

Vintage Radio

By Ian Batty



The unique GE 675 5-transistor radio



First marketed in 1955, GE's 675 radio uses just five transistors. It features a class-A audio output stage, has unusual AGC and volume control circuits, and is powered from a 13.5V/4.5V battery.

THOMAS EDISON began inventing at an early age but burst onto the public stage in 1877 with his invention of the phonograph. His wide-ranging interests led one author to subtitle an Edison biography as "Inventing the Century".

By 1889, Edison's output was spread over many technology companies and these were eventually consolidated into the Edison Electric Light Company. The Thomson-Houston Electric Company, a major Edison competitor, was amalgamated with Edison's holdings in 1892 to become General Electric.

Now a multinational giant, GE was one of just 12 companies that listed on the newly-formed Dow Jones Industrial Average in 1896. It's now the only one of those original 12 still listed

today. As an aside, in 1919 Owen D. Young founded the Radio Corporation of America (RCA) as the retail arm of GE. RCA was subsequently spun off as an independent business in 1930.

In common with several other electronics manufacturers during World War 2, GE worked on microwave diodes for use in radar receiver mixers. The company's eventual entry into transistor manufacturing began when Albert Hull, an electrical engineer with GE, read about Bell Labs' development of the transistor and decided that GE's extensive diode work gave them the necessary expertise in that field.

GE's 675

The GE 675 is a 5-transistor set with a class-A audio output stage. Depending on when it was made, it uses ei-

ther a diode demodulator or a class-B demodulator/first audio stage. It also uses an ingenious "sliding bias" volume control/bias circuit for the output stage.

A 5-transistor design may seem like a recipe for poor performance but it's worth noting that a conventional 6-transistor set has only five amplifying stages. That's because two of its six transistors are used in a push-pull audio output stage.

GE's 675 follows the style established by Regency's TR-1 (see SILICON CHIP, April 2013). It's a stark, minimalist design and like the TR-1, it uses thumbwheel tuning but has a front-operated volume/on-off control. It's also similar in size to the TR-1; ie, it fits into a coat pocket rather than a shirt pocket.

The set shown here came in its original leather case. Like the Philco T7, this case opens part way at one end to allow tuning and volume adjustments without completely removing the set. My GE 675 has a black cabinet but on-line catalogs show that it was also available in ebony, ivory, red and aqua.

The 675 is a later design than the TR-1 and has more audio output, as described below. It uses an air-spaced tuning gang with a smaller (cut-plate) oscillator section and as such, has a tendency to cramp the stations close together at the top end of the broadcast band.

Circuit details

Fig 1 shows the circuit details of the GE 675. It's a fairly straightforward superhet design using four PNP transistors (X1-X3 & X5) and one NPN transistor (X4).

Converter stage X1 is conventional, with collector-base feedback via oscillator coil T2. This stage feeds the tuned, untapped primary of the first IF transformer (T3) and its untapped secondary in turn is coupled to the first IF amplifier stage (X2).

On my set, X2 is neutralised using

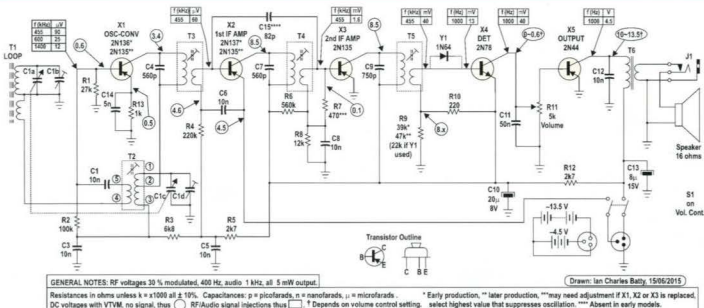


Fig. 1: The circuit of the GE 675 uses just five transistors (X1-X5). X1 is the converter stage, X2 & X3 are IF amplifier stages, X4 (or diode Y1 in some sets) is the detector and X5 is a class-A audio output stage. Power comes from a 13.5V/4.5V battery.

C15. As shown, this capacitor is connected between X2's base and the secondary of the second IF transformer (T4). However, earlier circuits do not show this, which meant that early sets worked without neutralisation of any kind. This helps explain: (a) the double-sided PCB used with an extra ground plane (very unusual in domestic radios), (b) the copper shield covering the set's entire component side and (c) the small ferrite rod mounted above the copper shield. All three methods are commonly used to improve shielding and reduce feedback.

An unusual design feature is that X2's emitter is connected to a 4.5V tap on the special 13.5V battery that's used in this set. Since X2 uses simple series bias from the main supply via resistor R4, this is an odd circuit configuration. There is no DC feedback from the demodulator, so this radio appears to lack AGC. However, this unusual circuit is, in fact, the AGC section (see later).

It looks rather like the configuration used in some valve sets that applied AGC to the converter alone. This allowed the IF amplifier to draw grid current (via a high-value grid resistor) on strong signals and to slide its bias, thereby reducing the gain.

The first IF amplifier (X2) feeds the untapped, tuned primary of the second IF transformer (T4). Its untapped secondary then feeds the second IF amplifier stage based on transistor X3.

