By Ian Batty

Sony's TR-63 Shirt-pocket Transistor Radio

Released in December 1957, the TR-63 was Sony's first pocket-size transistor radio. It's a 6-transistor superhet design with some interesting design features, including the use of Sony-manufactured NPN transistors in the circuit.

Masaru Ibuka served with the Imperial Navy Wartime Research Committee during World War 2, leaving in 1946 to join Akio Morita to form Tokyo Tsushin Kogyo Kabushiki Kaisha, "Totsuko". Morita, a physics graduate, had served alongside Ibuka in the Research Committee, and their friendship laid the foundations for the international powerhouse we now know simply as Sony.

Tokyo Tsushin Kogyo's first product, a rice cooker, says a lot about the company. Japan had suffered massive destruction during World War 2 due to bombing and people needed utensils to cook their staple food, which was rice.

So a rice cooker that simply used two insulated metal plates ingeniously met a vital need. That combination of opportunity and ingenuity set the model for Sony's future. Their first radio-related product, a shortwave converter for broadcast-only radios, helped open Japanese society up to the wider world. Tape recorders subsequently became a major product line and were widely used in schools and courts.

Following Ibuka's visionary 1952 trip to the USA to sign a licence with Western Electric, Sony acquired patent rights for the transistor and subsequently began manufacturing portable radios in 1955.

Early difficulties

Sony preferred NPN transistors because of their better high-frequency response but were initially unable to produce working examples.

NPN devices exploit the fact that electrons move more quickly than holes, ie, they have higher mobility. This is critical in the base region and it's here that low mobility has the most effect on high-frequency performance. The problem is that NPN devices were more difficult to manufacture using germanium feedstock.

Knowing that, theoretically, NPN transistors were the way to go, Sony saw experiment after experiment fail to demonstrate useful performance. After much discussion, Sony's research laboratory head, Mikato Kikuchi, suggested dropping Bells' preferred doping agent, indium, and substituting phosphorus instead. When that didn't work, Morita called for "more doping"!

It soon paid off and Sony were able to produce the transistors used in their first solid-state radios. Their TR-55 model, released in 1955, is now a rarity and the last one to be listed online some years ago had a price tag of $US1500.

One can only imagine the energy invested by Sony to leap from Ibuka's licensing agreement to a marketable transistor radio in just three years. It's also possible to imagine their frustration at being pipped at the post by Regency's TR-1 transistor radio (SILICON CHIP, April 2013), which was released less than six months before.

Sony's first "pocket-size" transistor radio, the TR-63, was subsequently released in December 1957. It was, however, reputed to be too big for a standard shirt pocket and the story goes

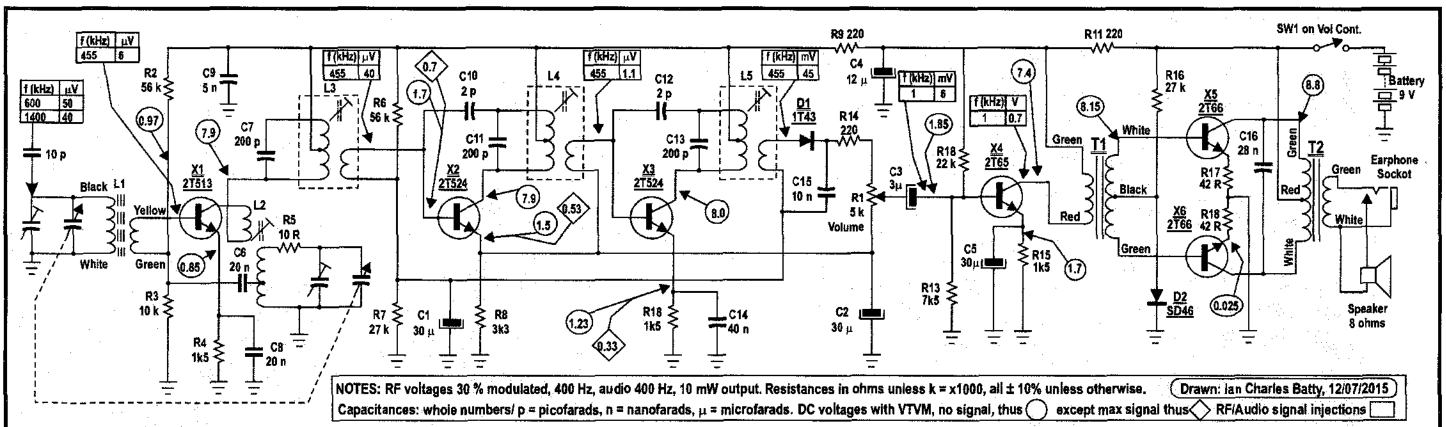


Fig.1: the circuit uses six NPN transistors (X1-X6). X1 is the converter stage, X2 & X3 are IF amplifier stages, X4 is an audio pre-driver and X5 & X6 form a push-pull audio output stage.

