Vintage Radio

By Dr Hugo Holden

The 1956 Sony Gendis TR-72 Transistor Radio

One of the earliest transistor radios on the market was Sony's TR-72. This was a high-quality design employing seven NPN transistors and housed in a very attractive timber cabinet.

THE TRANSISTOR RADIO era began in 1954 when the world's first commercially successful transistor radio, the American made Regency TR-1, was released (see Vintage Radio, April 2013). Very shortly afterwards, transistor radios from a plethora of manufacturers appeared on the market.

One such company, the Tokyo Tsushin Kogyo company of Japan (Sony), was hot on Regency's heels, bringing their TR-55 to market in 1955. They then followed up with the TR-72 7-transistor radio in early 1956.

It's interesting to note that the transistor had been invented just a few years before, in 1948 at Bell Laboratories by Bardeen, Brattain and Shockley. So there was only a modest delay before manufacturers came up with a major practical commercial application for these devices.

Early transistor problems

Early transistors suffered from a high collector-to-base capacitance. This is generally referred to as "Miller capacitance" and the negative feedback induced by this has the effect of progressively lowering the transistor's gain (or amplification) as the frequency increases. This makes such transistors useless as radio frequency amplifiers unless special precautions are taken.

In addition, if there is a tuned circuit of similar frequency in both the base and collector circuits (ie, in a grounded emitter amplifier), then the amplifier could oscillate. That's because the Miller capacitance can result in regenerative rather than degenerative feedback, especially when the two resonant circuits have similar frequencies. The Miller capacitance in this instance allows the two tuned circuits to exchange energy with each other and oscillation and instability can occur.

The Miller capacitance also reduces the input-output isolation of a transistor acting as a grounded emitter amplifier and it does the same thing to a triode in a grounded cathode amplifier configuration where it acts between the plate and the grid. Pentode valves don't have this problem because their screen grid provides input-output isolation.

The technique used to avoid the Miller capacitance problem is known as "neutralisation". This involves feeding an out of phase signal from the output (usually derived from an IF transformer or tuned transformer winding) back to the transistor's base to phase cancel the current from the Miller capacitance. This technique, used with triode valves in TRF radio sets, was popular in the 1920s and the neutralising feedback capacitors, called 'neutrodons', could be adjusted either by the user or a technician to prevent the RF (radio frequency) amplifiers oscillating.

In other circuit configurations, such as grounded base circuits or grounded collector circuits (emitter follower), the Miller effect is less of a problem because the transistor's collector and base are connected to low impedances. The cascode configuration eliminates it by keeping the lower transistor's collector voltage constant.

Another way of ameliorating the Miller capacitance is to use a relatively high collector voltage. That's because the feedback capacitance across the

