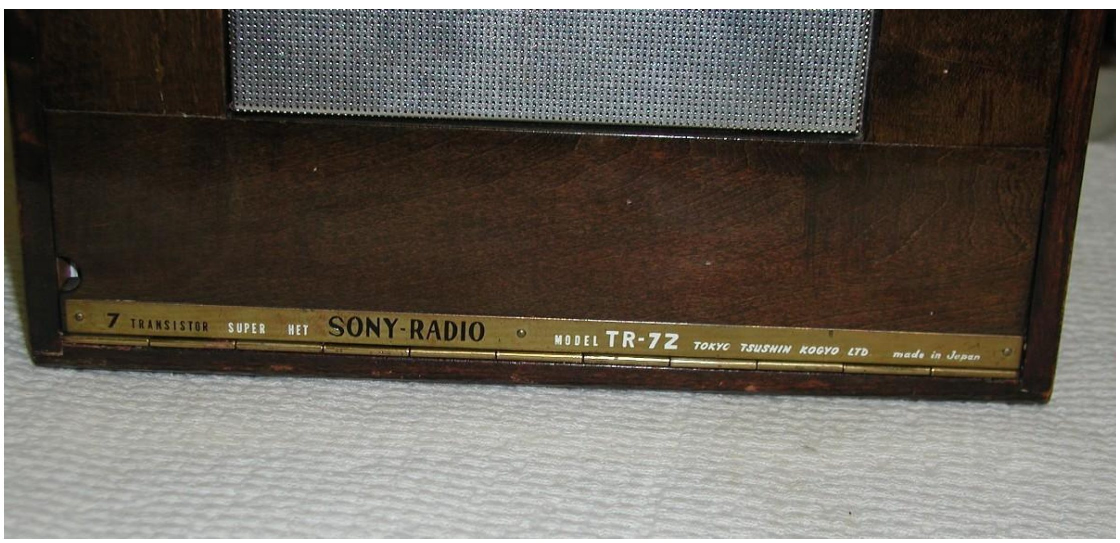
THE SONY GENDIS TR-72 TRANSISTOR RADIO FROM 1956.

H.Holden, 2013.



History:

The transistor radio era began in 1954 when the world's first commercially successful transistor radio, the American made Regency TR-1, hit the market. Very shortly afterwards many transistor radios from a plethora of manufacturers arrived. The Tokyo Tsushin Kogyo company of Japan (Sony) were hot on Regency's heels and brought their TR-55 to market in 1955.The Sony TR-72 arrived in early 1956. This was only a modest delay for a major practical commercial application for the transistor. The transistor itself had just been invented in 1948 at Bell Laboratories by Bardeen, Brattain and Shockley.

The difficulties with early transistors:

Early transistors suffered from a high collector to base capacitance. This is generally referred to a "Miller Capacitance". The negative feedback induced by this has the effect of progressively lowering the transistor's gain or amplification factor as the frequency increases. This makes the transistor useless as a radio frequency amplifier. In addition, if there is a tuned circuit of similar frequency in both the base circuit and collector circuit (in a grounded emitter amplifier) such as intermediate frequency or "IF" amplifier for example, or RF amplifier, then the amplifier will be unstable and will oscillate because the Miller capacitance allows the two tuned circuits to exchange energy with each other creating a positive feedback pathway.

The technique to avoid the Miller capacitance problem is known as "Neutralisation" where an out of phase signal from the output (usually derived from an IF transformer or tuned transformer winding) is fed back to the transistor's base in the correct proportion to phase cancel the current from the Miller capacitance. This technique, used with triode tubes in TRF radio sets, was popular in the 1920's and the neutralising feedback capacitors, which were called "Neutrodons", were adjustable by the user or technician to prevent the radio frequency amplifiers oscillating.

In other circuit configurations such as grounded base circuits or grounded collector circuits (emitter follower) the Miller effect is eliminated because the transistor's collector or base is pinned to a fixed voltage. Also the Cascode configuration eliminates it by stabilising the lower transistor's collector voltage.

One other method to ameliorate the Miller capacitance is to use relatively high collector voltages as the feedback capacitance reduces across the reverse biased base-collector junction with increasing voltage, much as it does with a Vari-cap diode. This is why the world's first transistor radio, the RegencyTR-1, used a 22.5 volt battery. As the transistor design improved then the 22.5V battery idea was dropped and larger capacity lower voltage batteries such as AA, C and D cells were used. The Sony TR72 for example is powered by three D cells or 4.5V.

Later on as transistor technology improved, germanium RF transistors such as the AF115, AF125, OC171 and AF178 had collector base feedback capacitances that were so low they would work in IF amplifiers without any neutralisation. For example the base to collector feedback capacitance for the vintage OC45 was about 10pF and for the more modern AF178 is only about 0.8pF. As another example the Eddystone EC-10 vintage transistor communications radio uses OC171's in its IF amplifiers with no neutralisation at all.

