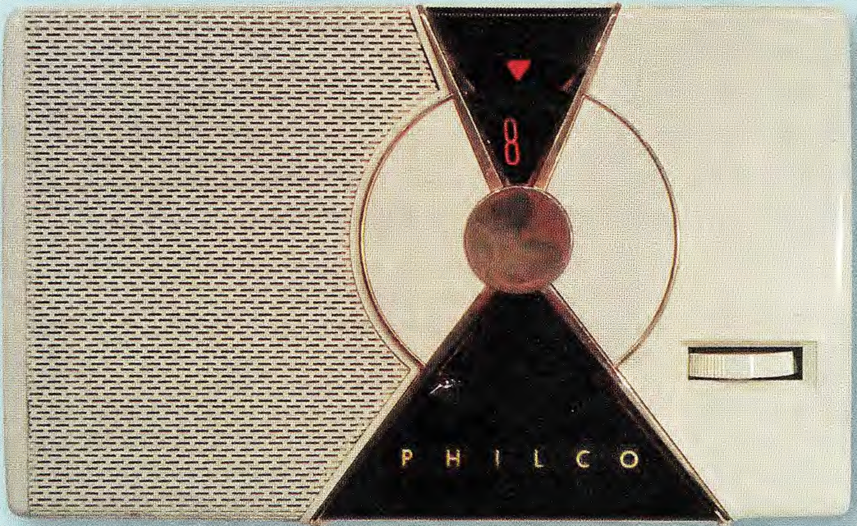
Vintage Radio

By Ian Batty

Trapped in Germanium Valley: The Philco T7 Transistor Portable Radio



. . . early to market & early to retire

Released in 1956, the T7 was Philco's first portable transistor radio. It used the company's proprietary SBT germanium transistors and compared favourably with other sets of the era but was soon overtaken by sets based on silicon transistors.

THE PHILADELPHIA Storage Battery Company was registered in 1906 and began releasing products under the Philco brand name in 1919. As noted in my article on Philco's Safari portable TV set in the January 2014 issue, the company was an early adopter of transistor technology, releasing their proprietary Surface Barrier Transistors (SBTs) in 1953.

At that time, alloy-junction transistors (such as the OC45) were restricted to a maximum frequency of about 15MHz. The limiting factor was how thin the base region could reliably be made. As a result, Arthur Varela of Philco reasoned that electrical etching would be more controllable than the somewhat random process of high-temperature alloying and so he invented the surface-barrier transistor (SBT) process.

In this, the base slice was held vertically and chemically etched away by very fine sprays to form emitter and base "wells" on opposite sides of the slice. Then, electrochemical deposition "plated" the emitter and collector regions onto the base slice, creating a fully-working transistor. The actual junctions worked just fine but with somewhat lower barrier potentials than for alloy-junction devices.

Surface-barrier transistors offered high-frequency operation to at least 30MHz. Adding diffusion to the process (MADT – microalloy diffused-base transistor) pushed frequencies to some 200MHz.

Philco devices (and their licensed equivalents from US Sprague and English Semiconductors Ltd) are easily recognised by their distinctive TO24 and TO25 "bullet" cases. These are shown in the photos on the facing page.

Philco's 1955 release of "the world's first all-transistor car radio" and their "fully transistorised portable phonograph" (released the same year) should have ensured that Philco remained a major consumer electronics manufacturer. However, Philips, working in parallel, were developing their alloy-diffused technology, eventually yielding the landmark AF186 transistor. This could be used as an RF amplifier at frequencies up to 860MHz.

Outstanding as this was, germanium's days were numbered with the rapid development of high-performance silicon technologies: mesa and planar.

With their ability to form an impervious surface layer of silicon dioxide (glass), silicon devices allowed cheap plastic encapsulation. Mass-production lithography also allowed many tens of devices to be made on one silicon die, resulting in skyrocketing volumes and nose-diving costs of production.

Philco missed this new silicon technology wave. Surface-barrier and other pre-lithographic technologies suffered from "one at a time" production techniques and their associated high costs of manufacture. The failure to move to silicon meant that Philco's lead in manufacturing had faded by the early 1960s to re-supply for existing equipment. Their specialist solid-state ground-based and aircraft computers, along with ground station equipment for the space exploration programs of Project Mercury, could not save Philco.

