Trough-Line Triumph!

Neville Roberts

Several companies have offered an upgrade service for the legendary Leak Trough-Line FM tuner in the past, but what can be achieved by amateur enthusiasts? Neville Roberts describes his approach to doing it yourself...

Upgrading the legendary Leak Trough-Line FM tuner was big business in the late '90s, but with rumours of the demise of FM stereo broadcasting in the UK, interest has dwindled in recent years. However, it now looks like good old FM has had a stay of execution and is set to continue for a while.

Before I start to describe my approach, I think it's worth exploring the origins of this famous tuner.

The start of the Trough

Back in the 1950's, we were still listening to Medium Wave and Long Wave and many budding audiophiles were waiting for the arrival of Frequency Modulation broadcasts, which promised greatly reduced background noise and far better sound quality.

The BBC, working in partnership with Standard Telephones and Cables Ltd (later STC plc), were developing this technology and a certain Harold Joseph Leak and his British company H. J. Leak & Company Limited were one of the first to develop their own tuner for this emerging market.

Trough-Line 2 front view before upgrades

Most FM tuners are of the superheterodyne design and the Trough-Line is no exception. The radio frequency signal enters a mixer, along with the output of a local oscillator, in order to produce a so-called intermediate frequency (IF) signal, which in the case of the Trough-Line is 12.5MHz. Tuning the receiver involves changing the frequency of the local oscillator so for the Trough-Line to tune in Radio 3 at 90.7MHz, the local oscillator will be tuned to run at 103.2MHz. The output of the mixer will be the difference of these frequencies: 12.5Mhz. Similarly, to tune in Radio 2 at 88.3MHz, the local oscillator will be tuned to run at 100.8MHz and the output of the mixer will again be 12.5MHz. This means that all further processing of the signal is conveniently done at a single frequency – the IF - thus no further tuning for different stations is required.

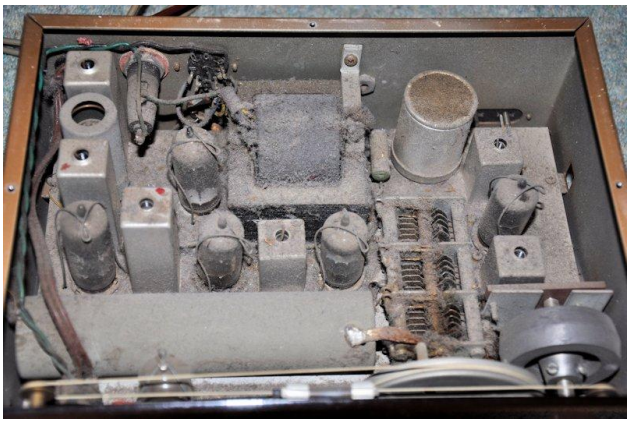
One of the difficulties of radio circuit design at the time was to design an oscillator that was stable. Many tuners of the time needed to be periodically re-tuned as they warmed up, otherwise they would distort. The problem was mainly caused by changes in inductor dimensions with temperature (a particular problem with valve equipment) would lead to significant variations in their electrical properties at the 100MHz region chosen for FM broadcasts.

Trough-Line 2 rear view before upgrades

Leak's solution to this problem was to design a circuit that used a tapped transmission line as the main tuning element, rather than conventional wound coils or inductors. He developed a tuner that used a quarter-wavelength section of transmission line, shorted at one end, which behaved as a parallel resonant circuit of very high Q and electrically stability. The mechanical construction he developed led to a device of great rigidity and electrical stability. Tuning across the frequency range was achieved with a conventional air-dielectric variable capacitor.

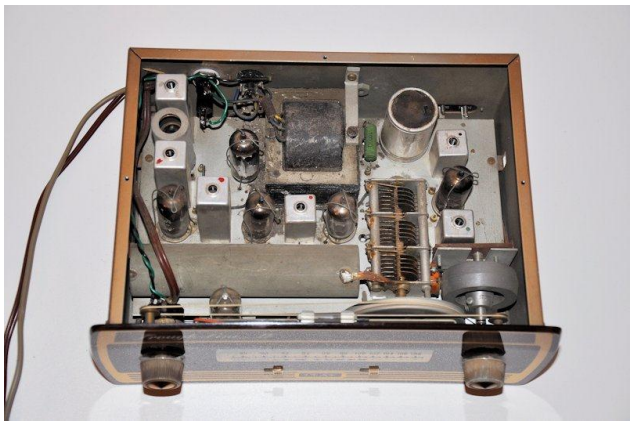
The first Leak FM tuners utilised a U-shaped trough as the 'concentric' outer conductor for ease of production and as a result, the tuner was christened "The Trough-Line". In the original model Trough-Line Mk.1 launched in 1955, the U-shaped trough had its open side placed facing downwards under the chassis. Subsequent models used a metal cylinder as the outer conductor.

