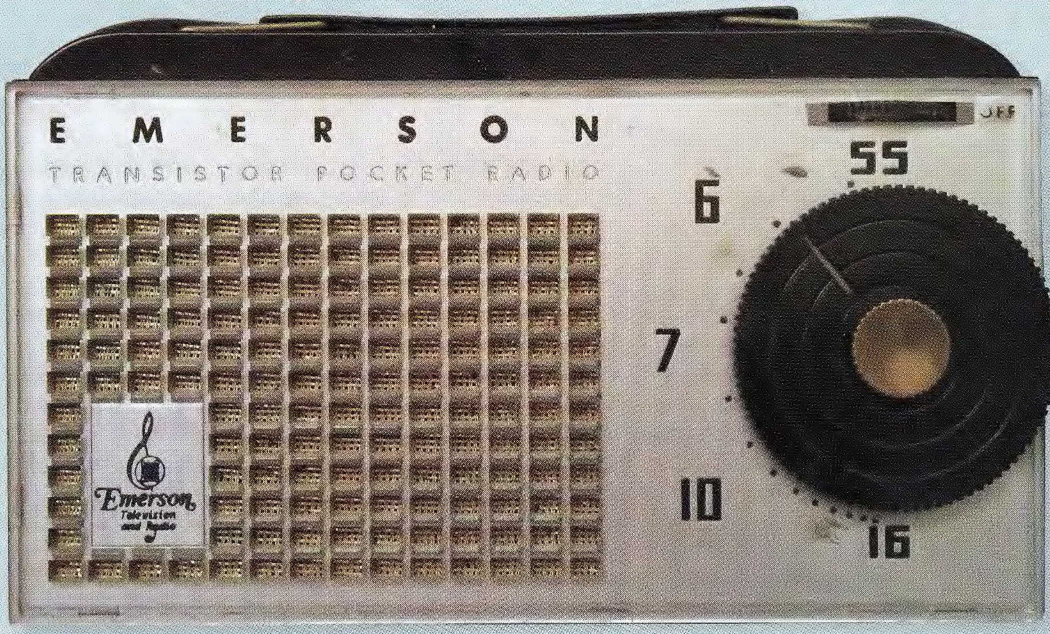
By Ian Batty

Emerson 838 hybrid valve/transistor radio



The Emerson 838 is a transitional design in more ways than one. It came at the end of the valve era, as transistors were starting to become widely available and thus uses both. Many of its components are mounted on a riveted phenolic board but it also has a metal chassis, representing the fact that it was introduced just before sets began to be built using printed circuit boards.

The Emerson 838, with its punched and riveted phenolic board chassis and metal frame, sits between the older all-metal chassis designs and upcoming printed circuit models.

All the RF stages, the detector and the audio preamp stage are valve-based while the push-pull Class-B output stage is based on a pair of PNP transistors. Despite the use of transistors, the loudspeaker is still transformer-coupled.

While the use of valves means that this set is not as compact as the Regency TR-1, shown next to it for comparison, it's impressively small for a hybrid set.