The company eventually filed for bankruptcy in 1961 and was bought out by the Ford Motor Company.

Philco's T7 radio

While I dislike overblown descriptions, I just have to use the word "stunning" for this design. Its stark tuning dial with its arrowhead design just stands out against the white cabinet. And why not add some gilt trim to complete the effect? Put it among any number of contemporaries and even the casual viewer's eye will linger over this one.

My only reservation is the tuning-dial thumbwheel. It's well-designed but the red lettering doesn't stand out against the black background as well as I'd like. Given the stark black-on-white of the cabinet, I'd have used white dial markings both for legibility and for aesthetics. Nevertheless, the T7 is an eye-catching piece of 1950s industrial design, even when fitted inside its leather case.

Internally, most of the parts are mounted on a PCB and this is secured to a metal chassis that also holds the speaker. The chassis is secured by screws to the inside of the plastic case, while the PCB is secured by twisted metal tabs. This means that the PCB is best left in place unless removing it is absolutely necessary, since there is a risk of breaking off these tabs.

Design details

The "first" of anything always interests me. That's because the engineers have created a solution to a problem that's sometimes well-understood but more often only vaguely perceived.

In this case, the obvious aim was to make an all-transistor radio that could be carried around and used anywhere. But how many transistors should be used in the design?

Rival company Regency, cutting costs savagely, began with eight transistors and finished with a mere four in their landmark TR-1 design (see SILICON CHIP, April 2013). The result was a handsome "coat-pocket" set that performed well enough in quiet living rooms in the city.

But at a football game or in the country? It was "a toy that didn't come at a toy price", as one wag put it.

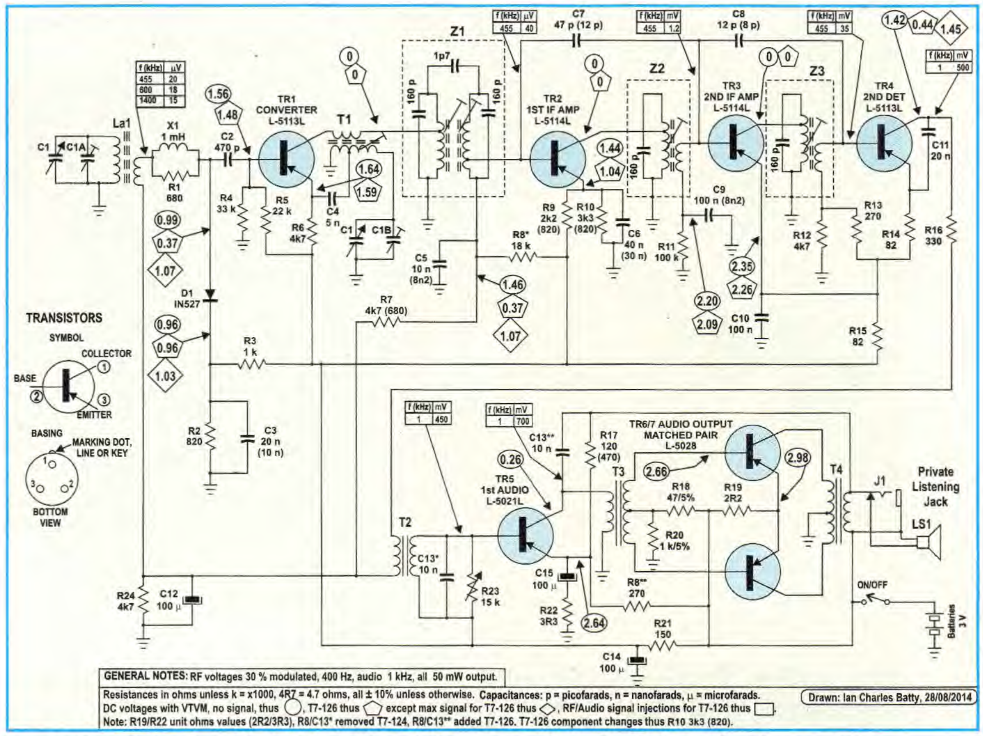


Fig.1: the Philco T7-124 schematic with suggested test points and voltages. The changes made for the T7-126 are shown in brackets. The set is a 7-transistor superhet design with TR1 functioning as the converter, TR2 & TR3 as IF amplifier stages, TR4 as the detector and TR5-TR7 as an audio amplifier.