As with the later models, the original Trough-line utilised a Foster-Seeley discriminator circuit and a 'magic eye' EM81 valve as a tuning indicator (incidentally, the EM81 and the later EM84 were often used as a level meter in early domestic tape recorders). There were two types of FM detectors that were popular at the time: the Ratio detector and the Foster-Seeley detector or discriminator. The Foster-Seeley discriminator has the disadvantage over the ratio detector of being affected by amplitude variations and therefore requires a limiter stage preceding it. It does, however, offer lower levels of distortion and that is why Leak chose to use that design.



Inside top of dusty Trough-Line 2!

The Mk.1 only covered the range of 88-100 Mhz, while the later models covered the full range of 88-108 Mhz. A particular feature of all the Trough-lines was that they were self-powered from the mains supply - unlike many other British tuners of the time that required HT and LT power from the power amplifier.

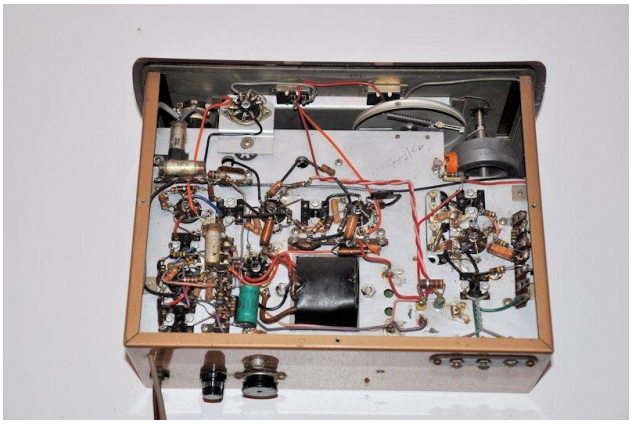


Inside top after vacuuming

In 1960, Leak launched the Trough-Line Mk.2, which sported a distinctive 'Art Deco' front panel made of Diakon (a form of acrylic plastic made by Lucite International Inc.) in brown and gold, rather than the gold enamelled steel finish of the Mk.1. This matched their range of Varislope amplifiers. Apart from the wider tuning range, the valve complement was changed to accommodate a switchable Automatic Frequency Control (AFC) and Local/Distance sensitivity control on the front panel, as well as some changes to the design of the line to reduce weight and costs.

At that time, no decision had been made nationally about the standard for FM stereo, so a separate output on the back panel prior to the de-emphasis circuit would allow the mono unit to be upgraded in the future to stereo by connecting an external decoder.

In 1964 the Trough-Line Mk.2 was phased out for the Trough-Line Mk.3, which adopted a new visual style. Silver and black was now the order of the day with the passing of the Art Deco style of the Mk.2. Apart from the exterior appearance, it was identical to the Mk.2 electrically.