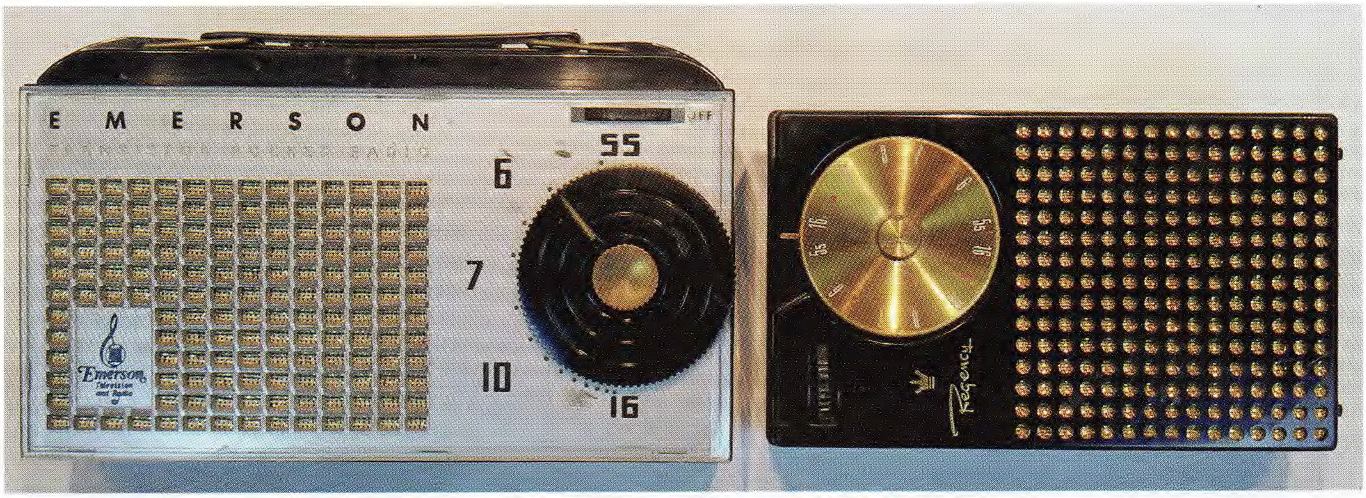
We covered the all-transistor Regency TR-1 set in our April 2013 issue; see siliconchip.com.au/Article/3761 The two sets were contemporaries, with the TR-1 (the first all-transistor set) released in late 1954 and the Emerson 838, in 1955.

The Emerson 838 was an evolution of the all-valve 747. Besides the labelling, there's little externally to distinguish them. The 838 comes in several different colour combinations.

I have the silver set shown here, which is also available with a red back and tuning knob, one in a maroon case with a gold faceplate and one in cream. You can see photos of other versions of this set at www.radiomuseum.org

Construction method

Major components such as the IF transformers are mounted using twisted



The Emerson 838 (153 x 90 x 33mm) shown at left with the Regency TR-1 (76 x 127 x 32mm) to its right. Considering the Emerson 838 used three sub-miniature valves, compared to the all transistor TR-1, its size is quite impressive.

metal lugs and the valves insert into in-line valve sockets specially designed to contact the thin wire connections of the miniature battery valves.

Likewise, the two transistors insert into chassis-mounted sockets. Most minor components are wired point-to-point, either to socket/IF transformer contacts or to chassis eyelets.

Like some other sets of the era, many minor components are fitted to a "Couplate"/ "Printed Electronic Circuit" (PEC), an early method of packaging components onto an encapsulated substrate. As it's buried behind other circuitry, you can't really see it in the photos.

These can crack over time, or become damaged but replacements for the more common PEC assemblies are available online. If you can't find a replacement, in the worst case, it is possible to make a substitute using more modern assembly techniques.

The "A" battery fits into a conventional spring-loaded bay retained by a slide cover while the "B" battery (also behind a slide cover) uses a snap fastener identical to those on the familiar PP9 transistor radio battery.

Circuit description

Rather than the conventional 1AG4 output pentode of its Model 747 predecessor, the 838 uses a push-pull transistor output stage.

This significantly improves battery life as it eliminates the 1AG4's constant 40mA filament current and 3mA HT current. The "A" battery operating current falls by 25% but the "B" battery current drops by over 50%.

Transistor audio amplifier designs were common by 1955, with the only real difficulty being in how to obtain an appropriate voltage to power the output stage.