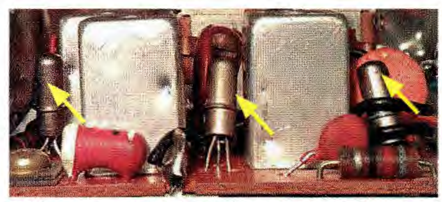
By contrast, industrial giant Raytheon, with a massive market presence in the industrial, military and domestic arenas and a reputation to uphold, went for a "picnic portable". Designated the 8-TP-1, it boasted eight transistors and a performance that equalled similar-sized valve portables.

Philco, eager to carve out market share, went one less. Their T7 transistor radio not only challenged Raytheon's "big set performance" but also targeted the personal portable/coat-pocket niche that was also being viewed by compatriot Zenith and by foreign start-up Sony.

Circuit details

Fig.1 shows the circuit details of the Philco T7. It's basically a 7-transistor design using PNP transistors TR1-TR7 and a 455kHz IF strip. Note that although this set uses PNP transistors, the battery supply is negative to ground rather than the positive to ground as in most contemporary Australian sets.

The following description is for the first "124" series, with the later "126" series modifications noted on the circuit diagram. Note that many online circuit copies do not show decimal points clearly (R22 is a 3.3Ω resistor,



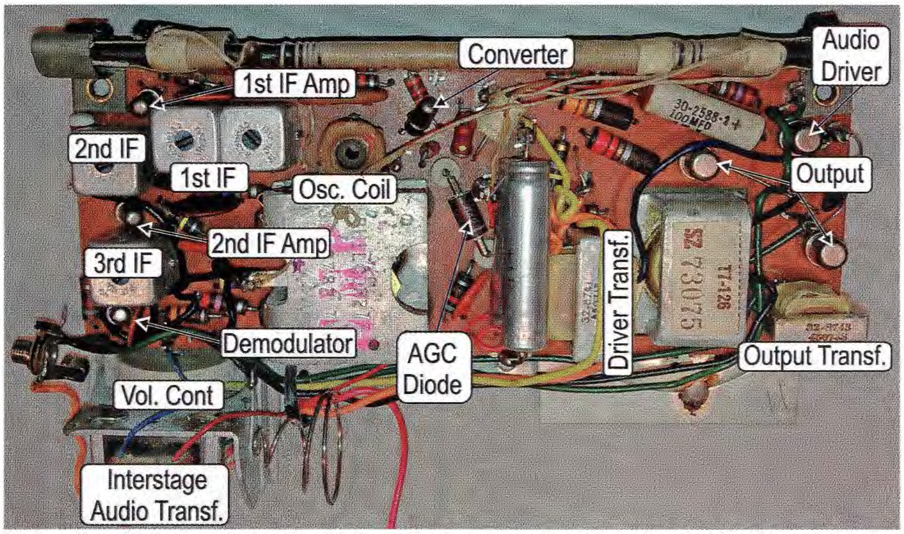
This close-up view shows the TO24 cases used for the converter & IF transistors (TR1-TR4) in the Philco T7.

The audio-stage transistors (TR5-TR7) used the larger TO25 cases.

while C10 is a 0.1µF capacitor).

TR1 functions as a fairly conventional combined mixer-oscillator stage (ie, as a converter). Like Raytheon's 8TR/7TR chassis, Philco applied AGC to the converter stage to give the most effective gain control possible. However, in Raytheon's set, the AGC controlled only the mixer stage and so there was no drift from the separate local oscillator.

So how did Philco fix this problem



Virtually all the parts in the Philco T7 are mounted on a single PCB. Note that the first IF transformer (Z1) actually has its windings in two separate cans, while the second and third IF transformers are each in a single can. The unit just needed alignment adjustments to get it going again.

The PCB is mounted behind a chassis plate which also carries the loudspeaker and the volume control at bottom right. The dial fits over the tuning gang shaft at centre right and features red markings on a black background.

with just one transistor in the converter stage?

Easy – use a diode attenuator (D1) in the antenna circuit. This technique was similar to that employed in some later sets which had an attenuator diode in the primary of the first IF transformer. Philco's circuit had the advantage of reducing signals before the mixer, effectively preventing overload on strong of signals. The converter itself operates with fixed bias, as do almost all single-transistor designs.