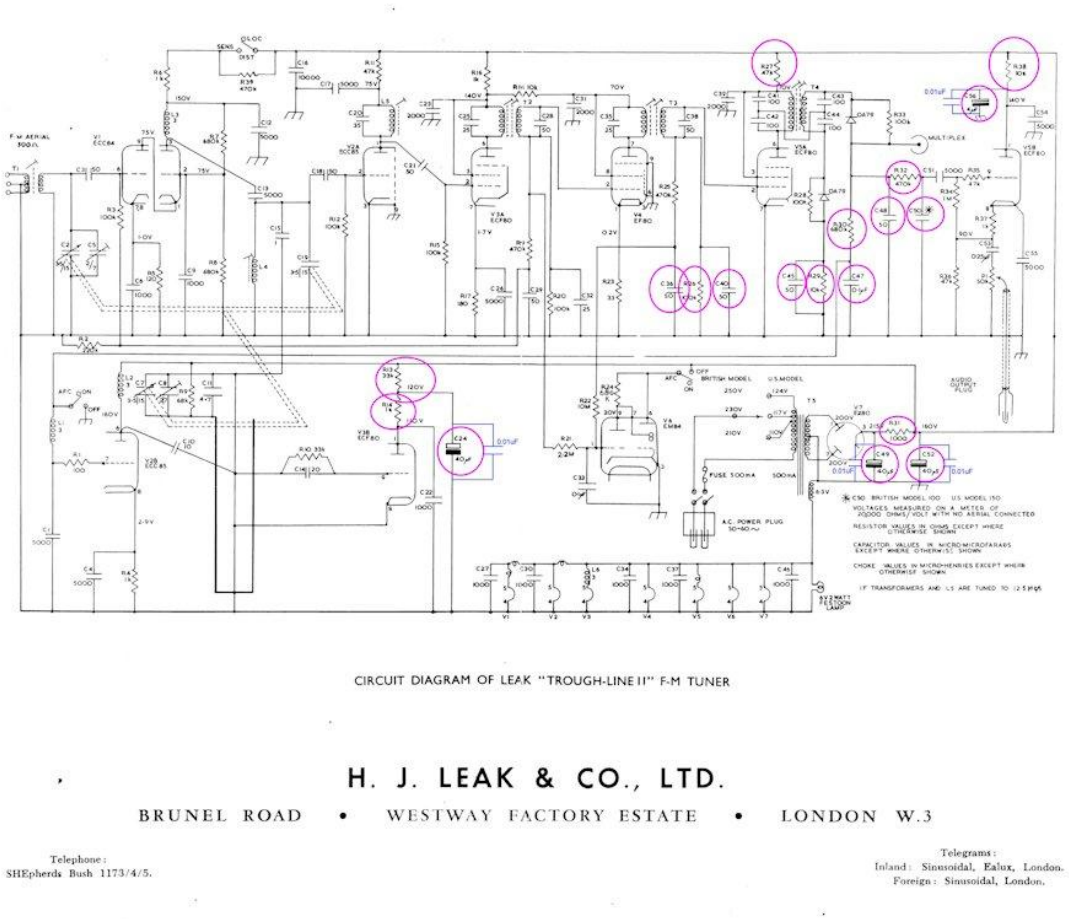


Underside before fitting of upgrades

Then, in 1966, the Trough-Line Stereo was launched as a result of the BBC adopting the same standard as in America, the GE-Zenith multiplex system. Some changes to the Mk.3 circuit and valve line-up were required as Leak did not want to change the Foster-Seeley discriminator, which has a limited bandwidth, and compromises were reached between increased bandwidth and lower sensitivity. This was necessary in order to feed the internal stereo decoder that, incidentally, used three AF126 germanium PNP transistors. Alas, this decoder falls short of the mark in terms of quality and is best replaced with a modern Phase Lock Loop (PLL) decoder.

By 1969, many companies looked towards the new Solid-State technology and Leak was no exception. The Trough-Line Stereo was phased out in favour of a new semiconductor-based design called the Stereofetic.

However, in the decades since the Trough-Line era, it became clear that no-one had ever bettered the sound produced by a Trough-Line. Consequently, a unit that has been fully serviced and upgraded with modern components is considered to be one of the finest sounding tuners ever made and it therefore highly sought-after.



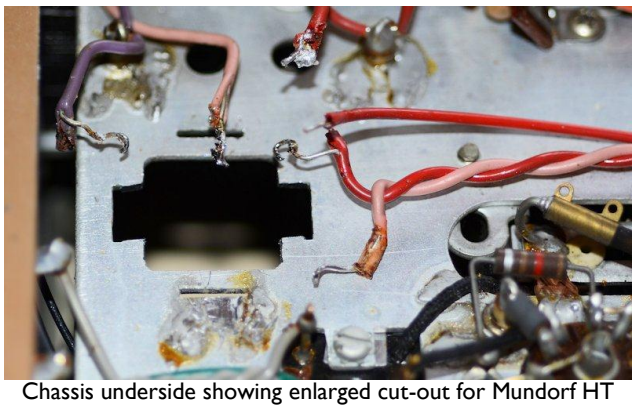
Leak Trough line 2 circuit diagram showing changed components

Going for a Leak

As GT Audio, one of the companies who used to offer a vintage restoration service puts it: "The restorations are not cheap" and with the rising cost of labour, it is becoming increasingly expensive. In any case, GT are not offering any restoration services at the present time.

This got me thinking – I wondered what could be achieved by a DIYer with inadequate test equipment and limited FM tuner alignment experience?

