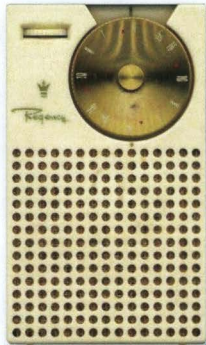
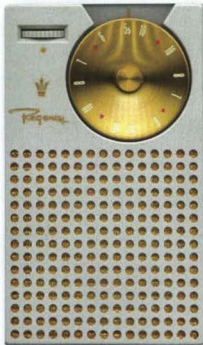


# Vintage Radio

By Ian Batty



## The First “Trannie” – The Regency TR-1 4-transistor radio



The world's first commercial transistor radio, the Regency TR-1, was released in October 1954 (Photo: Steven Reyer).

In this world of smart phones, tablets and MP3 players, no-one carries a “tranny” any longer. But before we forget them completely, let's look back at the first of these pocket-size marvels, the Regency TR-1 4-transistor radio.

**T**HE YEAR is 1953. Herbert Mataré, frustrated by the French Government's lack of support for his invention, the “Transistron”, has left F. V. Westinghouse in Paris and moved to Dusseldorf, establishing Intermetall.

The transistor had arrived but not as many of us understand history. Mataré had discovered the “transistor effect” independently of the famous trio of Bardeen, Brattain and Shockley. Yet, impressive as Mataré's ground-breaking radio was, it used point-contact

transistors, had no loudspeaker and was only a prototype.

The world would have to wait two more years for a commercial solid-state radio.

The first US transistor patents using semiconductors were issued to John Bardeen and Walter Brattain at Bell Laboratories in 1948. As a major US telecommunications company, Bell's primary intention was to use transistors as solid-state switches in exchanges, so portable radios were not

a concern. The only other intended uses were hearing aids, computers and military applications. Bell did, however, demonstrate “a transistor-powered radio” at their major press announcement of the transistor's invention on June 30, 1948.

Added to this, Bell's efforts were directed at point-contact technology, for which they held the patent. By the beginning of the 1950s, it was obvious that point-contact technology was too unreliable and costly for mass-

production. By this time, the original Bell team of Bardeen, Brattain and Shockley had broken up.

Shockley, realising the limitations of point-contact designs and resentful of his name being omitted from the patent application, had subsequently independently invented the junction transistor. He went on to share the 1956 Nobel Prize for Physics.

Shockley left Bell and, with funding from friend Arnold Beckman, started Shockley Semiconductor Laboratories in 1955, recruiting the best and brightest engineers and scientists he could find. However, Shockley's management style and inability to understand commercial imperatives resulted in failure to ship even a single commercial product and led to the mass exodus of the "Fairchild Eight".

Back in 1952, prior to the breakup of the Bardeen-Brattain-Shockley team, Bell Labs' Jack Morton had realised that Bell alone didn't have the resources to bring transistors into widespread commercial use. As a result, he arranged three famous seminars in that year, the first being for the US and NATO militaries while the second seminar was attended by industry giants and small innovators alike. Among the latter at this April 1952 seminar were Texas Instruments (TI) and Tokyo Tsushin Kogyo ("Totsuko"), later to become technology giant Sony.

### Pocket transistor radio

TI's Mark Shepherd was convinced that a pocket transistor radio was possible. TI had begun making transistors for hearing aids and for the military but these were not major earners. In 1954, TI manager Pat Haggerty signed an agreement with the Regency Division of Industrial Development Engineering Associates, an Indiana company involved in making TV antenna boosters. The aim was that the two companies would work together to manufacture and market the world's first commercial transistor radio. That's if Ibuka and Morita didn't beat them to it!

Totsuko's Masaru Ibuka and Akio Morita clearly saw the potential of the transistor. Working among the ruins of postwar Tokyo, they had started out by making a humble rice cooker and a shortwave converter. They had then successfully progressed to designing, manufacturing and selling high-quality tape recorders for use in radio stations and courtrooms.



**This tiny battery-operated transistor radio was demonstrated at the Dusseldorf Radio Fair in 1953 but never made it into production.**

At the time, TI's own laboratories, as basic as they were, would have seemed palatial to Ibuka and Morita. Nonetheless, we now know that Regency's release of the TR-1 in October 1954 beat Sony to market by just a few months. Morita visited the US in March 1955, offering their TR-55 to the market.