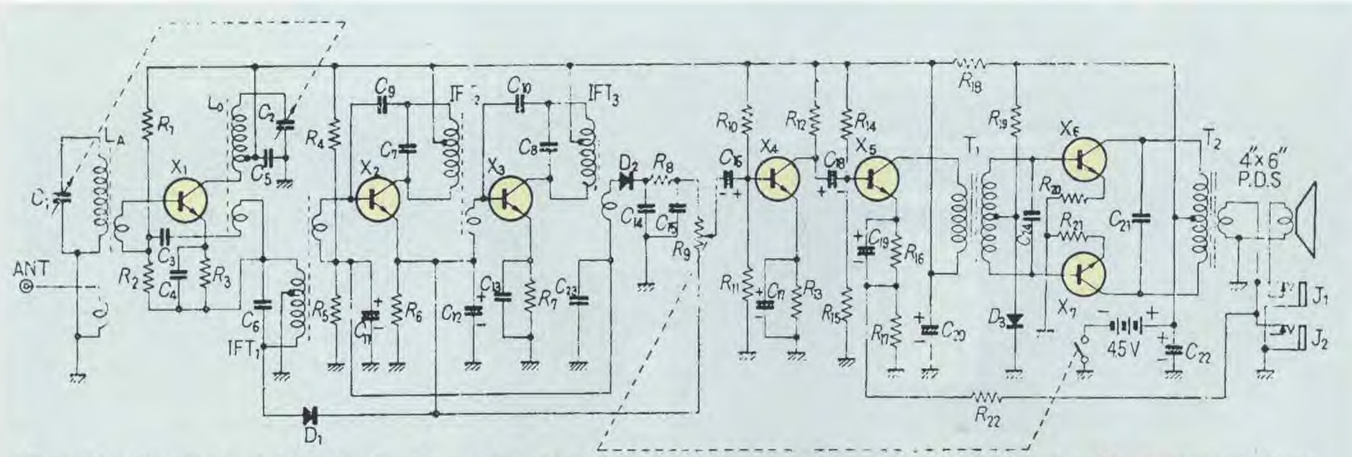


Fig.1: the circuit is a fairly standard superhet design using seven NPN transistors (X1-X7). X1 is the converter stage, X2 & X3 the first and second IF amplifiers, diode D2 the detector and X4-X7 the audio amplifier driver and output stages. The output stage (X6 & X7) operates in push-pull configuration, with diode D3 providing bias stabilisation.

reverse biased base-collector junction reduces with increasing voltage, much as it does with a varicap diode. This is why the world's first transistor radio, the Regency TR-1, used a 22.5V battery.

As transistor design improved, the 22.5V battery idea was dropped and lower voltage batteries made up from AA, C or D cells were used. The Sony TR72, for example, is powered from a 4.5V battery consisting of three D cells.

Later on, as transistor technology further improved, germanium RF transistors such as the AF115, AF125, OC171 and AF178 had collector-base capacitances that were so low they would work as IF amplifiers without any neutralisation. For example, the vintage OC45 germanium transistor has a Miller capacitance of about 10pF while for the more modern AF178, it's only about 0.8pF.

As another example, the vintage Eddystone EC-10 transistor communications radio uses OC171s in its IF amplifiers with no neutralisation at all.

Transistor radio advantages

One of the most remarkable features of simple 6 or 7-transistor radios is their very low current drain. Each transistor, except in the audio output stage, usually draws less than 1mA and the power delivered to the speaker is proportional to the volume setting.

In addition, the residual bias current for a transistor output pair running in class AB is usually in the order of 3-10mA at most. In fact, the total running current of the Sony TR-72 radio at a normal listening levels is about 10mA.

This means that with a set of 1.5V D-cells and normal daily use, the radio runs for months – completely unlike earlier valve radios which, depending on use, typically chewed through batteries in several days or perhaps a week or two.

Transistor radios also benefited from earlier developments with ferromagnetic materials. For example, the Meissner Company in the USA pioneered early examples of iron dust ferromagnetic cores in the late 1930s and these were used in their 1939 TV kitset: www.worldphaco.com/uploads/THE MEISSNER 5 INCH KIT AND THE ANDREA KTE-5.pdf

The later ferrite rod (or "magnetic bar") antenna works very effectively from 100kHz to about 12MHz and so was perfect for use as a compact antenna for the medium-wave 550-1700kHz band. This meant that AM transistor radios did not require a whip antenna and so they could be truly portable (or even pocket) devices.

Ferromagnetic core technology was also required to give high enough Q factors for the compact oscillator coils and IF transformers developed for use in transistor radios. It simply wasn't practical to use air-cored coils as they would need to be far too big.

So it wasn't just transistor technology that made compact transistor radios possible – the development of ferromagnetic material was also critical. This vital factor is often neglected in discussions about the evolution of the transistor radio.