There are, once again, some real bargains to be had on eBay and I was fortunate enough to pick up a Trough-Line Mk.2 for £60. When my prize arrived (which was described as 'working but untested'), it was not in bad condition externally, but upon removal of the lid, it appeared to have spent most of its life stored in a vacuum cleaner dust bag (see photo)!



Chassis underside showing enlarged cut-out for Mundorf HT capacitor

Further investigation revealed that, with my unit, part of the mains fuse was missing and the on/off switch on the volume control had failed. Another fortuitous eBay purchase enabled the volume control to be replaced with a New Old Stock (NOS) one and the

fuse holder, together with the mains lead, was also replaced. This was followed by a thorough vacuuming and an overall clean using isopropyl alcohol before powering it up to see how well it worked (if at all!).

Mundorf HT capacitor and Mills series resistor fitted

I am pleased to say that it worked like a dream and the sound quality from this mono tuner was nothing short of breath-taking!

Another thing I noted, which is likely to be an issue with any unit of this age, was that the little rubber feet had perished and weren't supporting the tuner properly. New feet were acquired via, you guessed it, eBay - black polyurethane 20.5mm square x 13.2mm high self-adhesive feet fitted the bill perfectly!

Obviously, getting the vintage tuner working is an important starting point. From there, one can determine what needs to be done, what is desirable to do and what should be left alone!

Let bottle commence!

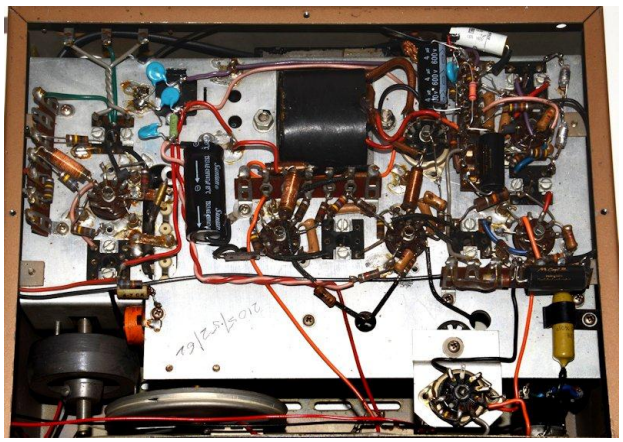
As far as I could determine, all the valves were original 'old shield' Mullard types. Armed with my trusty B&K Dyna-Jet Model 606 Valve Tester, I found that all but two of the valves were performing almost as good as new – not bad for 50 year old valves! However, two of them had problems – my V1 (ECC84) had a heater/cathode short (the cascode RF stage – it was amazing the set was working!) and my V6 (EM84 magic eye) was low on emission. Another couple of eBay purchases and I was able to replace both of them with NOS valves for a few pounds.


Chassis underside showing 3rd HT & bypass capacitors fitted

The result was a stronger signal and even Radio 3 was showing a near maximum on the tuning indicator. I am fortunate to have a good signal here in the Bournemouth area and I have a loft-mounted FM aerial.

Out with the old

Before starting to replace aging components, it is most important to decide first what not to touch. I had already learnt through bitter experience many years ago how to convert a working FM tuner into spare parts for the junk box by tweaking coils without the necessary test equipment or expertise! Apart from a multimeter and digital capacitance/inductance meter, I didn't have any RF equipment available, so I decided early on not to touch the RF/IF stages at all. The coils, etc, would have been carefully setup during manufacture. Furthermore, there are a number of components that are not easily replaceable, such as those contained within the IF cans and others, such as feed-through capacitors.


Chassis underside with upgrades completed

In the 'must replace' category are the 50 year-old electrolytic capacitors and that means re-building the HT power supply. That's not as difficult as you might think as there are only 4 components and one of those is the rectifier valve! Also a must is fitting a quality stereo decoder, but more about that later.

So, first up was to source a replacement for the now unobtainable triple can electrolytic capacitor which would doubtless have gone leaky by now. It is essentially three 40uF 300V capacitors in one can. What I did find was a 50uF + 50uF 500V in one can – a Mundorf M-Lytic High Voltage dual power electrolytic capacitor to replace both C47 and C52 in the accompanying circuit diagram, plus a separate axial-lead Suntan 47uF 450V which fitted the bill for the third capacitor C24 nicely.