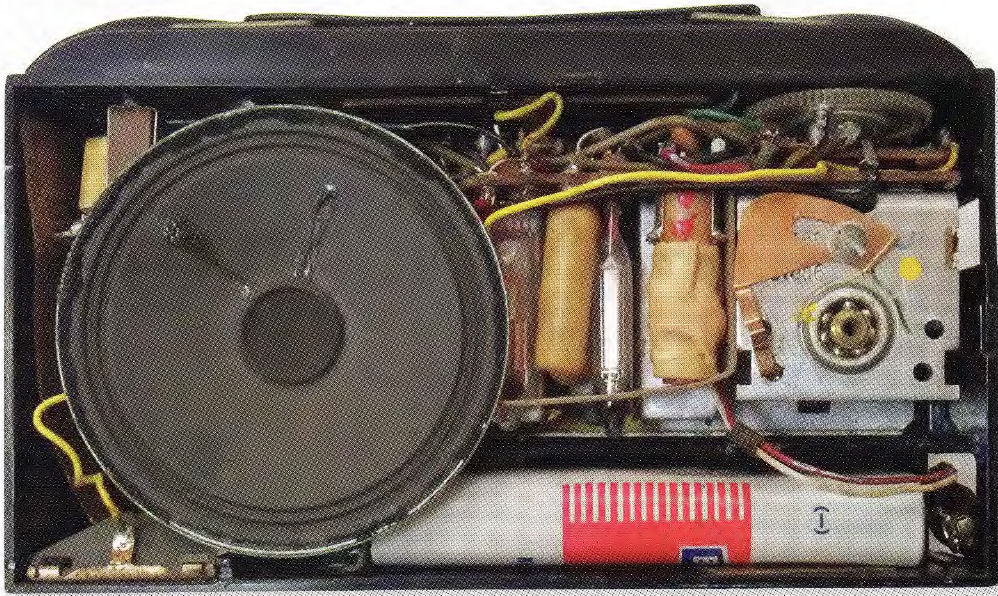
The solution was to use a 4V "A" battery rather than the more typical 1.5V type and compensate by connecting the three valve filaments in series, so they could also run from this 4V supply.

Dispensing with the output pentode also removed the need for its biasing circuit, so there's no wasteful back bias resistor, as there was in the 747.

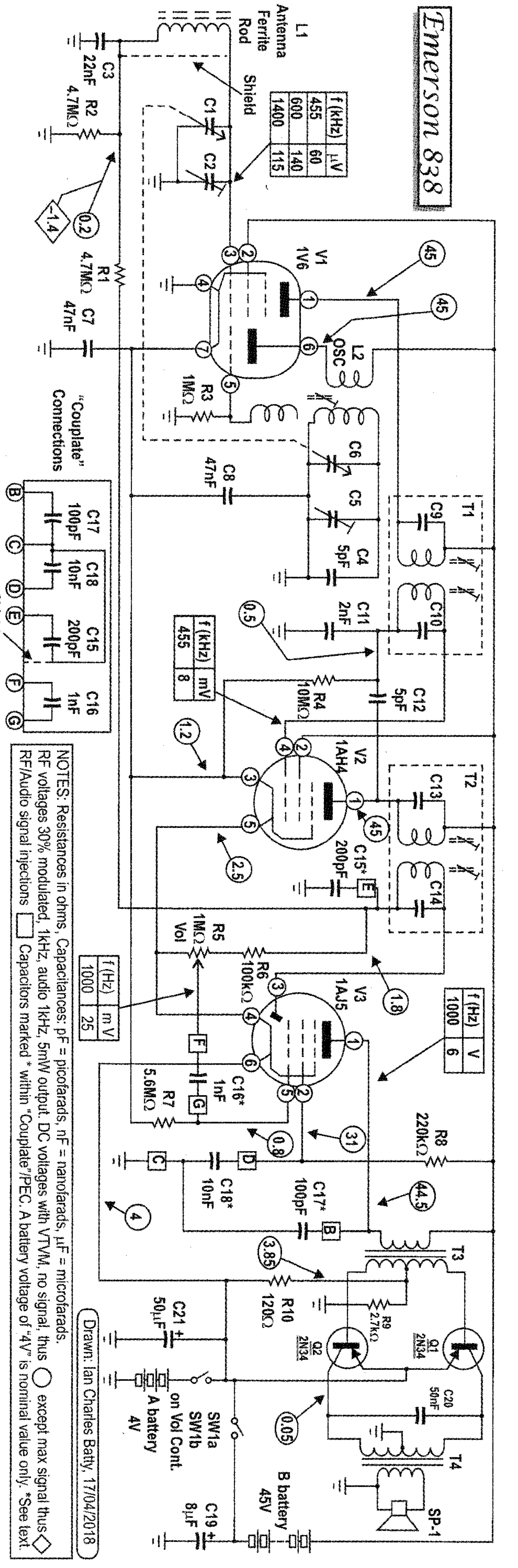
The set uses a ferrite rod antenna, moulded into the top of the case. The tuned antenna circuit feeds the signal to the mixer section of the converter, a 1V6 triode-pentode. Triode-pentodes fell out of favour in larger sets after the 1940s; while subminiature battery pentagrids (1E8) and triode-hexodes (2G21) were available, their conversion conductances are significantly inferior to that of the 1V6.