IF stages

Two IF amplifier stages (TR2 & TR3) follow, with conventional transformer coupling. The first IF (Z1) has tuned (and tapped) primary and secondary windings. In reality, my set has two separate cans for these windings, with the associated 1.7pF capacitor providing top coupling between the two tuned circuits.

As with the Pye Jetliner, capacitive coupling is an effective (if unusual) means of coupling two single-tuned transformers. This gives more compact IF transformers and eliminates the need to turn the set over to adjust a "bottom" ferrite core.

The second and third stages (Z2 & Z3) use tuned primaries and un-tuned low-impedance secondaries.

In common with most other designs, AGC is applied to the base of the first IF amplifier (TR2) while the second stage runs at full gain with fixed bias. Note that although Philco's surface-barrier transistors work somewhat differently from the more-familiar OC44/45 alloy-junction types, their high collector-base capacitances still require neutralisation in both IF stages. They also have lower base-emitter voltages than the OC44/45 types.

AGC circuitry

The demodulator (or detector), like that in the Raytheon 8RT1 chassis, consists of a transistor (TR4) operating just at cut-off in class-B (R12 & R13 set the bias). Compared to a diode demodulator, this class-B version provides some audio gain plus DC amplification for the AGC circuit.

As shown, TR4's collector current passes through R16 and the primary of audio interstage transformer T2, with the resulting audio signal then fed to T2's secondary. Bypass capacitor C12 filters the audio component across R24, leaving only the DC component to derive an AGC voltage (a simplified version of this circuit, with positive earthing, is shown in Fig.2).

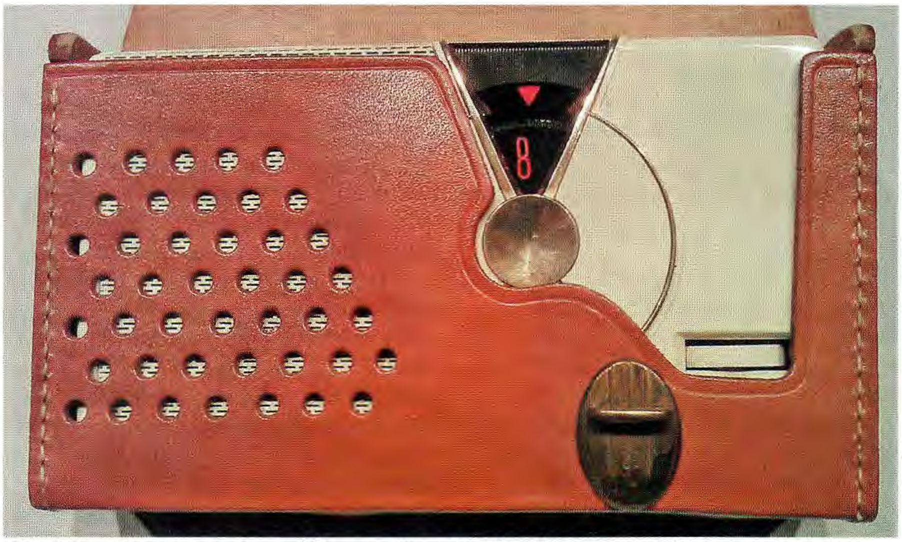
This AGC voltage is applied directly to the anode of AGC diode D1. Its cathode is fixed at -0.96V by a voltage divider based on resistors R3 & R2, so that it is "just out" of conduction with no applied AGC.

In operation, the stronger the received RF signal, the greater TR4's collector current and the higher the AGC voltage across R24. This pulls the AGC voltage towards the positive supply rail, thereby making D1's anode positive with respect to its cathode. As a result, D1 begins conducting and "damps" the signal at the converter base, thus reducing the signal reaching the converter.

Audio circuitry

The audio signal from transformer T2 is fed to a conventional 2-stage transistor power amplifier (TR5-TR7). TR5 operates as a class-A driver stage and this drives the primary of audio transformer T3 which acts as a phase splitter. T3's centre-tapped secondary output then drives transistors TR6 & TR7 which are configured as a class-B push-pull output stage.