that, for its launch, Sony had special shirts made with pockets that could take the radios.

Sony's TR-63

At first glance, Sony's TR-63 is a pretty conventional 6-transistor set, with three transistors used in the RF/IF section and the other three in the audio amplifier stage. All the transistors were manufactured by Sony and they are all NPN types.

As noted above, Sony preferred NPN transistors because of their better high-frequency performance. My set was kitted out with the rectangular TO-22 can transistors, the same style as used by Texas Instruments in the Regency TR-1.

Sony's hand-held TR-63 was offered in lemon, green, red and black. It used a miniature, solid-dielectric "poly-varicon" for the tuning capacitor and it also required a new battery design that became the iconic "PP9" and set the standard for transistor radios.

As a piece of portable electronics, the TR-63 is a winner. It's small enough to pop into my shirt pocket, something which couldn't be said for the TR-1 and other early sets from Raytheon, GE and Zenith. It also fits the hand better, the rounded edges giving it an easier feel than many others.

What's more, the TR-63 is a good performer. It's also one of Sony's last sets with the old "lighting bolt" logo that was superseded by the "Roman text" logo we're more familiar with. As well, it carries the "Totsuko" stamp on the rear cover.

But it's not just an elegant personal radio. It's described thus in Schiffer's *The Portable Radio in American Life*: ". . . (Sony) was not first, but its transistor radio was the most successful. The TR-63 of 1957 cracked open the US market and launched the new industry of consumer microelectronics".

With total exports to the US alone of about 100,000, the TR-63 was a true runaway success.

The accompanying photo of the TR-63 shows the red "Conelrad" marks on the dial at 640kHz and 1240kHz, as required by US law at that time. So what was "Conelrad"?

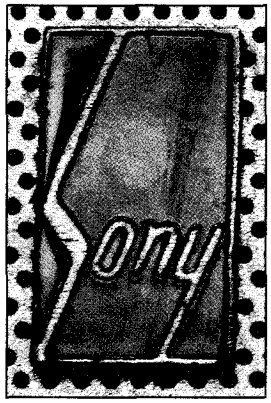
Basically, this acronym stood for CONtrol of ELectronic RADiation and was set up in the US in 1951 to provide emergency radio warnings to the public during the Cold War. If an alert was received, most radio stations were required to cease transmission, while each remaining station was to move to either 640kHz or 1240kHz. They would transmit for several minutes and then go off the air, and another station would take over on the same frequency in a "round robin" chain, the idea being to confuse enemy aircraft that might be navigating using radio direction finding.

By law, radio sets manufactured between 1953 and 1963 had the required frequencies marked by the triangle-in-circle (CD Mark) symbol of Civil Defence, so that the set could be quickly tuned to either 640kHz or 1240kHz.

Circuit details

Several circuit variations exist (denoted by the circuit board number) and these are based on either the early production R-6C1 sets or the later R-6C2 version. The circuit shown here (Fig.1) is based on my R-6C2 and is also the version shown in an H. W. Sams Photofact.

In addition, the schematics for both versions are available on www.radiomuseum.org and other sites. Any important differences between the R-6C2 and R-6C1 are noted in the following circuit description and on the circuit diagram.



