THE 1956 ZENITH ROYAL 500 TRANSISTOR “OWL’S EYES” RADIO.

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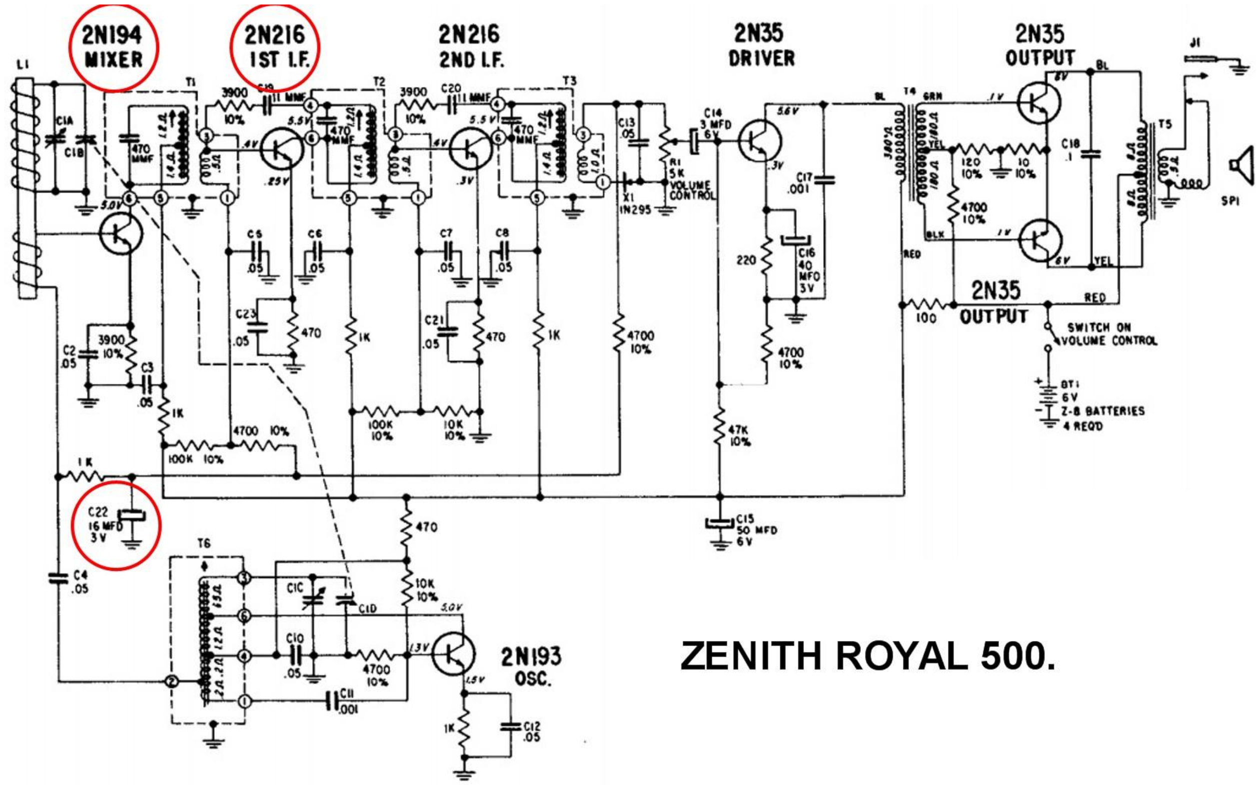
Introduction:

The Zenith Royal 500 radio appeared in 1956, two years later than the Regency TR1 which was the first commercial transistor radio in 1954.

Unlike the Regency TR1 though, the technology in the Zenith Royal 500 had matured into the conventional circuitry we know today as the typical “7 transistor AM radio”.

The Regency TR1 was powered by a 22.5V battery to help overcome the effects of base-collector junction capacitances of the very early transistor types and had 262.5kHz IF’s due to transistor limitations and a single class A output stage. However the Zenith Royal 500 had more advanced transistors, the usual 455kHz IF and was powered by 6 volts acquired from 4 AA cells and had a typical transformer coupled push pull audio system.

These radios have been dubbed “Owl’s Eyes radios” because of the appearance.



ZENITH ROYAL 500.

Transistor radio circuitry:

The Transistors used in the Royal 500 are NPN Germanium types. Many very early AM radios, such as the Regency TR-1 and the Sony TR-72 also used NPN types. However, by the early 1960's most manufacturers had gone to PNP Germanium types. By the early 1970's there was a general shift to silicon transistors in most new equipment. The schematic of the Royal 500 is shown above.