As usual, this stage works with fixed bias but without neutralisation. A brave move? Well, there's R7 which is used as a damping resistor across T4's secondary. If transistors X1, X2 or X3 are replaced, then R7 may need to be adjusted to prevent oscillation (its maximum value is 500 Ω). However, while this damping effect obviously prevents oscillation by reducing gain, adding neutralisation to the second IF amplifier stage would have given more gain and eliminated the need to adjust R7.

The Sams Photofact website (<https://www.samswebsite.com/>) states that demodulator diode Y1 was "used in late productions only". Without it, transistor X4 is biased so that it functions as a class-B demodulator, although in practice, it provides both demodulation and audio gain.

The amount of bias is quite small: just enough to bias the base into conduction while eliminating the incoming IF signal's negative peaks. Conversely, the positive peaks are amplified and then filtered by C11 to recover the audio signal (the circuit works similarly with Y1 in place).

Volume potentiometer R11 forms the DC and AC collector load for X4. The way in which this pot has been wired is rather unusual. As shown, X4's collector goes to the pot's wiper and so X4's load resistance (and thus the stage gain) varies with the volume

setting. Even more strangely, the top of the pot is connected to the base of output stage transistor X5.

X5 has no constant bias source. Instead, it's effectively biased due to X4's collector current flowing through R11 and that bias is modified by the volume control setting.

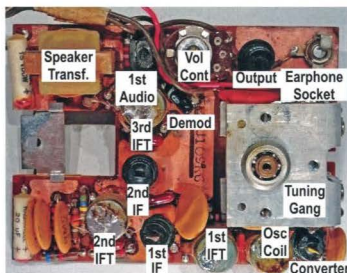
So what we have is a sliding bias circuit. At low volume settings, X5's bias is reduced but that doesn't matter as it doesn't need much collector current to reproduce a low-level audio signal accurately. Conversely, at higher volume settings, X5's bias is increased to allow higher output power without undue distortion.

Given the power-hungry nature of class-A stages generally, it's an elegant solution to the problem. In the absence of any signal, X5's collector current varies from about 2mA at the minimum volume setting to 3mA at the maximum setting. But X5's collector current also responds to signal strength since its bias is controlled by X4's collector current. Strong signals increase X4's collector current and this pushes X5's collector current up as well, to as much as 25-30mA.

In most sets, it's common to monitor signal strength by the drop in the first IF amplifier's collector current due to AGC action. By contrast, the 675 responds to stronger signals by increasing its output stage's collector current and I monitor either this or X2's emitter



The GE 675 is built on a small double-sided PCB, with the ferrite rod antenna mounted along one side.



This view shows the main parts side of the PCB, with the major components marked. Note the comparatively large tuning gang.

current during alignment and testing.

Given the elegance of this part of the circuit, it's puzzling as to why they didn't follow common practice and use neutralisation in the second IF amplifier stage to make the set stable. In addition, given that the 2N44 output transistor (X5) is rated at 250mW maximum dissipation and there's no thermal stabilisation, I'd be wary of running this set at full volume on strong stations for any length of time.

Restoration

As it came to me, my GE 675 was completely dead. Any five or 6-transistor radio should give some converter noise at full volume or, at least for an old set, would have a noisy (scratchy) volume control pot.

The power switch was an obvious

suspect so I checked this first. It was open circuit regardless of position and since it was soldered to the PCB, I temporarily bridged it out with some short wires. My intention at this stage was simply to get the set going and to replace the switch later.

The set was still dead and further checking revealed that the earphone socket had gone open circuit due to dirty contacts. A light polish with some wet-and-dry paper fixed that problem.

I then tried injecting 455kHz into the front-end but the set produced virtually nothing. A close inspection of the PCB revealed the probable cause – the IF transformer slugs had all been adjusted right to the top of their travel. By swinging the signal generator's frequency up and down, I quickly found a response at some 500kHz-plus. A

quick check of the Sams Photofact circuit confirmed that the IF should, in fact, be 455kHz.

As a result, I adjusted the IF coils and I could then hear some noise when a 455kHz signal was radiated in from my test loop. However, there was still no broadcast-band reception. So was the 675's local oscillator working correctly? I placed another AM radio nearby, tuned it to 1600kHz and swung the 675's tuning dial in either direction but to no effect.

In practice, there should have been a whistle from the other set as the 675's local oscillator swung through 1600kHz, so this oscillator clearly wasn't working. A subsequent close examination of the circuitry revealed that the lead from the top of the oscillator coil to the tuning gang had gone open circuit.

Repairing this open circuit resulted in broadcast-band reception at last. By the way, if you ever work on one of these sets, be aware that the flying leads from the various coils to the PCB consist of very fine wire. This means that you have to be very careful not to break them when working on the set.

Low sensitivity

Although the set was now working, its sensitivity was quite low, so it still had a fault somewhere. However, I already had a good idea as to what the problem was – some heavy-handed person had damaged the second IF transformer so badly that I was unable to tune its slug back out to its desired position. My guess is that someone had adjusted the IF slugs to their extreme positions in an attempt to get the set going, not realising that the fault was actually in the local oscillator.