To replace the triple can, first unsolder the connections to the three solder tags. Then untwist three of the four retaining tags on the can. The fourth one is soldered to the chassis and I found the easiest way to remove it was to tap a thin screwdriver underneath it and prise it away - the capacitor then comes away easily. Using a junior hacksaw blade, I enlarged the hole by cutting away the bit of metal on the top and bottom slots. The Mundorf then fitted nicely in the space and the earth tag was soldered onto the chassis in the same place as the old can with my iron turned up to maximum heat! I also fitted a capacitor clip on the capacitor and secured it with a single nut and bolt through a hole drilled in the chassis – see photos.

The next task was to replace the other electrolytic capacitor C56 (4uF 250V) with a new 4uF 600V counterpart. I also fitted all these with a bypass 0.01uF 1KV ceramic disc capacitor (the bright blue ones in the photographs) as electrolytics are not good at high frequencies.

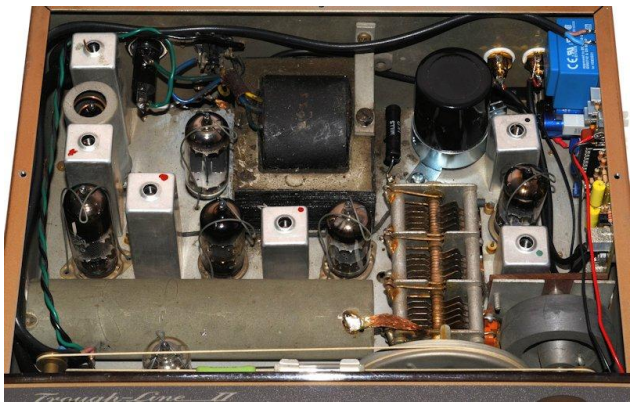
The other power supply component requiring replacement was the 1K ohm 15W resistor next to the Mundorf can and that was replaced with a modern Mills wire-wound type.

With reference to the circuit diagram, it can be seen that most of the components around V5B will never be used as that part of the circuit is for the mono output. Although I had replaced the volume control in my unit because of the faulty on/off switch, I removed the mono output flying lead as this will not be required after fitting the stereo decoder. In the end, I just changed the components circled on the diagram with new carbon resistors and polystyrene film for the low value capacitors. As for the 0.1uF and 0.25uF capacitors, I replaced these with 0.1uF and 0.22uF 630V Mundorf ZN capacitors respectively.

Allow yourself plenty of time to do these component changes and ensure you have a good temperature-controlled soldering iron available, or a fixed one of around 40W to do the job. Some of the tag strips require a lot of heat to melt the solder – especially those connected to the chassis earth.

With the component upgrades complete, it was time to consider a stereo decoder.

Two channels are better than one



Chassis topside with upgrades completed

Following some research, I found one company, One Thing Audio, who can supply a top quality stereo decoder board, complete with its own mains power supply on board, suitable for installing in a Trough-Line for £120. They also provided me with invaluable advice on how to get the best from my unit, as well as all the extra parts to enable easy drilling of the metalwork to accommodate the decoder.

The decoder is based around the LM4500AN Hi-Fi FM demodulator. It has a quoted very low distortion figure of 0.1% and features a blend circuit which optimizes the signal-to-noise ratio under weak signal conditions by gradually combining left and right channel information.

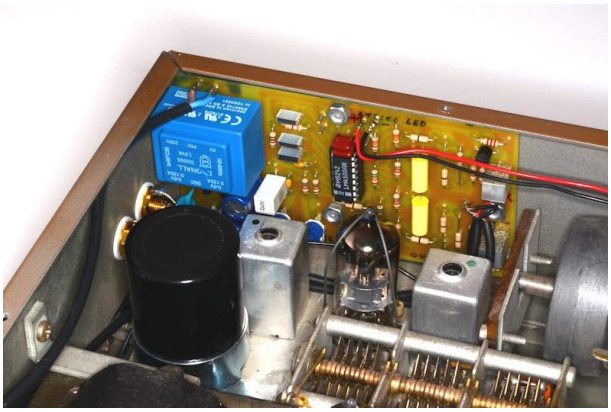
One Thing stereo decoder board

There are three potentiometers on the decoder board – VR1 adjusts the input gain, VR2 is the oscillator lock and VR3 is the stereo separation control. VR2 and 3 are 'factory set' and should not require adjustment, but VR1 will probably need rotating clockwise to reduce the level as the output from a Trough-Line tuner is quite high.