One neat design trick pulled by Philco is that TR5 is biased by the voltage drop across R21 which also serves as the decoupling resistor for the low-power stages. Talk about squeezing the last drop of juice out of a component!



The T7 radio was protected by an attractive leather case with a carrying strap. It's necessary to open the front flap in order to tune the radio and adjust the volume control.

Volume control is achieved by rheostat-connected potentiometer R23. This is connected directly across transformer T2's secondary so that it acts as a variable shunt. It's less elegant than a true potentiometer but effective nonetheless.

The output stage operates with fixed bias, as set by divider resistors R18 and R20. In addition, there's a small amount of local negative feedback via shared emitter resistor R19. This resistor also helps balance any differences in gain that might exist between output transistors TR6 & TR7.

The Philco T7 also uses feedback for the audio driver/output stages. That's done using feedback resistor R17 which couples a small signal from one of the speaker terminals back to the emitter of driver transistor TR5. This also implies an audio amplifier voltage gain of about 40 (the ratio of R17 to R22). Finally, the audio from the output transformer (T4) is fed to a 15Ω 2.5-inch (64mm) loudspeaker (LS1) via a headphone jack.

Getting it going

Cosmetically, my T7 set was in tip-top condition when I acquired it. But electrically? – it was very quiet and that's always a worry with any set that has five or more transistors.

Well, a quick tweak of the IFs couldn't possibly hurt, could it? At this point, you may be starting to cringe. Some collectors are firmly of the view that if a set has been left alone, you shouldn't expect "demon drift" in the IFs to have degraded the set's performance. It's often a wise to leave these settings alone, especially with complex equipment such as FM radios and (especially) TV sets.

But I was rewarded by tweaking the

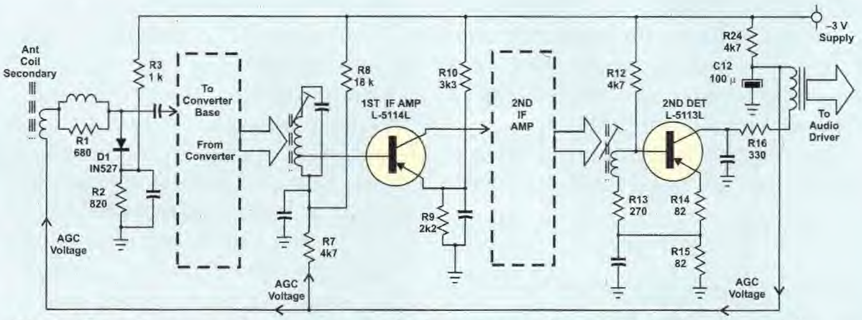


Fig.2: this diagram shows a simplified version of the AGC circuit used in the Philco T7. The AGC voltage is derived from the primary of the audio interstage transformer and is applied directly to the anode of AGC diode D1 and to the base of the first IF amplifier (TR2) via a 4.7kΩ resistor. D1's cathode is fixed at -0.96V by a voltage divider based on resistors R3 & R2, so that it is "just out" of conduction with no applied AGC.

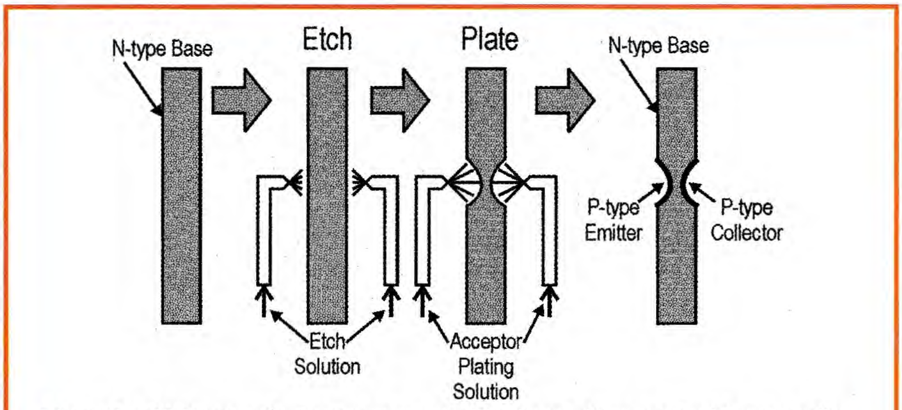


Fig.3: the SBT manufacturing process. The base slice was held vertically and chemically etched away by very fine sprays to form emitter and base "wells" on opposite sides of the slice. Electrochemical deposition was then used to "plate" the emitter and collector regions onto the base slice, creating a fully-working transistor.