Also, the 1V6 has only about half the conversion gain of its 1R5 B7G cousin. Given the 1V6's superior performance to its subminiature alternatives, it's no surprise that the 1V6 dominated commercial battery valve designs of this era.

While pentagrids and triode-hexodes rely on the oscillator's signal directly modulating the electron stream from cathode to anode, the 1V6 relies on the coupling between the two sections for LO (local oscillator) injection.



Inside the Emerson 838 case everything is packed neatly. The antenna in the set is directional, so you might be able to get better reception over its 540-1620kHz range by rotating the case.



Aside from the use of the triode-pentode, it's a conventional converter stage. The tuned signal is fed directly to the converter's signal grid. Bias for this stage, derived from the AGC circuit, is series-fed through the antenna winding.

The oscillator is a little unusual; the expected capacitive coupling from the top of the oscillator's tuned winding is absent. Instead, an open-ended coil winding is used, using parasitic capacitive coupling between the grids.

Grid resistor R3 (at 1MΩ) is much higher than usual, reflecting the generally lower voltages and currents in subminiature valve circuits.

The triode's anode current is supplied via the oscillator coil's primary and the mixer's anode via the tuned primary of first IF transformer T1. Its secondary, also tuned, feeds the signal to V2, a conventional sharp-cutoff pentode (1AH4). Despite its small size, it gives more gain than the larger B7G 1T4 work-alike with a 45V supply.

The IF amplifier does not receive gain control from the AGC circuit. That's a result of the set's series filament connection.

Since each filament is some 1.25V more above ground than the previous one, series-connected filament designs demand some tricky AGC action. There's an excellent description of this on pages 1114-1115 of the Radiotron Designer's Handbook.

Emersons' designers have picked the elegant solution of "contact potential" bias with no external gain control. Grid resistor R4 (10MΩ) allows V2's grid to drift weakly negative and provide self-bias.

I thought that this might also allow grid rectification on strong signals and thus provide its own local AGC but in later testing, I was not able to find any evidence of this.

Unusually, the second IF stage is neutralised by 5pF capacitor C12's feedback from the valve's anode to the "cold" end of the first IF transformer's secondary. This is odd because pentodes generally exhibit very low anode-grid capacitances and do not usually need such a high neutralisation capacitance.

The 1AH4's $C_{g\text{-}a}$ is just 0.01 pF but note that C12 forms a capacitive voltage divider with 2nF bypass capacitor C11, reducing its effectiveness, hence the relatively high value. Note also 22nF capacitor C3 from the bottom end of the antenna to ground, which is necessary to cancel out feedback in the overall circuit wiring in this tightly-packed little set.

V2 feeds its amplified IF signal to the tuned primary of second IF transformer T2 and T2's secondary delivers the IF signal to the diode section of V3, the demodulator.

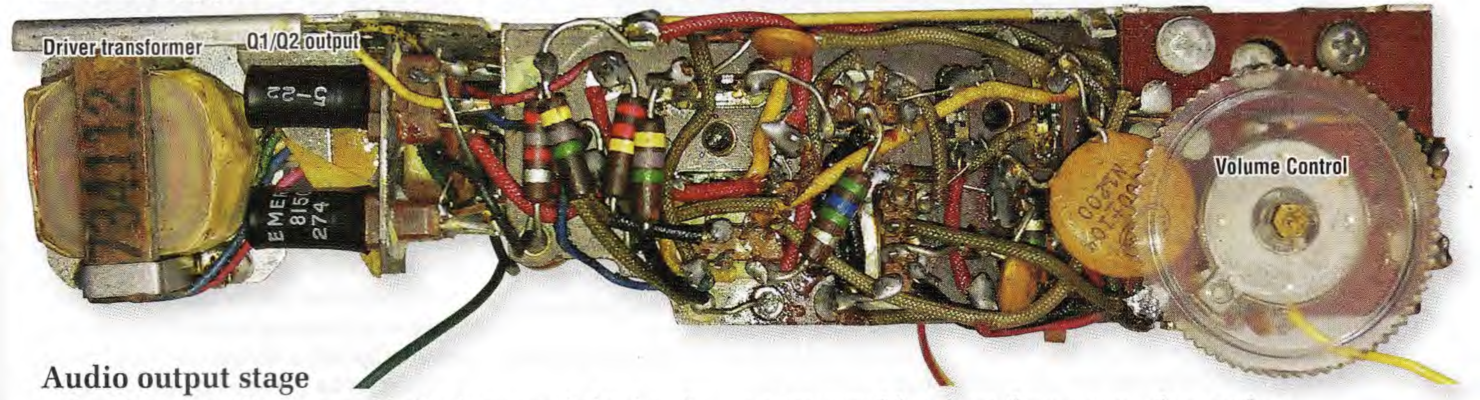
The AGC signal is derived from the DC component of the demodulated signal, fed back to the grid of converter V1 via the resistive divider formed by R1/R2.

