Vintage Radio

By Ian Batty

The 3-transistor Philips MT4 Swingalong

The Philips MT4 is quite an unusual set and not only for its minuscule transistor count. It is styled as a mantel radio but being battery-operated and quite compact, it can easily double as a portable. Perhaps its most interesting aspect is that it is a reflex superheterodyne circuit which means that one section handles both RF and audio signals.

I seem to be getting a reputation as an enthusiast for interesting and unusual radios. This set was offered to me for review by a fellow member of the Historical Radio Society of Australia (HRSA), Ron Soutter.

It has to be the most minimal set I've looked at so far. Forget 7-transistor sets such as the Stromberg-Carlson 78T11 (SILICON CHIP, July 2015, www.siliconchip.com.au/Article/8710) or the Philips 198 (June 2015, www.siliconchip.com.au/Article/8612) or the many 6-transistor sets I've looked at. And let's set aside Astor's 5-transistor M5 and the 4-transistor GE 2105 that, despite having only four transistors, could certainly hold its own.

The Philips MT4 Swingalong uses just three transistors! And surprisingly, it works pretty well. Add in its price of around $410 in today's money (actually £14.10s.6d in 1965) compared to a 7-transistor set at some $560 and I could imagine the Swingalong walking off the shelves.

First impressions of the MT4

I'm beginning to think I really have been too serious with my emphasis on performance measurements. With just three transistors, the MT4 is able to compete with five, six and 7-transistor sets for ordinary listening in the suburbs.

It may also work OK in the country but I've moved down the Peninsula to Rosebud. That said, I am still some 75km from the transmitter; not much closer than the previous 95km or so.

I'm getting good reception in the kitchen and even from some of the more remote stations such as 3WV in Horsham, broadcasting on 594kHz, are just detectable out of doors. Close examination of the dial shows city stations in all states but a smaller roll call of regionals of the day. Perhaps it's a de facto admission of the MT4's modest sensitivity. We'll find out how good it is later.

We're familiar with the "sinking ship" school of engineering by now, as in "get rid of anything which is not absolutely necessary". But how is anyone going to get any kind of performance with only three transistors? There's only one way to do it and the Philips MT4 resurrects an idea from the valve days: reflexing. The idea is simple; use one (or more) amplifying stages simultaneously at two widely-differing frequencies.

Maybe the inspiration behind the nickname "Swingalong" came from a Frank Sinatra song or perhaps a Canadian music TV show of the name. But no matter the source, the name was on the rear of the MT4's plastic case.

The idea became public over 100 years ago with the 1914 awarding of US patent US1087892 to Schloemilch and von Bronk. Note that this is still a superheterodyne set, with a self-oscillating converter stage feeding an IF (intermediate frequency) transformer and then a stage which handles both the modulated 455kHz intermediate frequency and the demodulated audio signal.

Reflexing has been popular at various times. Early sets, with valves costing as much as a week's wages, had to offer useful performance at a price that listeners could afford. Reflexed stages cut cost but they need careful design, and the "minimum volume" problem bedevilled valve designs for years.

The effect is caused by signal rectification at the grid of the reflexed IF amplifier in addition to the demodulator diode. The grid-rectified signal commonly acts in anti-phase to the audio coming back from the demodulator.

This gives the counter-intuitive effect that, since the two audio signals are in opposition; turning the volume control to zero (i) eliminates the audio from the demodulator, but (ii) still allows any grid-rectified signal to be amplified. Typically, it's not until the control is advanced "a little" from zero that complete cancellation – and thus zero volume – occurs.

Some valve radios (such as Astor's Aladdin FG, reviewed in August 2016) did use reflexing and seemed to have eliminated the problem.

But how about reflexing in transistor radios? This is the first such set I've come across, though I have seen a few circuit drawings also using reflexing. The design itself is pretty simple. Converter TR1, an alloy-diffused PNP germanium OC169/AF117, uses conventional combination biasing and collector-emitter feedback.

This design allows signal injection into the base, simplifying fault-finding and alignment. While converters using collector-base feedback work just fine, it's common to find that injecting a tests signal to the base stops the local oscillator dead.