Transistor radio advantage:

One of the most remarkable features of the simple 6 or 7 transistor radio is the very low current drain. Each transistor within the radio, except in the audio output stage, is usually running less than 1mA current and the power delivered to the speaker is proportional to the volume setting. The residual bias current for the transistor output pair running in class AB is usually in the order of 3 to 10mA at most. The running current of a TR-72 radio at a normal listening volume is about 10mA.

This means that with a set of D cell batteries and normal daily use the radio runs for months completely unlike the tube radio predecessors which chewed through batteries in days to a week or two.

On top of this transistor radios benefited from developments with ferromagnetic materials. The Meissner Company in the USA pioneered early examples of dust iron ferromagnetic cores in the late 1930's. Many of these were used in their 1939 TV Kitset:

www.worldphaco.com/uploads/THE_MEISSNER_5_INCH_KIT_AND_THE_ANDREA_KTE-5.pdf

The ferrite rod or "magnetic bar" antenna works very effectively from 100KHz to about 12MHz and was perfect for a compact antenna for the medium wave 550KHz to 1700KHz band. This meant that AM transistor radios did not require a metal whip antenna and they could be "pocket radios". Also the transmission & reception range of AM stations was very large with this system and people could tune into AM stations from different cites all over a single country. AM radio dials often had dozens of station labels from different cities, especially in Europe. However FM radios need a reasonable whip antenna, only work well within one city and the range is nowhere as good as AM despite the better fidelity. Ferrite rod antennas don't work well in cars so the AM radios there were forced back into whip antennas.

AM radios or FM radios do not work too far from the mouth going into long tunnels or underground as the signals are shielded. Although, there is the lyric in the excellent Van Morrison song Brown Eyed Girl: *"….going down the old mine with a transistor radio".* However the transistor radio doesn't work if you take it down a mine. Perhaps it was an open cast mine he was referring to.

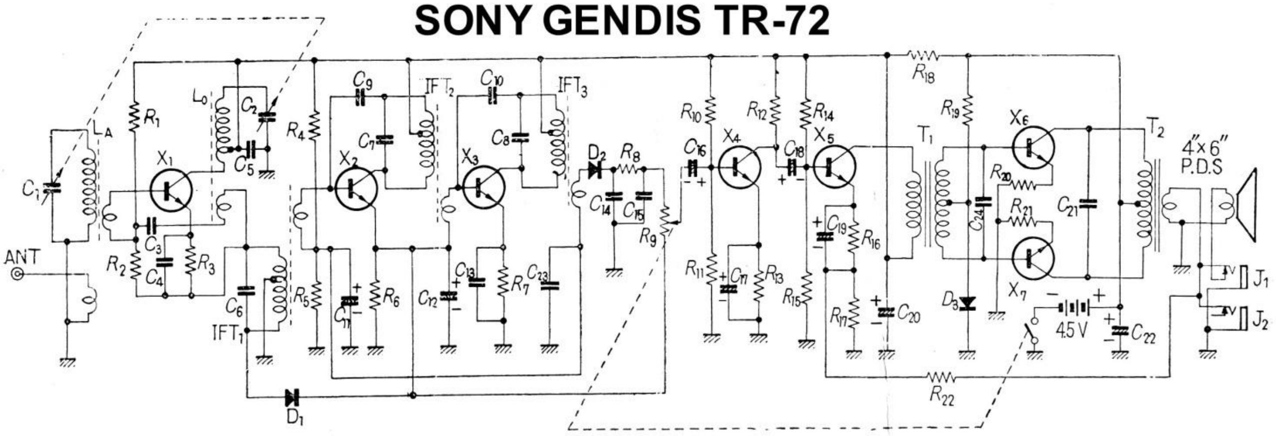
In addition ferromagnetic core technology was also required to gain high enough Q values for the compact oscillator coils and IF transformers in the transistor radio and it could not be done with air cored coils as they would need to be far too big. Therefore it was not just the transistor technology that made compact transistor radio possible, it was also the ferromagnetic material. This topic is often neglected in discussions of the evolution of the transistor radio.

The TR-72- one of the early masterpieces from Sony:

Sony made everything for their radios in house, specifically the transistors and diodes.

The circuit shown below is Sony's TR72 and it is interesting to look at the design features. Firstly the transistors are NPN. Many early commercial Germanium junction transistors were PNP however the Regency TR1 also used NPN devices. NPN germaniums are rare, however if one is stuck for a replacement the OC139 or OC140 will work or perhaps a 2SD11.There are a good number of early 2SD series NPN germaniums which at a pinch could act as replacements.