The AC component of the signal is filtered out by C3 (it's also an RF bypass capacitor, as mentioned above). Since the "cold" end of the second IF transformer is returned (via R6 and R5) to the valve's filament, there's no delayed AGC effect.

The audio signal at the wiper of volume control pot R5 is AC-coupled via C16 to the grid of V3's pentode section.

It gets bias from the negative filament terminal of V2, around -1.2V, via 5.6MΩ resistor R7. V3, a 1AJ5, is basically a subminiature version of the B7G 1S5, with about 80% of the gain for a 45V supply.

Above: labelled bottom view of the 838 chassis showing the two IF transformers, output transformer and tuning gang. Below: labelled top view of the chassis. The large 50µF ceramic capacitor (C21) just under the volume control bypasses the 4V LT supply, while the smaller 8µF ceramic next to it (C19) bypasses the 45V HT supply.



Audio output stage

Audio preamplifier stages ideally have anode load and screen dropping resistors in the megohm range. These very high values hit the "sweet spot" between increasing gain (with increasing load resistance) and decreasing mutual conductance (with lower anode/screen currents).

But this valve needs to deliver sufficient current to drive the following Class-B transistor output stage. The screen voltage of 30V gives V3 a mutual conductance of about 300µS (microsiemens), enough to provide both useful voltage gain and an adequate current.

Transformer T3 matches V3's high anode impedance to the low input impedance of Q1/Q2, with a high impedance primary and low-impedance, tapped secondary.

The circuit shows Q1 and Q2 as proprietary Part No. 815003. This set's devices were 2N34s, a grown-junction germanium PNP audio transistor type.

Crossover distortion is minimised by the biasing network of resistors R10/R9, providing the usual 150mV of forward bias to both bases. Unlike later designs, there is no shared emitter resistor to improve bias stabilisation and add local feedback.

The transistor collectors feed push-pull output transformer T4, with C20 providing a top cut function. T4's secondary feeds the 12Ω speaker directly as there is no

The side view of the chassis shows the oscillator coil, converter (V1) & demodulator valve (V3), with the IF amplifier (V2) hidden.

Trimmer alignment is done with the chassis and batteries in place. C2 and C5 can then be adjusted by removing a small plate on the side of the case as shown.

earphone socket on this set.

8μF capacitor C19 bypasses the 45V HT supply from the B battery while the LT supply is bypassed by 50μF capacitor C21.

Editor's note

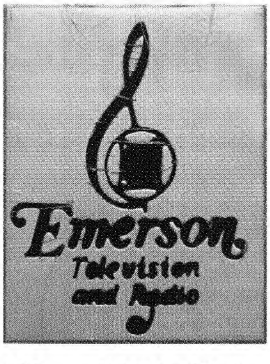
At the end of the valve era, hybrid car radios were quite common as local Australian manufacturers made the transition to transistors.

As with the American Emerson set described here, Australian manufactured car radios used battery valves for the RF sections and germanium transistors in the audio stages, mostly using a single germanium power transistor in Class-A mode.

The heavier current drain of the Class-A output stage was generally not a problem in these cases since the sets ran from the car's battery.

These hybrid car radios were a significant advance on the earlier sets with their vibrator power supplies. The lack of audible vibrator buzz was most welcome.

