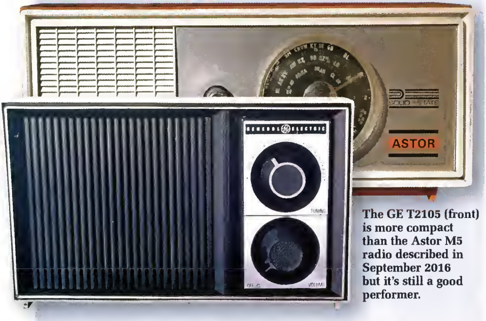
Vintage Radio

By Ian Batty



The GE T2105 (front) is more compact than the Astor M5 radio described in September 2016 but it's still a good performer.

The incredible shrinking mantel set: GE's T2105

Are five transistors really that much better than four?

In September, we looked at Astor's M5 & M6 5-transistor sets. By sacrificing an IF amplifier stage, GE's T2105 model reduces the transistor count to just four but the set still offers good performance.

THIS GE T2105 4-transistor set appeared at an Historical Radio Society of Australia auction last year but I'd gone intending to keep my hands well in my pockets. After all, I really have to stop somewhere when it comes to acquiring vintage radios!

After the auction, the person who bought it told me about its 4-transistor design and regret set in with a vengeance. An offer to buy the set was politely declined but I was very pleased when he offered to lend me the set so that I could have a good look at it. I was curious to find out if it was really any good or just a cheap-and-cheerful import with mediocre performance.

The T2105 – first look

Despite having only four transistors, I soon discovered that the T2105 is able to take on five, six and 7-transistor sets for ordinary listening in the suburbs. It also works just fine at my country property near Castlemaine, pulling in both Melbourne ABC stations as well as any other set, along with a heap of country stations from all over Victoria.

Perhaps it's a good thing that it's going back to its owner in the near future. My Astor M6 was beginning to wonder if it had any future in my kitchen and was looking decidedly nervous as I examined this new kid on the block!

Circuit details

If we have to take a "man overboard" approach to radio receiver design, it's easiest to dump the more complex stages. This certainly was Regency's reasoning when, after starting with an 8-transistor design, they finally arrived at their 4-transistor TR-1 which was a big success.

GE seems to have had the same idea. Like the TR-1, the T2105 uses a self-excited converter, a single AGC-controlled IF stage, a diode demodulator/AGC rectifier and two audio stages with resistance-capacitance coupling and a Class-A output configuration.

Like the TR-1, the T2105 uses NPN transistors. However, unlike the TR-1, the T2105 uses silicon planar devices (as opposed to the TR-1's grown-junction devices).

Fig.1 shows the circuit details of the GE T2105. It specifies SE1001 (TO-18 package) transistors for the converter and IF stages, a BC209 audio driver stage and a 2N3563 (TO-5 package) for the Class-A audio output stage. However, the set shown in this article has unmarked transistors for the first three devices and these are in a stepped non-standard case that's similar to a TO-226 package. A 2N3568 transistor is used for the output stage, as specified on the circuit.

Another surprise was that the IF amplifier stage (TR2) uses a grounded base configuration which is rather strange. This configuration made sense in sets that used alloyed-junction germanium

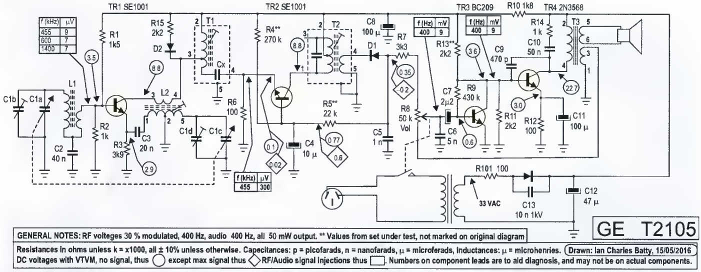


Fig.1: the GE T2105 is a 4-transistor design. TR1 functions as the converter, TR2 is an IF amplifier stage, diode D1 is the demodulator, TR3 is an audio driver stage and TR4 operates as a Class-A output stage. The set is mains-powered only and the power supply uses a power transformer to drive a half-wave rectifier and 47µF filter capacitor.

devices because it dispensed with the need for neutralising. However, silicon planar devices, as used in the T2105, have low feedback capacitances and so don't need neutralisation.

Looking at the circuit in greater detail, converter stage TR1 gets its base bias from divider resistors R1 & R2. This divider sets its base at around 3.5V and so its emitter sits at about 2.9V. Emitter resistor R3 limits the emitter current to around 0.75mA under DC conditions.

A final point about R1 & R2. Their values are quite low for a simple voltage divider but at the same time, they are also part of a divider network with resistor R10. This arrangement (in combination with the current drawn by the audio driver and RF/IF stages) ensures that the +24V supply is dropped down to the ~9V required to power the front end.

Is the LO operating?