The converter stage first feeds the first IF transformer and then the oscillator coil. This is the reverse of the usual arrangement, but it seems to work just as well. By the way, as was the usual practice with early transistor radios which mostly used PNP germanium transistors, the chassis is positive, not negative. This aspect can be confusing when you are working your way through the circuit.

The ferrite aerial rod is a full-length type, so I expected fairly good signal pickup. Usually, there's about a 10:1 ratio, meaning that a field strength of, say, 500µV/m gives about 50µV signal at the converter base.

The 2-section tuning gang is a cut-plate design. Don't let the identical shape of the moving plates in both sections fool you, as it's the stationary plates that differ in shape, to give good tracking between the oscillator (C3) and aerial tuning (C1) without the use of a padder capacitor. First IF transformer L6/7-L8 uses the familiar tuned, tapped primary and untuned, untapped secondary.

Reflexed second stage

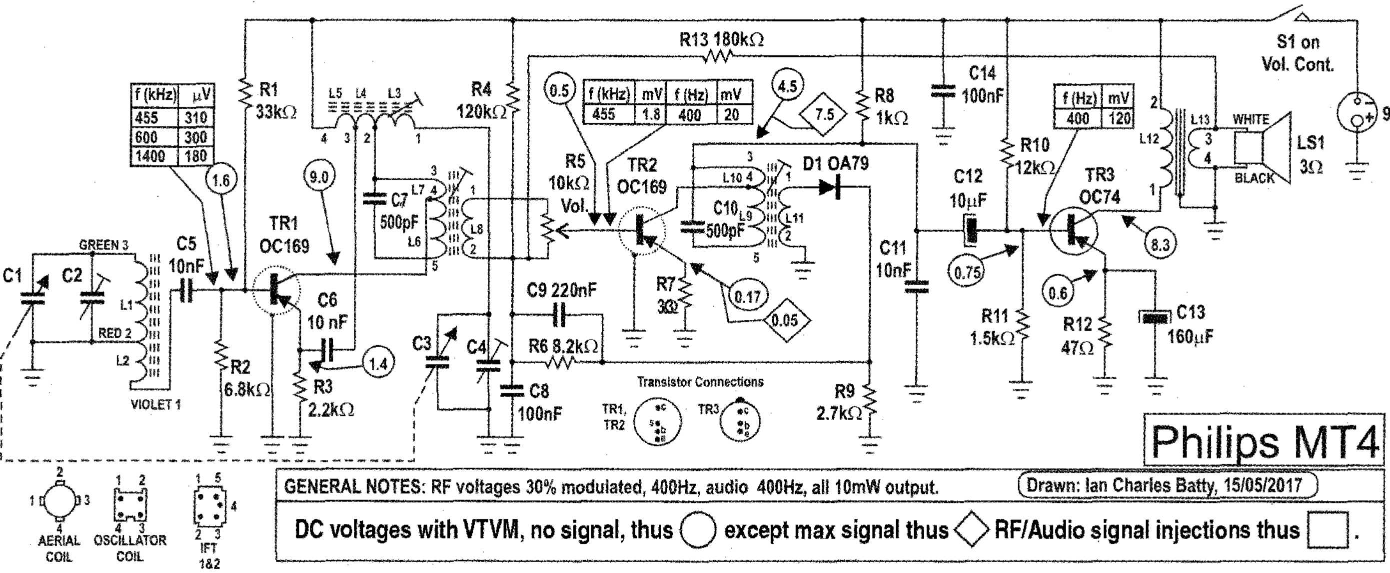
It's the circuit around TR2, another OC169/AF117, that is unusual. First, volume control R5 attenuates the IF signal from the first IFT's L8 secondary as it is turned down. We've seen this approach with the Astor Aladdin FG, where the reflexed second IF stage also had the volume control in the IF signal path.

This approach should eliminate the minimum-volume effect and it's notable that Langford Smith (writing in Radiotron Designer's Handbook, 4th edition) shows the volume control in the audio path between the demodulator and the grid of the reflexed stage (it's a contrast to this set and the FG). Langford Smith's design would permit grid rectification and thus accentuate the minimum volume effect.