### The Regency TR-1: a first look

The first junction transistors proved far more reliable and stable than the earlier point-contact types. They were also easier to manufacture and far less noisy.

Nevertheless, the "grown-junction" design relied on exacting manufacturing techniques and the devices struggled to operate at radio frequencies much above 1MHz. Internal collector-base capacitance reduced the performance and created feedback that could easily turn otherwise acceptable amplifiers into useless oscillators.

The solution was to run the transistors at their maximum permissible voltages, thereby reducing capacitance. As a result, the TR-1 used a 22.5V "hearing aid" battery to ensure good performance.

Fig.1 shows the circuit details of the TR-1. It's a simple 4-transistor superhet design with conventional RF and IF stages, ie, a single-transistor "autodyne" converter, two stages of IF (intermediate frequency) amplification, a diode detector and AGC (automatic gain control).

The IF, however, is only 262kHz, a value also used in some US car radios. This compromise was forced by the limited high-frequency performance of TI's grown-junction transistors.

The audio section is less familiar and uses a single transistor operat-

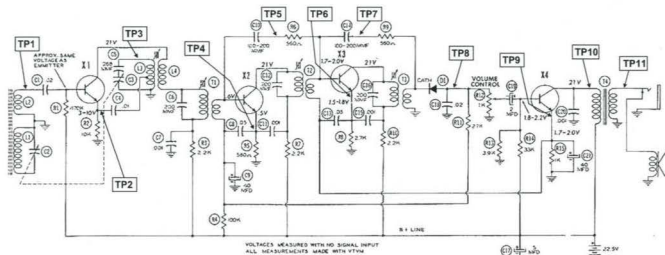


Fig. 1: The circuit is a simple superhet design with a single-transistor "autodyne" converter (X1), two stages of IF (intermediate frequency) amplification (X2 & X3), a diode detector (D1), AGC and a single-transistor Class-A audio output stage (X4). Diagram: [www.radiomuseum.org/tr/regency\\_pocket\\_radio\\_tr\\_1\\_tr1.html](http://www.radiomuseum.org/tr/regency_pocket_radio_tr_1_tr1.html)

ing in Class-A, the simplest but most power-hungry type of operation.

An interesting and somewhat unexpected aspect of the design is that it used NPN germanium transistors. Most of the germanium transistors manufactured at that time were PNP types.

The use of only four transistors was an economic decision, since they wanted to sell the radio for just \$49.95. The TR-1 prototype used eight transistors, ie, in the mixer, oscillator, two IFs, detector, audio driver and a push-pull audio output stage. However, with each transistor costing around \$2.50, this would not have permitted the magical \$49.95 price point.

As a result, the engineers took a "man overboard" approach. The mixer/oscillator combination became a single-transistor converter (US Patent 2880312) the transistor detector became a diode, and the 3-transistor audio section (with Class-B push-pull output) became a single-transistor Class-A stage.

Raytheon's competing 8TP, released some months later in March 1955, had eight transistors and sold for \$79.95. That was over half as much again as the cost of the TR-1 and the equivalent of around \$683 today. By contrast, the TR-1 cost about \$426 in today's dollars. It's rather ironic that Raytheon's 8TP is similar to the original TR-1 design.

### The author's TR-1

I bought my TR-1 (serial number 47.939) online for \$200. The "506" date-stamp on the tuning gang shows that it was made in the sixth week of

1955. Cosmetically, it was in very good condition, with acceptable wear on the case and no battery corrosion.

Unfortunately, when I tested it, it was dead. A few quick checks revealed oxidation on the on/off switch contacts and on the earphone socket. Once these were cleaned up, the set then responded weakly to my signal generator.

I then injected audio into the top of the volume control but it needed hundreds of millivolts to give even a weak output.

One of the main causes of faults in valve sets are defective paper and electrolytic capacitors. Transistor sets also suffer from faulty capacitors, mainly electrolytics that have "dried out" and gone almost open-circuit.

This set was no exception. Replacing the coupling capacitor (C19) in series with the volume control gave some improvement, while replacing the emitter bypass capacitor on transistor X4 gave a big improvement. It now took just 20mV in to give the full 6mW output at the onset of clipping.