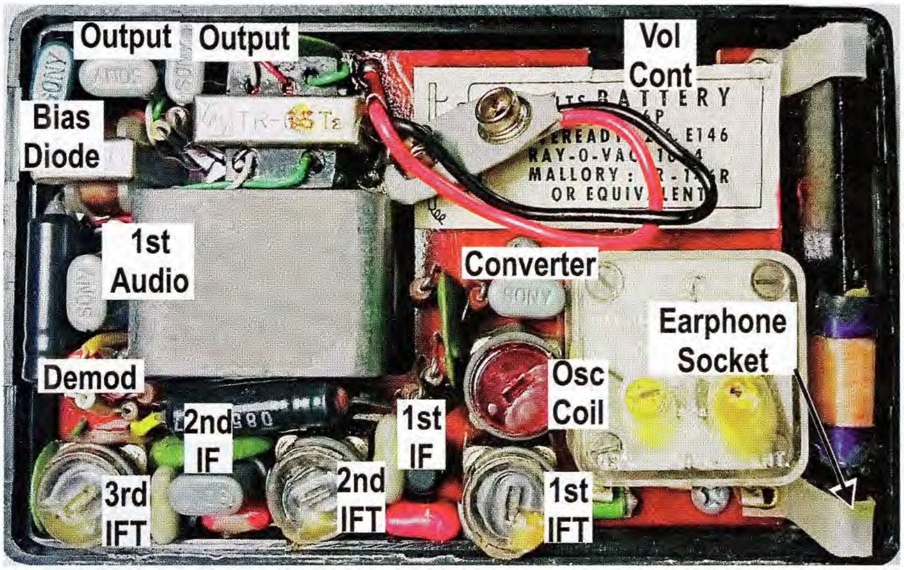
The TR-63 was one of the last sets with Sony's old "lighting bolt" logo.

Converter stage X1 uses base injection and a cut-plate tuning gang (ie, the oscillator section is smaller than the antenna section), so there's no need for a padder capacitor. This stage follows the common practice of fixed bias, so gain control is left for the following IF section.

The first IF transformer (L3) uses a tapped, tuned primary and an untapped secondary and this feeds the first IF amplifier stage which is based on X2. This stage is gain-controlled by the DC voltage fed back from the demodulator. Unusually, X2's bias is derived from a voltage divider (R6 & R7). While this would usually provide constant bias and thus constant gain, R6 and R7 have higher values than usual and this allows "relaxed" control of X2's base voltage.

Basically, this allows the AGC circuit to control X2's gain but with less effect than in the circuits commonly used in other sets.

The second IF amplifier is based on transistor X3 and this gets its bias from X2's emitter, so AGC is applied to both IF stages to give effective control. Note



This view inside the unit shows the PCB from the component side. The parts are packed close together, although individual components are still easy to access.

also that the AGC return from the demodulator is fed to X2's emitter, again an unusual configuration. Commonly, the AGC return is to ground, which means that the IF amplifier's emitter resistor forms a negative feedback circuit for the AGC control voltage. This helps to "soften" the very strong "sharp cut-off" AGC action that would otherwise occur if the control voltage were simply applied between base and emitter.

In operation, the R-6C2 version of the TR-63 applies a moderate amount of AGC to both IF stages and directly applies AGC between X2's base and emitter. By contrast, the 6C1 uses a conventional series bias circuit for X2 but still has the AGC voltage applied directly between base and emitter.

Transistor X2's collector feeds the tapped, tuned primary of the second IF transformer (L4). As shown, L4's centre tap connects directly to the supply rail, while the top of the primary connects to neutralising capacitor C10 (2pF). L4's untapped, untuned secondary feeds the base of the second IF amplifier (X3).

As mentioned, X3 in the R-6C2 version gets its bias from X2's emitter. This means that the AGC controls both IF stages. By contrast, the R-6C1 version simply uses fixed voltage-divider bias for X3 and so its resistance to overload isn't as good.

The third IF transformer (L5) feeds demodulator D1. In the R-6C2 circuit, the AGC return is via R14 and volume control R1 to X2's emitter (and X3's base). Alternatively, in the R-6C1, the AGC return goes to the emitter of X2 and also to the emitter of X4, the audio driver stage. The AGC control voltage itself is derived from D1's anode and is series-fed back through the third IF transformer's secondary to X2's base (both versions).

Audio amplifier

The recovered audio from demodulator D1 is fed to transistor X4 via the volume control and capacitor C3. This audio driver uses combination bias. The R-6C1 circuit (unusually) connects X4's emitter to X2's emitter, so that X4's emitter voltage varies somewhat with AGC action. The R-6C2 circuit omits this connection, giving a constant voltage on X4's emitter.

X4 feeds driver transformer T1's primary. The R-6C1's circuit shunts this winding with a treble-cut capacitor but the R-6C2 omits this component. Transformer T1's centre-tapped secondary then drives a push-pull Class-B output stage based on transistors X5 & X6. This stage uses bias diode D2, which is described as a "varistor".

