect them. A coat of clear varnish can be added after that, if required.

Performance

After repairs my sample Zenith 500 radio performed well with good sensitivity and a reasonable tone, despite the small sized speaker. It is as good as any transistor radio made a decade or more later, possibly better, because of the quality of the case and components used.

For example the variable capacitor frame in the radio is solid 1/8-inch thick brass and the speaker has a good-sized magnet although it is compact overall.

For all vintage transistor radios I recommend using carbon zinc cells as their current-sourcing ability is much lower than alkaline cells for short circuit conditions. And if the carbon zinc cells leak fluid, it is much less destructive than that from alkaline cells.

Conclusion

I think the Zenith Royal 500 transistor radio makes a very worthy member of a vintage transistor radio collection. It indicates how quickly transistor radio technology accelerated just two years after the introduction of the Regency TR-1. SC