At this stage, I decided to take a look at a second GE 675 set I'd obtained. This had an open-circuit track to the output transformer and its ferrite rod had also come loose, resulting in broken leads. Once these problems had been fixed, the set began working and after alignment, it performed quite well.

Apart from that, the set only required a quick clean-up. The cabinet was given a polish, while a wipe-over with leather preserver soon had the case looking almost as good as new.

Performance

So just how well does it perform? First, its output at clipping was only

about 35mW but even at this low level, the output stage current drain increases noticeably. The GE Transistor Manual, 2nd Edition (pages 99-105), shows several circuits with class-A output stages. Each of these quotes a significantly higher output of 75mW, while their sensitivity figures are specified at an output of just 5mW (which I've used for testing).

The circuit diagram shown in Fig.1 is a composite of several online examples. The component numbering follows the circuit in Beitman's "Most-Often Needed 1956 Radio Servicing Information" Volume R-16, which is more detailed than the Howard W. Sams Photofact. The Beitman circuit also includes coil resistances but omits the transistor resistance measurements in the H. W. Sams document.

Be aware also that the Beitman circuit recommends using a 20k Ω /V meter for voltage measurements. However, a 20k Ω /V meter gives a misleading low measurement of just -3.5V on the base of the first IF amplifier (X2).

In addition, the Sams circuit shows only one voltage for the output transistor's collector (X5) while the Beitman circuit shows the expected range according to the volume control setting. The Beitman and Sams circuits are both available on Ernst Erb's website (see listing at the end of this article).

How does it compare?

The GE 675 is just a little bigger than Regency's TR-1 but its greater output power is noticeable. And because there are no coupling capacitors in the signal path, its audio response is controlled by the IF-stage bandwidth and the output transformer (T6). In fact, the frequency response from antenna to speaker is 160Hz to about 4.3kHz which is quite good for this type of set.

The IF selectivity is -3dB at ± 6 kHz and -60dB at ± 65 kHz. The audio performance is adequate: at 5mW output, the THD (total harmonic distortion) is around 6% at 1kHz, while at 30mW it rises to around 8%. As stated above, it begins to clip at 35mW output.

The RF sensitivity at converter X1's base is about what you'd expect: 25 μ V for 5mW output at 600kHz and around 12 μ V for 5mW at 1400kHz. Due to its low-gain IF stages, it achieves this for a signal-to-noise ratio of about 18dB. By contrast, the Philco T7 has a sensitivity of about 50-80 μ V respectively for a 50mW output.



The leather case opens at one end to allow tuning & volume adjustments without completely removing the set.

In practice, the GE 675 provides an output of 5mW for a field strength of 750 μ V/m at 1400kHz and struggles to better 2mV/m for 5mW at 600kHz. The small ferrite rod is probably the cause of this problem, as the set's sensitivity is quite acceptable when signal is directly applied to X1's base.

What about AGC? Despite there being no feedback from the detector to control IF amplifier X2's bias (and thus its gain), its emitter current does in fact fall with increasing signal. This results in the output rising just 6dB for a signal increase of around 25dB.

So how does the AGC work? The answer involves 220k Ω resistor R4 which provides a bias current of about 40 μ A to transistor X2. As the IF signal on X2's base increases to several millivolts, X2's base-emitter junction (which is already forward-biased) begins to act as a rectifier. The resulting current effectively opposes the 40 μ A bias current supplied via R4, thereby reducing X2's collector current and its gain.

In operation, X2's collector/emitter current falls proportionally according to increases in signal strength. In fact, it behaves just like a more conventional gain-controlled stage.

As mentioned earlier, a similar scheme was used in some valve radios, with a grid-leak circuit providing gain reduction on strong signals.

Would I buy any more?

Although this set's design is rather unusual, it's not a remarkable performer. Nor has it the eye-catching design of (say) the Philco T7. I'm still puzzled by

its poor performance and it's possible that some obscure fault still exists that I've yet to track down.

I also think that this was a rushed design. In practice, transistor production spreads could have been handled by selecting neutralising components to match individual transistors. Although this is time-consuming and adds to the cost, it's exactly what Regency did with their TR-1 and something that GE could have adopted. If my measurements are accurate, this set's RF/IF design badly lets it down.

That said, the GE 675 is worth having as an example of early transistor radio engineering. If you are interested in obtaining one of these unique sets, they're often available online at low cost.

Finally, it's worth noting that the GE 657-678 models are all similar apart from a few component changes.

Further reading

- (1) Thanks to Mark P. D. Burgess for his outstanding site at <https://sites.google.com/site/transistorhistory/Home/us-semiconductor-manufacturers/general-electric-history>
- (2) The GE Transistor Manual is at: http://n4trb.com/AmateurRadio/SemiconductorHistory/GE_Transistor_Manual_2nd_Edition.pdf
- (3) Thanks to Ernst Erb for his Radio Museum's listing of circuits and other information on the GE 675 at http://www.radiomuseum.org/r/general_el_675.html

A discussion page is at: <http://antiqueradios.com/forums/viewtopic.php?f=4&t=208340>

SC