Setting the volume control's IF attenuation aside, TR2 works as expected. Bias is supplied through a high-value base resistor (R4, 120kΩ) and is balanced by the AGC voltage fed back from demodulator diode D1 via the 8.2kΩ resistor, R6. There's one wrinkle: TR2's 33Ω emitter resistor has no bypass capacitor, so emitter degeneration slightly reduces the gain of the stage.

TR2's collector feeds the second IFT's primary, L9/10, which form a tuned, tapped winding. Untapped, untuned secondary L11 feeds IF signals to demodulator D1, a germanium OA71. D1 feeds AGC voltage and the demodulated audio back to the base of TR2. Since R6 would attenuate the audio markedly, it's shunted for audio signals by the 220nF capacitor C9.

A close-up of the dial shows that it had station markings for all of the Australian states.



GENERAL NOTES: RF voltages 30% modulated, 400Hz, audio 400Hz, all 10mW output.

Drawn: Ian Charles Batty, 15/05/2017

DC voltages with VTVM, no signal, thus ○ except max signal thus ◇ RF/Audio signal injections thus ☐.

Fig.1: the circuit of the Philips MT4 is quite unusual in that the second stage involving transistor TR2 is reflexed. This means that it amplifies the 455kHz intermediate frequency as well as the recovered audio from diode D1. This approach enabled good gain with only a limited transistor count.

Now, TR2 is set up as an audio amplifier (even though it also amplifies the IF signal). First, volume control R5 will have little effect on audio gain (in theory), as it's shorted (for audio) by the 1st IFT's low-resistance L8 secondary; more on this later.

So TR2 gets the demodulated audio on its base and the amplified audio signal appears at its collector. Its audio load is the 1kΩ resistor, R8. Any IF signal appearing across R8 is shunted by 10nF capacitor C11 and the audio signal is fed via 10µF capacitor C12 to the base of output transistor TR3, an alloyed-junction OC74.

TR3 is a conventional Class-A stage, drawing a constant 13mA of collector current. This is a lot more than a comparable Class-B push-pull stage with no signal, and is why the set uses the large 276P battery.

It's around 51 x 63 x 80mm. The original battery (with a capacity of 1500mAh) would give some 100-plus hours of playing time; modern equivalents would approach 500 hours.

With a supply voltage of 9V, TR3 dissipates about 115mW. Theory implies that the maximum output power could be around 50mW, so can its Class-A stage do much better than previous review sets? We will see.

TR3 drives the primary of output transformer L12-L13, which in turn drives the 3Ω speaker. Finally, there's negative audio feedback from the speaker to the base of the IF/audio amplifier, TR2, via 180kΩ resistor R13.

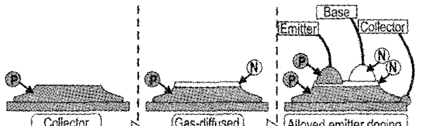
Alloy-diffused transistors

As described in my article on the Grundig Taschen Transistor Boy (December 2016, www.siliconchip.com.au/Article/10485), Philips began transistor production with the second generation of junction transistor technology – alloyed junctions. While these could reliably produce the trusty OC44/45 RF/IF transistors, an operating frequency of some 15MHz was about the limit.

The problem – as it has been since Bardeen and Brattain's first examples – was to get the active base region as thin as possible. Alloying, relying as it does on two mutually-dissolving materials (a bit like lead and tin in solder) could not produce base layers fine enough for very high-frequency operation.

The third generation of transistors combined established alloying techniques with the newer principle of diffusion at near-melting temperatures. Diffusion of a gas, or a metal vapour, can be made to progress into a substrate more slowly and with much greater control.

Construction began by working just one side of the transistor die. The bottom side would become the collector (let's say P-type) and the N-type base layer would be diffused from the top down into the collector. So far, we would just have a very good diode.



This diagram shows the steps to produce analloy-diffused transistors.

But now, placing a P-type dot onto the base surface and using alloying, the emitter could be formed on top of the base layer, giving the familiar PNP "sandwich" construction. Alloy-diffused OC169/170/171 transistors were used in the front ends of FM tuners, and the 175MHz AF118 was used as a video amplifier.