SONY GENDIS TR-72



C1	V.C. Ant	C18	10 μF 3V	R10	33 KΩ ±5%¼L	X5	AF2 Transistor
C2	V.C. Osc	C19	30 μF 6V	R11	10 KΩ ±5%¼L	X6	AF3 〃
C3	0.01 μF	C20	100 μF 6V	R12	1.5KΩ ±5%¼L	X7	AF3 〃
C4	0.01 μF	C21	0.1 μF	R13	1 KΩ ±5%¼L		
C5	0.01 μF	C22	100 μF 6V	R14	10 KΩ ±5%¼L	D1	SONY Diode, A.G.C.
C6	200 PF ±5%	C23	0.05 μF	R15	3.3KΩ ±5%¼L	D2	〃 Diode, Det.
C7	200 PF ±5%	C24	0.02 μF	R16	270 Ω ±5%¼L	D3	〃 Varistor,Stabilizer
C8	200 PF ±5%	R1	100KΩ* ±5%¼L	R17	5 Ω ±5%¼L	Lant	Bar Antenna Coil
C9	2 PF ±30%			R18	60 Ω ±5%¼L	Losc	Oscillator Coil
C10	2 PF ±30%	R2	15 KΩ ±5%¼L	R19	2.7KΩ ±5%¼L	IFT1	I.F.Transformer AM
C11	100 μF 6V	R3	1 KΩ ±5%¼L	R20	5 Ω ±5%¼L	IFT2	〃 BM
C12	30 μF 6V	R4	33 KΩ*±5%¼L	R21	5 Ω ±5%¼L	IFT3	〃 CM
C13	0.05 μF	R5	15 KΩ ±5%¼L	R22	60 Ω ±5%¼L	T1	Input Transformer
C14	0.01 μF	R6	1.5KΩ ±5%¼L	X1	Mix Transistor	T2	Output Transformer
C15	0.01 μF	R7	470 Ω ±5%¼L	X2	IF1 〃	J1	Earphone Jack
C16	10 μF 3V	R8	1 KΩ ±5%¼L	X3	IF2 〃	J2	〃 〃
C17	30 μF 3V	R9	5 KΩ VR & SW	X4	AF1 〃	*	Adj.

In my TR-72 all of the transistors were still perfect. The detector diode had gone open circuit so a germanium crystal diode was tacked across it to restore the function of the set. In addition one of the primary wires on the audio output transformer had sheared off the bobbin, disconnecting itself and the collector of X6 and resulting in asymmetrical and distorted audio output. The transformer was removed, the wire repaired and the transformer re-fitted. The wires pass without any slack from the transformer bobbin to the pcb and they are fairly thin and taught, so this could be a common problem.

Some of the circuit features are worth discussion:

Notice the IF stage neutralisation capacitors C9 and C10 for the reasons outlined above. Also notice there is no neutralisation required in the oscillator or “converter stage” of transistor X1. This is because the tuned circuit in its collector stage running at the oscillator frequency runs at a substantially different frequency than the tuned circuit in its base (the ferrite rod coil and coupling coil) which is the received frequency, so there is little risk of energy exchange between the base and collector circuit. This is unlike the IF stages were the base circuit and the collector resonant circuit have the same frequency.

Transistor X1's circuit total current is composed of a DC bias current and the oscillator currents, which are relatively larger than the current generated from the received signal which are smaller. These two currents are mixed together. However, due to the fact that the transistor X1 is biased into a non linear region the two signals produce output currents relating to the square of their sum so the total X1 circuit current contains sum and difference products of the two frequencies. It is a requirement for the *sum & difference* of the two signals to be present in the total current of the X1 converter stage. These currents pass through the 1st IF transformer primary (IFT1) which is tuned to the *difference* between the oscillator signal and the received station signal, this is the intermediate frequency signal or IF signal.(Notice how the bias resistor R1 is lower than R4, these low bias values are typical in a converter stage compared to an IF stage).This converter is sometimes referred to as an Autodyne converter.

The signal then passes through the neutralised IF amplifier of X2 and X3 to the detector diode D2. A negative AGC voltage is developed across C23 and reduces the bias on X2 and X3 to lower the gain of the IF amplifier. Cleverly X3's bias is derived from X2's which saves another divider network. It should be noticed that most of the voltage gain in a transistor radio (unless it has a RF stage) is in the IF amplifier and it can be as much as 80dB for two stages.

There are two other clever circuit features here:

1) Firstly the DC voltage drop of the base-emitter junction of X2 is used to provide a small forward bias to the detector diode D2, they did this by cleverly returning the lower leg of the volume control to the emitter of X2 and from the DC perspective the anode of D2 is at the base voltage of X2.This helps in the detection of weak signals.