In reality, this diode is the collector-base junction of a transistor. It's used here as a temperature-sensitive bias supply that matches the base-emitter characteristics of the output transistors. It basically provides thermal compensation for the push-pull output stage and is a mark of good design by Sony. Any number of other manufacturers were still struggling with less-effective fixed/adjustable bias schemes or complex thermistor-compensated bias circuits.

X5 & X6 drive output transformer T2 which is shunted by a top-cut capacitor in both versions. T2 in turn drives a 3.5-inch (89mm) internal speaker via an earphone socket. The earphone socket disconnects the loudspeaker when an earphone is plugged in.

Initial tests

This was another easy set when it came to restoration, at least as far as its appearance was concerned. A good clean and a light polish were all that were needed to restore it to near-new condition. A quick check of the earphone socket revealed that it was OK and I gave the volume control a light spray of contact cleaner to ensure trouble-free operation.

I then applied power and checked the supply current. This was as expected and there was some noise from the set when the volume control was operated. This was then followed by wild oscillation on all stations and then silence.

Replacing C1 and C2 (both 30μF electrolytics) cured the oscillation at those times when the set was working. Unfortunately, there were still times when it refused to work.

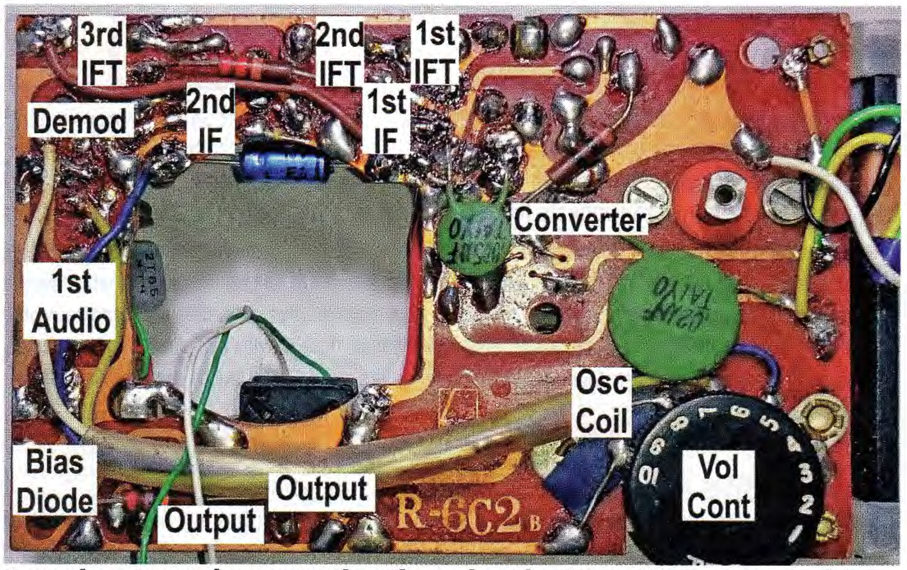
I soon discovered that when the set stopped working, X2's base and emitter voltages were way too low. The bias circuit itself checked out OK and the problem turned out to be a faulty transistor.

In operation, X2's internal collector connection was going intermittently open circuit. Normally, the bias circuit supplies the base current and multiplying this by the transistor's current gain produces the emitter current and thus the intended voltage across the emitter resistor.

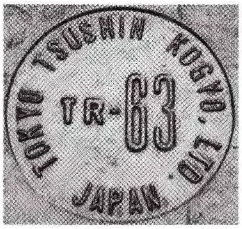
However, if the collector connection goes open circuit, the base-emitter junction behaves as a simple forward-biased diode. If that happens, the emitter resistor is pretty much shunted across the bottom resistor in the bias network, resulting in very low base and emitter voltages.

The most common causes for open collector connections are open-circuit loads (especially inductors and transformers), bad solder joints and bad socket connections. In this case, the set came good after a few sharp taps on transistor X2, indicating that its collector was going open circuit inside the can (probably between the collector lead wire and the germanium slice).

I needed a replacement transistor



Several parts are also mounted on the underside of the PCB, as shown in this photo. The old TR-63 was easy to restore to full working order.