With the audio amplifier stage sorted, I then found that the set burst into oscillation as a station was fully tuned in. At first, I suspected instability in the IF stages but the oscillation only happened with strong signals. Capacitor C9 (base circuit of transistor X2) was the culprit. It was open-circuit and was failing to bypass the detected audio signal on the AGC line to ground.

Allowing this detected audio back into the IF stages was the cause of the

oscillation. The AGC line should have only been returning smoothed DC for gain control.

In the end, I "replaced" all the electrolytics by wiring new capacitors in parallel with the existing units. Fortunately, I was able to insert the new capacitors between the circuit board and the metal chassis, so the set still looks original. Of course, this approach would be impractical with any capacitors that had shorted rather than gone open circuit.

The RF "front end" turned out to be operational, although the set's performance was still a bit below par. Subsequent testing showed the IF alignment to be unsatisfactory.

Fortunately, the oscillator coil and IF transformer cores were sealed with soft wax, rather than the dreaded plaster-like paint seen on so many sets. As a result, it was easy to make the necessary adjustments. As noted above, the IF should be 262kHz but on this set it was just a bit high, so it was adjusted down.

Sets with ferrite rod antennas commonly have no "low-end" aerial circuit tuning. With long ferrite rods, it's possible to slide the aerial coil along the rod to peak the performance at a specified frequency at the low end of the dial but the TR-1's coil was wax-sealed. Because of this, it's very tempting to simply adjust it at the specified 535kHz (as the Regency service manual advises) but this method does not always give the best results.

In the end, as a compromise, I sim-



These two photos show the author's fully-restored Regency TR1 transistor radio. This unit has a black case but grey, red and ivory were also initially available, with other colours added later.

ply tweaked the oscillator slug up and down, readjusting the generator each time, until I found a setting that gave maximum sensitivity – at almost exactly 540kHz.

### Easy access

The set is designed with the solder side of the circuit board facing the metal chassis. As a result, most of the resistor ends are easily accessed and signal injection into various points on the circuit is also fairly easy.

For IF alignment, it's easy to connect TP3 to ground to kill the local oscillator (LO). That done, I found that signal injection into the first IF at TP5 worked fine but injecting into the second IF at TP7 occasionally provoked loud oscillation.

Signal injection to the audio stage can be either direct into the wiper of the volume pot or you can disconnect the lead from the detector and inject the signal directly into the top of the pot.

Table 1 shows the signal input lev-

els at test points TP1, TP5 & TP8 for 3mW output with the volume control at maximum (about 0.23V across the speaker). The RF and IF signals were 30% modulated at 1 kHz, while the audio signal into TP8 was a 400Hz sinewave.

### Battery

Transistor feedback capacitance (ie, collector-base capacitance) reduces with increased collector-base voltage. Conversely, this capacitance increases as the battery voltage falls.

As a result, one common cause of oscillation in this set is low battery voltage, ie, as the battery runs down. My set "takes off" below about 16V.

The original battery was a 22.5V No.215 hearing-aid battery which is still available online. Alternatively, if you have an old battery, you can remove the innards and fit two 12V A23 types (as commonly used in doorbell transmitters) inside the old casing.

If, like me, you'd rather not apply the full 24V to the set, it's fairly easy

Table 1: Signal Levels For 3mW Output

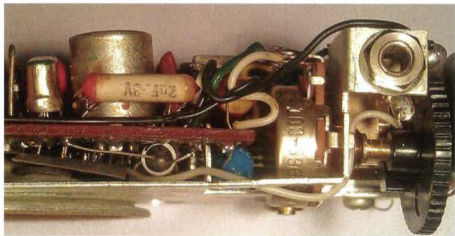
TP1 (540kHz)	TP5	TP8
30µV	13mV	25mV

to pry open one end of the wrap-around metal case, remove one cell and re-crimp the end (Editor's note: this shouldn't be necessary as a 22.5V battery would have delivered around 24V when new). It's then just a matter of connecting the two batteries in series and stuffing them into the old battery's casing.

By the way, you can also do this for the 22.5V batteries used in AVO (and other) analog multimeters (the full 24V is just fine). I've also done this with replacements for the miniature 415-type 45V battery used in super-compact valve sets (four A23 12V batteries in series gives 48V).