As an aside, valve converters often derive their oscillator's anode supply via a dropping resistor. A large variation in the anode voltage from normal can indicate LO (local oscillator) failure and I recently used this fact to confirm this type fault in a friend's Eddystone set. By contrast, stopping the T2105's LO gives no significant change in the circuit voltages.

Basically, if you suspect that a transistorised LO is not operating, circuit voltages don't seem to be a useful indication.

As shown on Fig.1, TR1 uses collector-emitter feedback, resulting in less LO radiation back through the antenna rod. The output from the converter is fed via L2 to the first IF transformer which is an autotransformer, ie, with a tapped winding. This is similar to the scheme used in the Pye Jetliner (Silicon Chip, September 2014). IF amplifier stage TR2 is then fed from the first IF transformer's single winding via capacitor Cx.

Since the "top" of the IFT's winding (via pin 2) goes to the positive supply rail (and thus to IF ground), the IFT's "hot" end connects to the circuit via pin 4. Tuning for the IFT is achieved using Cx, which connects to TR2's emitter and then to IF ground via T2.

This makes TR2's emitter circuit part of the first IFT's tuned circuit and the low voltage/impedance tap provides optimal matching into TR2's low emitter impedance. Emitter resistor R6 (at 100Ω) provides a path for the DC emitter current to ground. The signal from T1 modulates this current and since the base voltage is essentially fixed, this varies the base-emitter voltage and thus the collector current.

Before leaving the front-end stages, let's consider the role of diode D2 and resistor R15. While such components are used purely to limit the LO's signal amplitude in some sets, in this set D2 & R15 are also part of the converter's collector load.

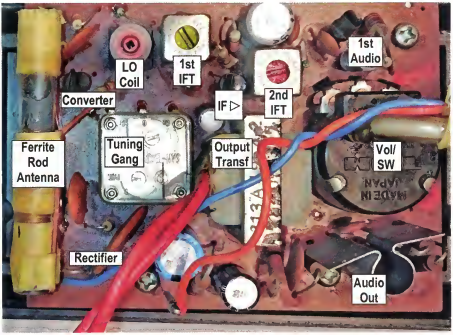
Disconnecting D2 confirmed its role in limiting very strong signals, well after the main AGC voltage had cut TR2's gain to almost unity. However, unlike the conventional AGC extension

Indicated RF Signal Levels & Gain

As noted in the article on the Astor M5 mantel set last month, all signal injection voltages shown on the circuit are as indicated by the generator's output controls. However, there is an issue with the GE T2105 concerning the accuracy of the indicated injection voltage into the emitter of IF amplifier TR2.

A quick calculation indicates an input impedance of some 20-30Ω at TR2's emitter and that's low enough to load down my 50-ohm generator so that the indicated value is artificially high. However, since most of us are simply going to connect a standard test lead (with a blocking capacitor) to the circuits we're testing, "uncompensated" readings are probably the most useful.

Some readers may be puzzled as to how a set amplifying a signal of about 10µV at the converter's base (TR1) can deliver a power output of around 50mW into the speaker. That represents a power gain of around about 110dB! However, if you allow a gain of around 27dB per stage and multiply that by four, it's easy to see how this figure is achieved. So why hadn't anyone done it before?



Most of the GE T2105's circuit parts are mounted on a single PCB, as shown in this labelled photo. Note the flag heatsink fitted to the audio output transistor at bottom right. The mains switch is on the back of the volume pot, directly above the output transistor.

diode used in (for example) the classic "Mullard" design, D2 acts a simple clamp diode. It does not rely on the first IF amplifier's change in collector voltage as the main AGC circuit comes into action.

As stated earlier, IF amplifier TR2 has a grounded base configuration and while a grounded-base stage's current gain is slightly less than one, its voltage gain can be considerable – more than for a common-emitter stage.

TR2 feeds the tuned primary winding of IF transformer T2 and its secondary in turn feeds demodulator diode D1. The recovered audio signal is then filtered and fed to the base of audio driver stage TR3 via volume control R8 and a 2.2μF coupling capacitor. TR3's collector then directly drives the base of TR4, the Class-A output stage.

This direct-coupled audio section saves on capacitors and output stage biasing components and is an unusual circuit. All other direct-coupled designs I've seen thus far use DC feedback around the output stage to stabilise the operating point. This means that temperature variations (or even transistor substitutions) have negligible effect on circuit operation.

By contrast, this circuit works by using quite a high value output emitter resistor (100Ω) to provide strong local negative DC feedback, with a 100μF bypass capacitor to ensure that the AC signal gain is still high. The driver stage based on TR3 is stabilised separately.

Let's take a closer look at TR3's biasing arrangement. This stage uses collector bias, with DC feedback from collector to base. While it's not as immune to temperature and component changes as combination bias, it works well enough for audio applications where the collector voltage changes with collector current.

Check The Mains Wiring Before Restoration

If you have one of these sets, note that the mains power is controlled by a switch on the back of the volume control potentiometer. This means that the leads running to this switch and the switch contacts operate at mains potential.