Sony's TR-72 masterpiece

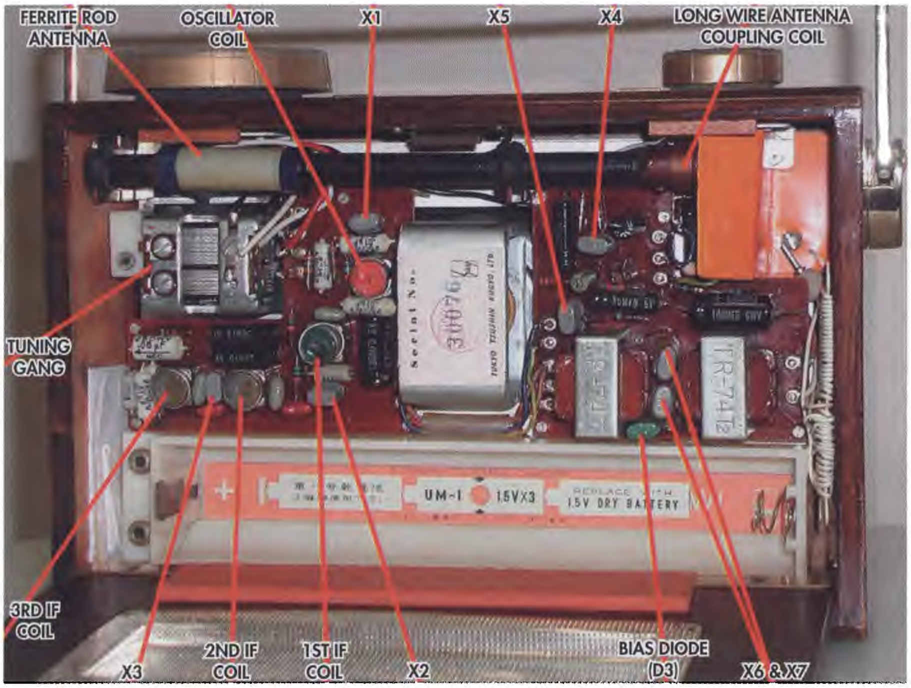
In typical Japanese fashion, Sony made just about everything for their radios in-house, including the transistors and diodes. Fig.1 shows the circuit of their TR-72 and it's interesting to look at the main features of what is a fairly standard single-conversion superhet design.

First, the transistors used in this radio are all NPN types. Most early commercial germanium junction transistors were PNP types and NPN germanium devices were rare, although it's worth noting that the Regency TR-1 transistor radio also used NPN devices.

If you have one of these radios and are stuck for a replacement transistor, an OC139 or OC140 will work, or perhaps even a 2SD11. There are also quite a few early 2SD series NPN germaniums which could act as replacements at a pinch.

Fortunately, in my TR-72 radio, all the transistors were still perfect. However, the detector diode had gone open circuit and so a germanium diode was neatly tacked across it. In addition, one of the primary wires on the audio output transformer had sheared off the bobbin, disconnecting the collector of transistor X6 and resulting in an asymmetrical and distorted audio output. As a result, the transformer was removed, the wire repaired and the transformer refitted.

Some of the circuit features are worth discussing. First, note that neutralisation capacitors C9 and C10 have been used in the IF stages for the reasons outlined above. However, there is no neutralisation required in the oscillator or "converter stage" based on transistor X1. That's because the tuned circuit at its collector runs at



This inside view of the Sony TR-72 shows the locations of the major components and the high standard of construction. Despite its age, the PCB and its various parts look almost like new.

the oscillator frequency and this is substantially different to the tuned RF signal frequency at its base. This in turn means that there is very little risk of signal being coupled from one circuit to the other. Also, the stage gain is low, so bandwidth is not an issue.

Conversely, in the IF stages, the transistor base and collector tuned circuits have the same frequency, hence the need for the neutralising capacitors (C9 & C10).

As stated, transistor X1 is the converter (ie, mixer/oscillator) stage and this type of converter is sometimes referred to as an "autodyne" converter. The oscillator frequency is varied by the tuning control (ie, variable capacitor C2, which is one section of a dual tuning gang). It runs 455kHz above the received frequency and the two frequencies are mixed to produce sum and difference products (ie, the sum and difference frequencies of the oscillator signal and the received station signal).