As far as we can determine, no other hybrid radios were produced by Australian manufacturers although there were a number of hybrid TV sets and here the situation was reversed: silicon transistors did all the work in the small signal stages, while valves were used in the high voltage video and sweep stages (ie, yoke and EHT circuitry).



The Emerson logo features a take on a G-clef followed by the phrase "Emerson Television and Radio".

Cleanup and adjustment

The example shown here was in good physical and electrical condition, needing only a polish to smarten it up. It worked right away and didn't need any adjustment. But if you do need to adjust an 838 (or its predecessor, the 747), I have some helpful hints.

The chassis sits behind the front cover. To gain access, remove the tuning knob and gently prise the latch beside the tuning gang to begin releasing the front cover catches. Replace it by first seating the catches at the opposite end to the gang and then work towards it.

The chassis needs to be removed for IF and oscillator core alignment. Trimmer alignment must be done with the chassis in place in the cabinet, so an access plate is provided for trimmer capacitors C2 and C5 (see above).

Be careful when adjusting the coil slugs. Many sets of this era used a wax seal and this is best eased off with the light application of a heat gun. Don't be tempted to use the sprays meant for loosening bolts and screws. My experience with the Emerson 747 shows that these lubricants can freeze the adjustment slugs.

Luckily, in my case I was able to remedy the problem by applying heat but it's best to avoid the problem altogether by not attempting to lubricate coil slugs.

Also, the 747 service guide advises that you do not measure valve filaments with an ohmmeter. Analog meters can put out around 100mA on low range and this advice also applies to the 838.

Comparisons & performance

The most direct comparison I can make is with Emerson's own 747, a four-valve set similar in design to the classic four-valve B7G portables of the '50s and '60s.

There's also the Hoffman "Nugget" and the ingenious Crosley book radios, where the radio chassis nestles inside a "book-alike" case. Then there's the contemporary all-transistor Regency TR1, as mentioned in the intro.

The TR-1 used a hearing aid battery that lasted only about 20 hours, compared to the Emerson 838 which I would estimate would last around 40 hours, despite having a more powerful output stage. So it compares quite favourably.

Overall, I would have to say that the 838 is a great performer for its size. Its audio output is adequate, and sensitivity is good – it's superior to many transistor sets of the day. The maximum audio output is around 50mW. I did all my testing at 5mW as this seemed like a typical use case.

I measured the sensitivity at 600kHz at around 300μV/m, rising to 600μV/m at 1400kHz. In both cases, the signal-to-noise ratio was over 20dB. That equates to around 900~1800μV/m at a 50mW output, compared to adjusted figures for the TR-1 of 2000~2800μV/m for the same theoretical output level.

Selectivity at –3dB measured ±1.9kHz, at –60dB it was ±30kHz. The AGC allowed a 6dB increase in output volume for a 60dB increase in input signal level. It was hard to overload, needing some 750mV/m before producing noticeable distortion.

At 50mW audio output, Total Harmonic Distortion (THD) is around 10%, with 6% THD at 40mW and only

A brief history of Emerson

Victor Emerson incorporated a phonograph company in 1915. Releasing America's first radio-phonograph combination in the 1930s, Emerson emerged from obscurity offering the wildly successful "peewee" set in 1932.

With the peewee selling as many as 60% of all radios in the first half of 1933, Emerson's 50% share of this bonanza saw them become a major player. The 1947 release of a 10-inch television marked Emerson as an innovator, continuing to release the first clock radio, and solar-powered transistor pocket radio.

The Emerson hybrid model 838 radio described in this article was released in 1955.

The miniaturisation of valves

The triode was invented around 1907 and the tetrode in 1919. By 1939, multi-function valves (eg, diode-triodes) were common. That was also the year that the B7G series of battery valves was released, which abandoned the historic pinch construction, connecting the internal assembly directly to a set of base pins embedded in the bottom sealing disc.

These valves were electrically similar to their older, octal predecessors but the B7G series occupied some 25% of even the most compact octal valves' volumes. While the B7G design allowed such advances as the revolutionary BC-611 "Handy-Talky", the pressure for even greater miniaturisation remained.