The Totsuko "stamp" is moulded into the TR-63's rear cover.

and a search through my trusty junk-box soon yielded a Sony 2SC73 (a germanium NPN). This transistor has a bandwidth (Ft) of 8MHz as opposed to the 2T524's 2.5MHz, so I expected to get more gain with the new transistor. This was subsequently proven to be correct.

During my initial tests, I found that the audio section needed many tens of millivolts to produce an output, so electrolytics C3 & C5 were replaced. This immediately brought the audio gain up to expectations.

As an aside, using electrolytic capacitors for IF/RF bypassing is now considered poor design and as noted above, the set's initial violent oscillation problems were cured by replacing C1 & C2. Electrolytics exhibit considerable series resistance and inductance, restricting their effectiveness to audio frequencies. Common practice would now be to shunt C1 & C2 with disc ceramic capacitors to ensure effective RF bypassing.

How good is it?

Looking at the circuit and its build quality, the TR-63 appears to be a well-engineered set but how well does it perform? To find out, I decided to make some basic sensitivity and distortion measurements.

As shown on the circuit, a 10pF capacitor is connected to the top of the ferrite rod. As this set uses base injection for the local oscillator, connecting my signal generator to X1's base stopped it dead for broadcast-band signals. I was able to get IF sensitivity readings but no RF readings.

The simplest way around this was to connect the generator via the 10pF capacitor. This gives reliable results but it doesn't give the actual signal voltage required at the converter's base connection, as would usually be specified. The set did, however, respond correctly to a direct IF injection, so I've given this result as it's a better guide to the set's sensitivity and will help in diagnosing low-gain faults.

Dealing with the audio stage first, the TR-63 goes into clipping at 20mW, with a THD of 8.5%. At 10mW, its distortion is 6% and the -3dB frequency response from volume control to speaker is 290Hz - 5.9kHz, with a peak at around 1.3kHz. From antenna to speaker, it's 290~3000Hz.

The diode biasing circuit used in the output stage contributes to the low-battery performance. With a 4.5V supply, the set begins to clip at only 5mW and its THD at 4mW is around 7%, with little sign of crossover distortion. Admittedly, 5mW isn't much but the set is still working perfectly when the battery is down to 4.5V. Of course, it's only delivering one-quarter the power output at half supply but its low-battery performance is excellent and anticipates sets such as the Pye Jetliner.

Because the set begins to clip at around 20mW output, the following RF/IF measurements have been taken at 10mW output. The RF bandwidth is ±3.7kHz at -3dB and ±55 kHz at -60dB. The AGC is quite effective and limits the output to an increase of just 6dB in response to a 26dB signal increase.

The received signal performance is quite good, though with poor S/N ratios. At full gain, for 10mW output, my modified TR-63 needs 200μV/m at 600kHz and 110μV/m at 1400kHz. However, both these figures result in an S/N ratio of only about 5dB.

The set's early AGC detracts from the 20dB S/N ratio figures, so I've opted for 15dB. This demands an input of around 700μV/m at 600kHz and 500μV/m at 1400kHz. In this set, however, I had replaced transistor X2 with a higher-performing substitute (as mentioned), so you can expect an unmodified TR-63 to have around half the above sensitivity figures.

With only 20mW of audio output at clipping, is it good enough? The answer is that while you'd need to use the plug-in earphone at the football, it's perfectly adequate on the bench in my 130m^2 shed.

Would I buy another?

Would I buy another one? The answer is "yes" if an R-6C1 version became available as I'd be interested to compare it's AGC action against my current R-6C2 version.

Finally, is it possible to "hot up" an old set with better-performing RF/converter and IF transistors? Sure but that's not the point. Repair necessities aside, these are old radios and it's best to keep them in original condition.

Further Reading

(1) Many online sites describe the TR-63. For a thorough description, see James J. Butters' fine site at: http://www.jamesbutters.com/sonytr63.htm

(2) For a tear-down and description: https://www.ifixit.com/Teardown/Sony+TR-63+Transistor+Radio+Teardown/1219

(3) A photo catalog is at: https://www.flickr.com/photos/transistor_radios/sets/72157603555111543/

(4) Ernst Erb's Radio Museum: http://www.radiomuseum.org/r/sony_tr63_tr_63_tr_63.html (6C1, 6C2) and http://www.radiomuseum.org/r/sony_transistor_si_tr_63a.html (6C1) SC