In addition, mains power is also present on a tagstrip that's held in a plastic cover attached to the speaker frame.

These mains connections were all adequately insulated on the set described here but it's something to watch out for. In fact, you should always check the insulation of all mains wiring and any associated connections before working on any mains-powered equipment.

TR3's collector load is also rather odd. As shown on Fig.1, this load consists of voltage divider R13 & R11 which also sets TR4's base voltage.

At first glance, this may appear to provide a low-impedance load for TR3, resulting in a low voltage gain. However, TR4's input impedance is only a few hundred ohms at most, so the parallel combination R11 & R13 is actually high enough to have little effect.

In short, it's a "cheeky" design that connects the driver's output straight into the output stage's bias divider.

As stated, TR4 operates as a Class-A amplifier stage. It dissipates some 600mW of power with no signal, which is quite a lot and so it's fitted with a flag heatsink to aid cooling. This transistor, a 2N3568, is also encapsulated in a ceramic-body, epoxy-topped TO-105 case.

TR4's collector drives output transformer T3 and its secondary in turn drives a 4-ohm loudspeaker. A second winding on the transformer provides feedback to the bottom end of the volume control, to reduce distortion.

The power supply is about as simple (and economical) as it gets and consists of a power transformer, a half-wave rectifier and a 47μF filter capacitor. Resistor R101 in series with the transformer's 33VAC secondary limits the surge current into the rectifier when power is first applied, while C13 filters any RF interference from the supply.

Why silicon transistors?

The first transistors were made using germanium rather than silicon. Germanium has a melting point of about 940°C and this made it easier to work with than silicon which melts at 1420°C.

Eventually though, germanium's scarcity and its high leakage current led to the adoption of silicon. This has several advantages, including significantly lower leakage currents, higher operating temperatures and much lower feedstock costs than germanium.

Silicon devices are also naturally better protected than germanium devices. Germanium dioxide is a soluble compound and so germanium devices require well-designed encapsulations and perfect (hermetic) seals to guarantee long lifetimes.

By contrast, a silicon dioxide surface (ie, glass) provides highly effective protection for silicon devices. This natural protection allows economic encapsulations, even permitting the use of epoxy resins for many low-power audio and RF transistors (such as those used here) and industrial-grade ICs and microcontrollers.

Cleaning it up

As it came to me, the set was in quite good working condition. I simply cleaned the cabinet and sprayed the noisy volume-control pot with contact cleaner and that was it. The set was then ready for the test bench.

As an aside, I've not seen any other 4-transistor all-silicon designs from the mid 1960s. While Regency's TR-1 is also a 4-transistor set, any comparison between it and the GE T2105 would be unfair. Although only 12 calendar years separate the 1954 TR-1 from the 1966 T2105, we would be comparing a radio using first-generation grown-junction germanium devices against a set using fifth generation silicon planar devices.

How good is it?

GE's T2105 isn't in the same league as the 7-transistor Philips 198 from 1958 (SILICON CHIP, June 2015) but it's still a creditable performer given its simplicity.

Its sensitivity (at 50mW output) is 300μV/m at 600kHz and 1400kHz and it achieves this figure with a 20dB signal-to-noise (S/N) ratio. This 20dB S/N ratio is a result of the set's comparatively low RF/IF gain, due to its use of a single IF amplifier stage (TR2).

The IF bandwidth was ±2.5kHz at -3dB. Testing at -60dB was impractical but it exhibited a bandwidth of some ±60kHz at -30dB, again due to its simplified IF channel.

Like most small sets, the T2105's audio performance is best described as "adequate". Its audio response from the volume control to the speaker is 200-2000Hz, while from the antenna to the speaker it's 200-1500Hz. The audio distortion at 50mW is 4% and is just 2.4% at 10mW out. As expected, the distortion rises to around 10% at the onset of clipping, at which point the set is delivering 180mW.

The set's audio output power is actually less than one-third of the power drawn by output transistor TR4. This is in line with other practical Class-A designs. It appears as though real-world Class-A output stages simply can't approach the theoretical maximum of 50% efficiency.

The set's sensitivity is also lower than would normally be expected. Based on other sets I've tested, the converter's sensitivity of some 7μV should translate into an "air sensitivity" of 70-100μV/m instead of the measured 300μV/m. The T2105's minuscule ferrite rod antenna is probably the culprit; it simply picks up less RF energy than the larger ferrite rod antennas used in bigger sets.

Despite this, I really do like it. Electrically, it's a good performer in all but the most demanding settings. I also like its cheap and cheerful design. Whoever put this set together was able to extract maximum performance with a minimum of complexity and some clever engineering. **SC**

Further Reading

(1) The original circuit (it was redrawn for this article) is on Kevin Chant's website at http://www.kevinchant.com/general-electric.html

(2) Photos of the set can be found on Ernst Erb's Radiomuseum website at http://www.radiomuseum.org/r/general_el_t2105a.html