The bulk of the work to fit the decoder is drilling the case to accommodate the two RCA phono sockets

on the rear panel and the three mounting holes for the printed circuit board (for which One Thing provide a drilling template). Also included with the board is a little red LED as the stereo beacon, which I wanted to mount in the front dial backplate next to the EM84 tuning indicator.

When drilling (and filing) the metalwork, be sure to use plenty of masking tape (especially on the front dial) to minimise the risk of scratching the paintwork should the drill slip! It is really worth the effort of doing this carefully as the final result can look very professional, which is very rewarding.


Stereo decoder fitted inside

To connect the decoder, first wire up the stereo output sockets and then connect the decoder input to the multiplex output socket (I connected this at the tag strip end, rather than the phono socket) via a supplied 1uF 160V coupling capacitor. Next, hook up the stereo LED beacon (observe the correct polarity of the LED) and finally the mains input to the connections on the Trough-Line on/off switch.

Time to switch on and listen!

Premier performance

With the AFC switched off and the Trough-Line tuned in to Radio 3 at 90.7MHz, the tuning indicator again showed a good, strong signal and the stereo beacon lit up, showing that all was well.

There was no audible hiss (or hum for that matter) and the Trough-Line was so quiet that I wondered if I had connected everything up correctly. As it turned out, it happened to coincide with a pause between movements of a broadcast concert and when the orchestra started playing, I quickly realised that all my efforts had been richly rewarded!

The sound was absolutely superb – full and rich as you might expect from a valve tuner and excellent image placement, so the decoder was doing its stuff rather well. In fact, all I could hear was the lovely Trough-Line sound and I was completely unaware of another circuit, i.e., the stereo decoder, in the signal path – a real testament to the One Thing decoder.

But what was really incredible was the sense of presence and the feeling that you were sitting there in the studio with all the performers. It is difficult to put into words the sense of immediacy and realism I felt. I worked briefly for the BBC as a student in the 70's, during which time I had the opportunity to work in a studio and it was like having that experience all over again with the atmosphere of a live performance all around you.

Rear view of Trough-Line showing stereo sockets fitted

However, I'm sad to say that was not the case across all stations! Tuning into, well, let's just say into a station further up the dial, was a bit of a disappointment, to say the least. It became apparent that not everyone uses the same quality of compression that the BBC uses, nor does everyone take the same care with the broadcast quality (especially with live concerts). The level of distortion that is evident with some stations is due to a combination of poor compression, high modulation and artificial boosting of the top and bottom end in an effort to tailor the broadcasts for in-car listening and little tranny portables! Of course, a lot of this goes unnoticed when listening on DAB, but all shortcomings are clearly revealed when listening through a quality system.

Incidentally, I have never experienced any drifting with the Trough-Line, so I tend to leave the AFC switched off – partly because it is unnecessary, but mainly because I like to see the lovely green glow of the 'magic eye' next to the red of the stereo LED (yes, I am a sad person!)

As I have mentioned previously, do not attempt to adjust the IF cans without the necessary test equipment or expertise. If you do feel some re-alignment is required, send it off to a professional company, like One Thing Audio, who can do this for you. However, there is one exception – the Foster-Seeley discriminator coil (T4 on the circuit and the one located next to the fuse at the rear). This is the one can you can tune by ear and I am indebted to Ron and Steve at One Thing for this advice.

To carry out this adjustment, make sure that the station is optimally tuned once the tuner has had at least 10 minutes to warm up. Leave the AFC switch in the 'off' position. Then, with the appropriate trimming tool, gently turn the bottom slug in both directions about half a turn until you locate the optimum setting for minimum distortion. Then go to the top slug and do the same until you achieve maximum audio output.

However – a word of warning. The slugs might be seized up, in which case, do not attempt to force them as they can easily disintegrate and you can even damage the plastic core. In that case, leave well alone, or send it away for professional care if absolutely necessary.

The finished Trough-Line 2 – now in stereo!

Conclusions

Although the modifications I have described here are for a Trough-Line Mk.2, they equally apply to the Mk.3 as the circuit is virtually identical. A similar set of upgrades can be performed on the Trough-Line Stereo by noting the different numbering of the components on the newer model and by replacing the old stereo decoder. The Trough-Line Mk.1 is not worth upgrading for use as a Hi-Fi component because of its limited frequency range.

This has been a highly rewarding experience and I have ended up with a tuner that will not be out of place in the best audio systems.

And actually, I rather like the addition of an 'art deco' look to my system!

--ooOoo—