The 455kHz difference frequency is then passed by the first IF transformer primary (IFT1) which is tuned to 455kHz. This is called the IF (intermediate frequency) signal. It passes through IFT1 while other frequencies (including the oscillator and sum frequencies) are rejected.

However, there is another RF signal which could pass into the IF amplifier – that from a radio station broadcasting at exactly twice the IF frequency (ie, 910kHz) above the tuned station. This is known as the "image" frequency and it is also picked off by the 455kHz IF amplifier because it is exactly 455kHz above the oscillator frequency (thus resulting in another 455kHz difference frequency). However, due to the tuning of the ferrite rod's resonant circuit, the gain at the image frequency is low, so this isn't usually a problem.

Even so, a strong local station could still break through. For example, if the radio was tuned to 600kHz, a strong local station broadcasting close to 1510kHz could cause problems. The way around this is to have a highly-selective tuned RF stage which requires a 3-gang variable tuning capacitor. This type of arrangement appeared in transistor radios just a year later, eg, in the New Zealand-made Pacemaker Transportable radio. This radio looks similar to the TR-72 and will be described in a future column.

Following IFT1, the signal then passes through neutralised IF amplifier stages X2 & X3 and is then fed to detector diode D2. A negative AGC voltage is developed across C23 (on the secondary of IFT3) and this reduces the bias on X2 and X3 to lower the gain of the IF amplifiers in strong signal conditions to prevent overload.

Note that transistor X3's bias is derived from X2's, which saves adding another divider network. Note also that most of the voltage gain in a transistor radio (unless it has an RF stage) is in the IF amplifiers and it can be as much as 80dB for two stages.

There are two other clever circuit features here. First, the DC voltage across the base-emitter junction of X2 is used to provide a small amount of forward bias to detector diode D2. That's been done by connecting the

The TR-72 was housed in a sturdy timber case and this, combined with a 10 x 15cm loudspeaker, ensured relatively good bass response from the set. The volume/on-off switch (left) and tuning knob are at the top.

lower leg of the volume control to X2's emitter, which means that, from a DC perspective, D2's anode is at X2's base voltage. This helps in the detection of weak signals.

Secondly, under very high signal conditions, AGC diode D1 comes into play. It works like this: when the IF signal voltage is high, D1 conducts and charges capacitor C12. This decreases the bias applied to transistor X2, thereby lowering its gain, and also applies some reverse bias to detector diode D2. This helps prevent overload on strong signals.

Audio amplifier stages

The audio amplifier is quite standard and consists of pre-driver transistor X4, driver stage X5 and a transformer-coupled push-pull output stage based on X6 & X7. The output stage in turn drives the loudspeaker via another centre-tapped transformer.

The two coupling transformers are relatively large and combined with the good-sized (10 x 15cm) speaker and the ventilated timber case, give this radio quite a decent bass response. It's not at all like the 'tinny' sound that comes from many transistor radios.

Note the use of negative feedback via resistor R22 around the audio driver and output stages to lower distortion. The output transistors, which are not on heatsinks, are DC stabilised by 5Ω emitter resistors and "bias diode" D3. D3 tracks the variation in the base-emitter voltages of the output transistors with temperature and adjusts the bias to prevent thermal runaway.

Construction quality

An accompanying photo shows the inside view of this radio. The construction quality is remarkable and is practically unmatched by any modern consumer electronic device. Note that there is an additional coupling coil on the ferrite rod for a long-wire antenna. This is placed well away from the main tuning coil so that it has no effect on the tuning due to loading.

The cabinet appears to be made from a high-quality Japanese timber and the white Sony badge on the front is enamelled. The speaker mesh is made from anodised gold-colour expanded aluminium, while the back hinge assembly is made of brass.

Finally, all wires connect to the PCB via eyelets with solder tags and the transistors each have a good coat of paint. The overall quality is such that the inside of the radio looks as good as new after nearly 60 years! **SC**