Diffused-alloy transistor construction is a bit of a mix-and-match, but (i) it gets away from the messy "two-sided" manufacturing of purely-alloyed devices and allows greater automation, and (ii) the combination of diffusion and alloying finally produced transistors such as the AF186, able to work to over 800MHz.

Clean-up and alignment

I received the set in good condition. Apart from a cabinet clean and a contact spray for the noisy volume pot, it was ready for the test bench and the photo session.

Some restorers prefer to leave sets "as is", unless the performance is obviously lacking. But every set I've reviewed so far has benefited from a basic alignment. Original factory settings may have been a bit less than optimal and it's normal for the alignment to drift over many decades.

This set responded to local oscillator adjustment at the bottom end, with sensitivity coming up some 2~3 times. The IFTs came out spot on.

The Philips MT4 was equipped with a full-size ferrite rod antenna which ensured good signal pickup. The PCB on the left was quite compact given the relative complexity of the circuit. The large space on the right accommodated the Eveready 276P battery which gave somewhat more than 100 hours of life.

The audio injection of 20mV at TR2's base may seem high. As usual, I've relied on my generator's output meter rather than the actual injection voltage, as readers may not have audio millivoltmeters to hand that would allow measurement of actual audio levels during testing. I did check the circuit voltages, and found around 7mV at TR2's base and 35mV at TR3's base. That's more in line with the signal levels in other sets.

I found the antenna and oscillator trimmers, on the "inside" end of the gang and hidden behind the ferrite rod bracket, very difficult to access. I'd have (i) spun the gang around 180° or (ii) used a gang with trimmers on the other end.

How good is it?

It's certainly not in the same league as the earlier Philips 198; almost nothing is. But it's a creditable performer given its simplicity. As described below, maximum output is under 20mW, so all testing was done at 10mW output.

Sensitivity (10mW output) is 1.6mV/m at 600kHz, 1mV/m at 1400kHz, and it achieves these figures with better than 20dB signal-to-noise ratio. These figures reflect the lower RF/IF gain caused by a single IF stage not amplifying converter noise as much as a two-stage IF channel does. The AGC is rudimentary; output increased by 6dB for an input rise of only 15dB, after which output fell rapidly as the converter overloaded.

IF bandwidth is ±1.3kHz at 3dB down. Testing it at -60dB was impractical, however, it did show a -30dB bandwidth of some ±12kHz; again confirming its simplified IF channel configuration.

Audio response from the volume control to speaker is about 240Hz to 8kHz with a 2dB peak around 1kHz. It's another set that could have used some top cut. From aerial to speaker it's 200Hz to 1.9kHz. Distortion at 10mW is creditably low at 2.5%, but it rises rapidly, reaching 10% and clipping at around 15mW output.

The volume control does have most effect on the IF signal, as full rotation of the pot only reduced the audio gain by some -3dB. It's essentially an IF attenuator rather than an audio one.

With a collector current of some 13mA, the output stage only manages some 15mW out while drawing around 115mW from the battery, so the output stage efficiency is only around 15%. It's another example of real-world output stages failing to approach Class A's theoretical maximum of 50% efficiency.

Against this, the converter's best sensitivity of some 180μV, for an air field of only 1mV/m, shows efficient coupling from the antenna rod to the converter base.

How good is it? Like the GE T2105, it's a good performer in just about every setting. Having described the GE T2105 as cheap and cheerful, I'm going to tag the MT4 similarly – budget designs can work and quite well. Whoever designed this set did some pretty clever engineering, combining adequate performance with minimum complexity.

Would I buy one?

This set will go back to its generous owner but I'd like to have an example. It's a good performer and a reminder of how much performance a fine engineering team can get out of simple circuitry. And yes, one showed up at the HRSA's Radio Market in June at a great price. Not a member?

Go to www.hrsa.asn.au and take up the invitation.

Further reading

My special thanks to Ron Soutter of the HRSA for the loan of his set and the original circuit diagram, which I have redrawn (Fig.1).

You'll also find the MT4 on Ernst Erb's Radiomuseum: www.radiomuseum.org/r/philipsaus_mt_4.html **SC**