The schematic has an error though, the detector diode X1 (1N295) is drawn reversed. It is not wired this way in the real radio where the diode cathode is returned to ground (negative). Subsequently there were a number of circuit variations produced for the Royal 500, dictated by parts supply, with changes to the AGC design and some versions using PNP transistors too.

As the negative going AGC voltage builds up, it is developed across C22, a 16uF 3V electrolytic capacitor. With low signal levels this electrolytic capacitor is exposed to a small correct polarity voltage from the bias network of the 2N216 first IF amplifier (the 100k and 4700R resistor connected to C22's positive). 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 has reversed applied 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. This issue appears to have gone unnoticed for over half a century for many transistor radio designs. The remedy is to fit a bipolar electrolytic AGC filter capacitor instead.

It is interesting that this AGC filter capacitor often goes open circuit in early transistor radios. C22 was open circuit in this Zenith radio. The un-bypassed feedback causes oscillation of the IF stages.

When I received the Royal 500 radio, it was clear from the heterodyne sounds on tuning stations that probably the IF was oscillating and 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 1st IF transistor was noisy too. The faulty components are indicated by the red rings on the schematic. All the other electrolytic capacitors, aside from C22, were normal on test for capacitance, ESR and leakage which surprised me, considering their age.

As the photos show, the case on this radio is interesting. It is made of Nylon. And it says "Unbreakable Nylon". That might be asking for trouble. It does appear to have lasted well and in this radio specimen there are no cracks in the case.

Of note the radio has a separate oscillator and mixer transistor. Many later radios had a single mixer-oscillator transistor and saved a transistor in this manner, but then again, quite a few designs added an extra audio pre-amp transistor, so the total transistor count remained the same at 7.

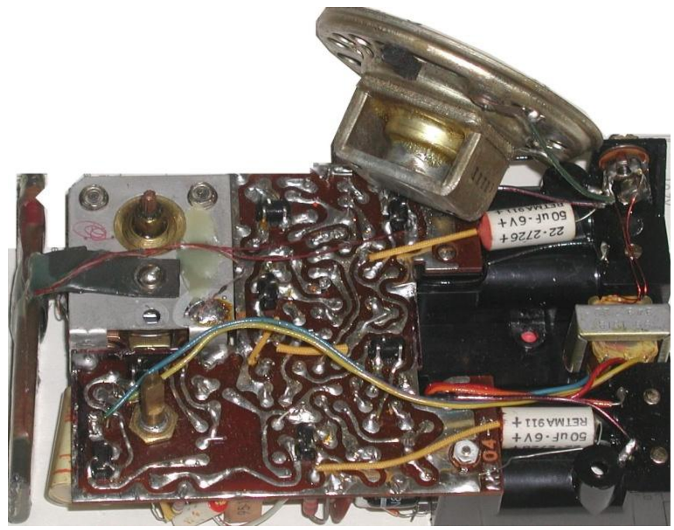
The design of the Royal 500 is conventional and became "world standard" for an AM radio with three IF transformers with a detector diode and a three transistor two transformer audio system with a class A driver stage and a push pull output stage.

Vintage transistors such as the 2N916 have a fairly high base to collector feedback capacitance. This would cause oscillations in the IF amplifier stages unless neutralisation was employed. As can be seen this is effected by the 11pF and 3900 Ohm feedback components around the two 2N216 IF transistors. Many European made PNP transistors for IF work such as the OC45, also required neutralization when used in 455kHz IF amplifiers in typical AM radio circuits.

When it comes to replacing the 2N916 transistors, ideally they are replaced with an NPN germanium type with the same feedback capacitance properties, or the IF stage will become unstable and oscillate unless the feedback components are adjusted to compensate. In radios of the mid to late 1960's, Germanium transistors with very low feedback capacitances were deployed, making the need for IF neutralization unnecessary. These types include devices such as the AF117 or AF127.

I couldn't find any 2N194 or 2N216 transistors, however I found some 2N94 types which made suitable replacements.

The photo below shows the radio's interior. One thing of note is that all the transistors are in sockets. This feature helped with the fault finding.



Some versions of the radio had a metal chassis and were hand wired.

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.

Repairing aligning and testing vintage transistor radios:

One thing to bear in mind, is that many vintage transistor radios have phenolic pcb's and the adhesion of the copper foils to the pcb is nowhere near as good as modern fibreglass pcb's. So it pays to avoid soldering if possible and when forced to, to use a good temperature controlled iron with the minimal required heat.