IFs on this simple set. Starting with barely any reception, each adjustment of the IF coils brought in more and more signal. The set then really came alive when I adjusted the oscillator coil slug (T1) and the two associated trimmers.

A light spray of contact cleaner on the volume control and this set was done and dusted. In my opinion, it was now working just as well as it was when it has handed over to its original owner, some 57 years ago.

By the way, the original T7-124 was introduced in 1956 for the 1957 model year. By contrast, the one I have is a slightly later T7-126 model. The Philco-manufactured tuning gang bears a stamping with a "748" code, implying the 48th week of 1957 for this set.

How good is it?

So how good is it compared to the 7-transistor Raytheon T2500 (Silicon Chip, June 2013)? Well, leaving aside the T2500's higher audio output and better overall response (two speakers and a larger cabinet), it's a good match.

The Philco T7 manages a sensitivity of around 220µV/m at 600kHz and 170µV/m at 1400kHz. Its 1400kHz performance is a bit noisy at this level

An unusual hour-glass shaped tuning dial is a feature of the T7. The tuning thumbwheel has red lettering on a black background but white lettering would have been easier to read.

though, with a signal-to-noise ratio of about 17dB. A 20dB signal-to-noise ratio requires an RF signal level of about 200µV/m.

These figures are pretty similar to Raytheon's T2500. However, the Raytheon set makes up for its single IF amplifier stage with an extra (third) audio stage, making it a bit noisy at minimum volume. Philco's approach of two IF amplifier stages and only two audio stages pays off and the T7 is quiet at minimum volume.

The selectivity is around ±19kHz at -60dB while the AGC is excellent, with only a 6dB increase in audio output over the range from 200µV/m to around 40mV/m (the effective AGC range is some 46dB). It does go into overload soon after but 40mV/m is indeed a very strong signal. The extensive AGC range justified the "diode attenuator" approach and foreshadowed the Mullard implementation by some four years.

Audio performance is a mixed bag, with the set going into clipping at an output of 80mW. Given the low supply rail of only 3V and the fact that many 6V sets only manage around 250mW, this is still quite respectable.

The audio response (starting at 400Hz) between the volume control and the speaker terminals rises by about 2dB at 3kHz and then remains fairly flat until dropping by -3dB below the 400Hz reference at 37kHz (some high-frequency roll-off would have been nice). The low-frequency response following the volume control goes down to around 110Hz. Unfortunately, it only manages about 500-1800Hz from the antenna to the speaker.

The THD (total harmonic distortion) is reasonably low, the figures being 2.2% at 10mW, 3% at 50mW and 8% at 100mW. With a "flat battery" supply of 1.5V, an oscilloscope trace shows visible crossover distortion at 10mW output and the THD increases to around 5%. The set manages a maximum output of around 20mW and 9% THD with the low battery.

Would I buy another?

So would I buy another one? Well, it is tempting – one for the lounge room and one for the workshop display shelf. As I write this, there's one being advertised on-line for just under $300 but I really do need to stop somewhere.

Different version

The original T7-124 and T17-126 are quite similar, as Fig.1 shows. Note that I've omitted the link connections (L1-L9) that connect to the PCB for clarity.

So what are the differences? First, AGC diode D1 and interstage transformer T2 have been removed from the T7X (model 128). Output transformer T4 has also been removed. Instead, the TX7 employs a single-ended push-pull "output-transformerless" circuit that couples directly to the loudspeaker, with the return connection going to a 1.5V tap on the 3V battery. This output design will be described in an upcoming article on Philips portables. SC

References

(1) Thanks to Ernst Erb for his Radio Museum site at: www.radiomuseum.org This site has service data for two T7 models (the 124 & the 126) and for the T7X (model 128).

(2) Surface-barrier transistors are described at:
http://www.rfcafe.com/references/radio-news/amazing-surface-barrier-transistor-august-1957-radio-tv-news.htm
http://en.wikipedia.org/wiki/Surface-barrier_transistor
http://www.google.com/patents/US2843809