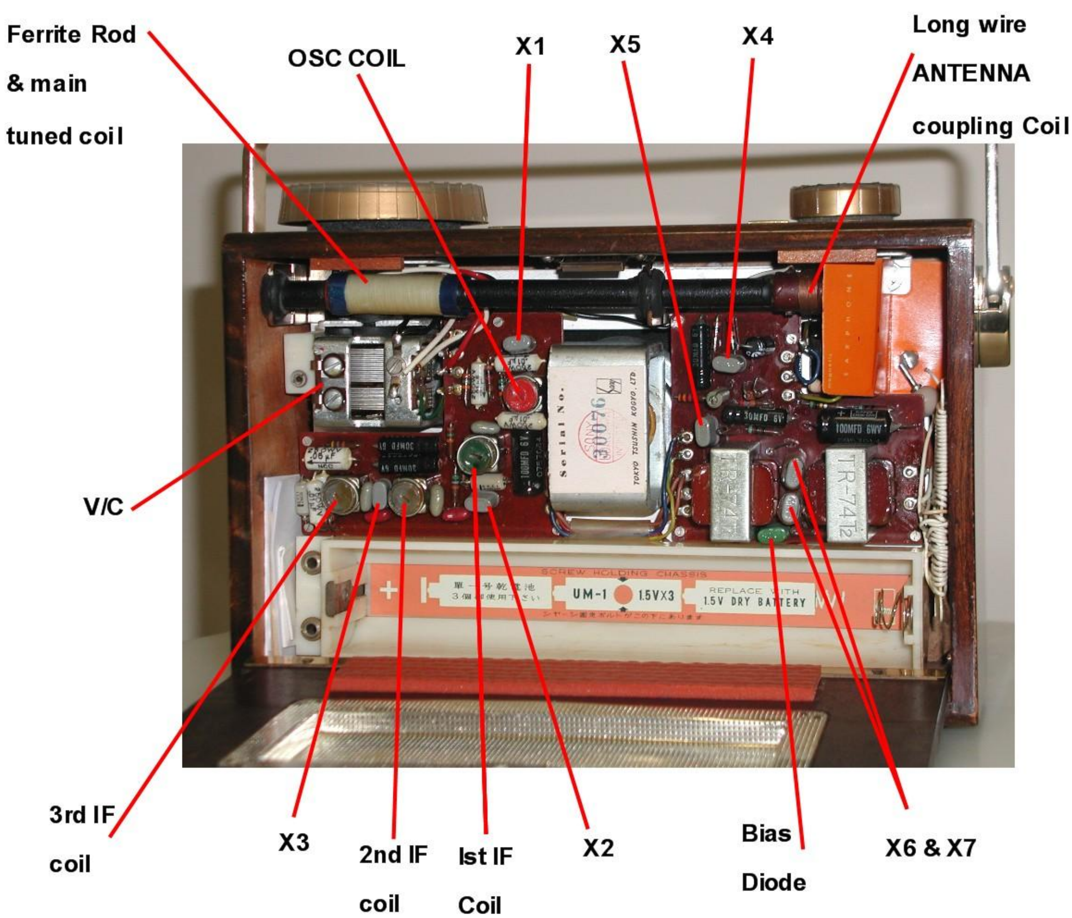
2) Secondly, with very high signal conditions an additional type of AGC diode comes into play, D1. With high IF signal voltage D1 conducts charging capacitor C12.This tends to take X2 out of conduction lowering its gain and tends to reverse biases the detector diode D2 which helps prevent overload on strong signals.

The audio amplifier is very standard with a pre driver transistor X4 and a driver X5. The coupling transformers as can be seen in the photograph below are relatively large and with the good sized speaker and the rear ventilated wooden case this radio has a terrific sound and mellow tone with a good bass response which is very impressive and not at all like some "tinny" sounding radios.

Note the use of negative feedback via R22 around the audio driver & output stages to lower any distortion. The output transistors, which are not on heat-sinks are DC stabilised by 5 ohm emitter resistors and a special purpose “bias diode” D3 which tracks the base emitter voltage change with temperature of the output transistors, thereby helping to prevent thermal runaway.

The diagram below shows the inner view of this radio. The construction quality is remarkable and practically unmatched by any modern consumer electronic device. There is an additional coupling coil on the ferrite rod for a long wire antenna. These were placed well away from the main tuned coil so that the loading from the long wire antenna did not detune the main coil.

The wooden cabinet appears to be some very high quality Japanese wood and the white Sony badge on the front is enamelled. The speaker mesh is anodized gold expanded aluminium. The back hinge assembly is made of brass. In all places where wires connect to the pcb they used eyelets with solder tags. Each transistor has a very good coat of paint and the inside of the radio looks as good as new after nearly 60 years:

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