Also, in other radios where the transistors are soldered, they should, if possible, have heat extracting clips placed on their leads while soldering. Vintage germanium transistors are more sensitive to heat damage than modern silicon devices. Obviously one advantage of the sockets for transistors is that the transistors do not get exposed to heat from soldering. But one disadvantage is that the connections can become intermittent.

It is better to do exhaustive tests before concluding any component in the radio needs removal or un-soldering. The electrolytic capacitors can be checked in circuit with an ESR 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 signal generators and the oscilloscope is helpful. (Recently I designed and built a complete tool for AM radio alignment called an H-Field Transanalyser which is the subject of another article)

The manufacturer's general alignment instructions should be followed. However if the IF transformers have not been touched and the original transistors are present & ok, it would be better in many cases not to adjust the IF transformers, sometimes the slugs can be difficult to free up.

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

Any test signal generators 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 Transanalyser mentioned avoids this by using magnetic coupling to the ferrite rod.

Setting the IF tuning:

One useful method to adjust the IF stages/transformers is to temporarily deactivate the local oscillator. In this particular radio it just involved unplugging the oscillator transistor. Then coupling the signal generator in with a 1 turn loop on the ferrite rod with a 1kHz modulated 455KHz carrier. The detected audio can be seen at the volume control with the oscilloscope, heard in the speaker or measured with a millivolt meter. This is only convenient for a radio design with a separate local oscillator transistor rather than a mixer oscillator stage. Coupling a 455kHz signal to the ferrite rod still works without deactivating the local oscillator, but a higher signal level is required to break through the mixer.

It is of little help sweeping the IF and plotting the response curve, because the IF coils are all tuned to a maximum peak on the same frequency, typically 455kHz. The point being that the IF amplifier band-pass characteristic is set by the design of the IF transformers themselves, not by the technician adjusting or “stagger tuning” the IF stages. Therefore an IF sweep or “wobulator” for tuning the IF stages in AM transistor radios in my view has little utility value to help with repairs & adjustments. The opposite is true in correctly adjusting analog Television video IF amplifiers though.

Also, generally, it is best to set the IF’s or the radio’s other adjustments with a low level modulated RF signal, but with just more of the modulation tone 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.

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 V/C fully meshed) at the low end of the band. The oscillator trimmer capacitor on the V/C 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 V/C set the high end. The exception to this rule is when there is an adjustable padder capacitor in series with the oscillator tuning gang and this sets the low end of the band or correct oscillator frequency, which runs the IF frequency above the low end tuned frequency.

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

Setting the ferrite antenna tuning:

Always, the Trimmer capacitor on the section of the V/C that tunes the ferrite rod antenna coil is set for maximum signal *near* the high end of the band, for the Royal 500 radio the manufacturer’s instructions specified 1260kHz. If a radio station is 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. Often the low end ferrite rod antenna tuning cannot be easily set for a peak, because it requires sliding the antenna coil on the ferrite rod to adjust the inductance, but often the coil is waxed in place and its 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 & lubrication of the on-off switch and volume control is often required.

Sometimes as in this radio, there was corrosion and a white oxide on the transistor bodies, this was carefully removed without affecting the labels/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 of the Zenith Royal 500:

After repair this Zenith 500 radio performs 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 would recommend Zinc-Carbon cells. The current limiting is much lower than Alkaline cells for short circuit conditions. And if Zinc-Carbon cells leak fluid, it is much less destructive than the chemicals from Alkaline cells.

General Transistor radio performance:

A question always crops up: Even if a pocket transistor radio appears to be “working” how can you know for sure if there isn’t some relative impairment in its performance? It might just appear a little weak compared to another radio. Sometimes there is not enough data in the manufacturer’s service sheet about power output for any signal level input. (This is one reason why the H- Field Transanalyser mentioned above was built to test the radio with limited manufacturer’s data)

One issue, unlike most valve radios, most pocket style transistor radios do not have an external antenna input connector with a known input impedance to feed in a “standard *voltage* test signal”. All signals are received via the ferrite rod instead.

On the audio side of things, it easy to inject a 1kHz or other audio frequency test signal at the volume control and drive the audio driver stage and output stage to clipping and check for gain, distortion performance, power output and that both the output transistors are closely matched and the clipping symmetrical.

However, on the RF side of things there are more variables to consider and ideally it would require a controlled electromagnetic field intensity chamber delivering a field of intensity some known volts per meter for test purposes, rather than connecting into the radios circuitry with a probe & generator which often de-tunes the circuit where the generator connects, despite attempts at keeping the coupling “loose”.

Some early transistor radio alignment instructions did specify a magnetic loop to do it and this was a very wise idea.

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 2 years after the introduction of the Regency TR-1.

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