### How did they do it?

Although small, the TR-1 is not as compact as it might have been. Emerson Radio Corporation was already



This close-up view shows how two capacitors (C19 & C21) were added to the underside of the circuit board. The old capacitors were left in place on top of the circuit board to maintain the original appearance.

producing compact valve sets using sub-miniature valves, although these sets were somewhat larger than the TR-1. The TR-1 measures 35 x 125 x 76mm, whereas the 4-valve Emerson 747 measured 37 x 155 x 90mm.

Unlike Sony's preference for in-house components, Regency took the expedient approach of sourcing existing components. The TR-1 prototype even used a "salvaged" tuning-gang from an Emerson 747.

The only purpose-designed components were the ferrite rod, the oscillator coil and the three IF transformers. These new designs were necessary to match transistor circuit impedances, which are low in comparison to valves. In addition, IF transformer design was simplified and made more compact by using single tuned circuits, whereas most valve sets use two tuned circuits for each IF transformer.

The resistors and capacitors used in the set were types commonly available at the time.

The high collector-base capacitance of the transistors used isn't a problem in the converter and audio stages. However, the IF stages, just like the TRF valve sets of the 1920s, cannot operate successfully with significant internal capacitive feedback.

Just as TRF sets were rescued by the Hazeltine "Neurodyne" patent, using carefully-adjusted feedback to neutralise anode-grid capacitance, Regency used controlled feedback to "unilateralise" their IF amplifiers. The relevant components are C10/R6 and C14/R9, with selected capacitors individually supplied with their companion transistors for assembly.

These RC networks are required since the feedback from the transistors isn't exactly 180° out of phase. This means that the neutralising network's feedback phase also needs to differ from the simple 180° specified in the Neurodyne patents.

### Minimising the current drain

In operation, the Regency TR-1 receiver draws around 4mA, giving about 20 hours of operation from a 22.5V hearing-aid battery.

To minimise current drain (and extend battery life), the bias divider usually required for the second IF stage was discarded. Instead, this stage derives its bias directly from the emitter of the audio output transistor (US Patent 2,892,931). This saves about 600µA of battery drain, a reduction of around 13%.

### How good is it?

The TR-1's performance is mediocre, even by the standards of the early 1950s. In fact, the April and July 1955 issues of "Consumer Reports" separately put the TR-1 and Raytheon's 8-transistor 8TP to the test and concluded that Raytheon had every reason to call its 8TP the first serious transistor radio. The April 1955 review of the Regency TR-1 found the \$49.95 TR-1 to be a toy-like novelty which didn't come at a toy-like price, and stated that "the consumer who has been waiting for transistor radios to appear would do well to await further developments before buying".

My own tests on the TR-1 were all done at 3mW output, at which point the second harmonic distortion was

-20dB and the third harmonic distortion was about -13dB. The frequency response (at the speaker terminals) was -3dB at 270Hz and 2.3kHz, referenced to 1kHz.

The audio output is rather limited but the RF sensitivity is quite respectable at about 500µV/m at the bottom end and around 700µV/m at 1600kHz. Most sets, however, give better sensitivity at the top end and the difference can easily be a 3:1 improvement. In this case, the TR-1's lack of improvement at the top end indicates that the converter is working at the upper end of its frequency range.

Indeed, one milestone in the TR-1's development was when the converter proved capable of oscillating reliably up to about 1.9MHz, so that the receiver could reach the top of its intended tuning range.

The above figures may sound poor but it's not surprising considering that the design uses just four transistors. In fact, a 5-transistor Mullard design using the alloy-diffused OC169/170 transistors from the 1960s has only about 10 times better overall sensitivity than the TR-1, ie, about 50µV/m for 3mW output at 540kHz.

Ultimately, the signal-to-noise performance of any set is determined by the "front end", especially the mixer. That aside, the TR-1's performance is almost as good as most of my 6-transistor pocket radios.

### An iconic design

The TR-1 is now lauded as an iconic design. Its release, along with the early transistor sets from other companies, firmly established solid-state technology as the future of electronics.

These days, you can buy a smart phone for less than the equivalent 1950s price of a TR-1. By contrast with the TR-1's four transistors, a smart phone has billions of transistors embedded in its internal microchips and, along with its phone functions, includes a camera, an audio player, a GPS and email and internet browsing capabilities – all accessible with the swipe of a finger across a touch-sensitive screen.

However, it probably won't let you listen to radio stations on the AM band and that's something the TR-1 can do!

For further information on the Regency TR-1 transistor radio, point your browser to <http://www.mequonsteve.com/regency/> **SC**