Abandoning base pins entirely and bringing connecting wires through the envelope's base allowed further compaction. Three strategies emerged:

I. The E8 format has a cylindrical T3 (3/8-inch) envelope, retained a miniaturised version of the B7's base disc, but with eight connecting wire leads rather than pins. The compaction was remarkable. The subminiature 1E8 valve has only 6.25% of the original 6SA 7GT's volume. E8 types could be soldered directly in place or, with clipped leads, plugged into sockets.

The E8 base also allowed the encapsulation, for example, of independent dual triodes, a construction that had been impossible in B7G construction. Directly and indirectly-heated E8 valves were built, from VHF transmitting triodes to audio output pentodes, at least one pentagrid, one triode-heptode and even a subminiature version of the iconic "Video Pentode", 6AC7.

II. A second approach reverted to pinch construction, with all leads (between three and seven) in the one plane exiting through the flattened "press" at the base of the envelope. These types generally used a flattened envelope such as the T2X3 (2/8-inch x 3/8-inch). Some came with long "flying" leads and could be soldered in or (again with clipped leads) plugged into a socket.

III. A third class used a cylindrical envelope and base but presented the leads in a row, similar to the T2X3 and could also be soldered or plugged into sockets. A few EHT rectifier diodes (designed for solid-state television sets) with two leads in the base and one at the top (for the anode) used this construction

Generally, a reduction in filament/cathode heating power leads to a reduction in mutual conductance and (at least for pentodes) in gain. The designers of the 1V6-1AH4-1AJ5-1AG4 series (replacing the 1R5-1T4-1S5-1S4), as used in the Emerson 838, economised a little by cutting filament currents from 50mA to 40mA.

Although manufacturers managed to retain good performance in amplifying stages, Emerson's designers still had to work hard when designing the 838 to ensure it was a credible performer.

Miniaturisation and the cachet of "military-type" subminiature valves had appeal but the practically-minded would also be wary of running costs, so battery life was important too.

The 20% reduction in filament current helped the 838 achieve a good battery life. But the most significant improvement was from eliminating the typical Class-A valve output stage and its poor efficiency, as described in the main text.

Pentagrid converters from left to right: 2A7, 6SA7, 1R5, 1E8

3% at 10mW. Audio response from volume control to the speaker (–6dB) is 300Hz to 6.5kHz, from antenna to speaker is 280Hz to 1.7kHz.

Small sets are notorious for having a short battery life but this one draws a modest 2.6mA from the B battery (HT), falling to around 1.4mA on strong stations.

This implies a life of more than 70 hours from the National Electronics Distributors' Association (NEDA) Type 213 battery, which had a typical capacity of 140mAh.

I wasn't able to find data for the 4V NEDA 1300 A battery. The set only draws about 50mA so I'm guessing an original "A" battery would have a life of 40+ hours, as mentioned above, given that mercury batteries had capacities roughly double that of alkaline types.

Replacement batteries

The Eveready 415 45V battery (or its equivalents) can be bought online but at some $25+ it's an expensive way to power these sets. I have previously bundled up four 12V batteries (as used in remote controls) using everybody's favourite wrapping – duct tape. Likewise, I taped up three AA cells in series for the A battery.

Bruce Wilkie (Radio Waves, January 2016) has a more elegant solution. His Crosley JM-8 "book radio" now uses a plastic AA holder for four 12V batteries and a 3-cell holder from a cheap LED torch for three 1.5V cells. Bruce's radio is very similar to my Emerson set and it's worth reading his article to compare the two sets.

I'd prefer to use three NiCd/NiMH rechargeable cells (for about 3.8V total) to give closer to the original Mercury battery's 4V.

Further reading

- Emerson 838: siliconchip.com.au/link/aal7
- Series-filament AGC systems, in Radiotron Designer's Handbook (complete, searchable PDF, around 90 MB in size): siliconchip.com.au/link/aal8
- Complete Centralab catalogue: www.audiophool.com/Techno.html (search for Centralab; it's a Deja View [.DJVU] file, so you'll need the viewer plugin).
- Bruce Wilkie, The Crosley JM-8 Hybrid Book Novelty Radio, pp10-14, Radio Waves, Jan. 2016, Historical Radio Society of Australia (HRSA). SC