THE TRF-ONE Dr. H. HOLDEN. 2019.

(Revisiting past projects from Electronics Australia)





INTRODUCTION:

The single IC radio has always been a source of excitement and intrigue for radio constructions. The notion that nearly all the work can be done inside a single IC package is very appealing. This did not escape the attention of Jamieson Rowe in 1969, when RF capable IC's were making their debut:

Our Simplest TRF Receiver--- ELECTRONICS AUSTRALIA. only 14 transistors & 9 diodes!

Contradictory though the title of this article may seem, it's true. The little radio receiver described herein contains no less than 14 transistors and 9 diodes, and features a highefficiency RF amplifier, automatic gain control (AGC) and a low-distortion active detector; yet at the same time it is probably the most simply-constructed receiver we have ever described, not counting "crystal" diode sets.

by Jamieson Rowe

The key to the apparent contradiction is that all 14 transistors and 9 diodes used in the basic receiver, together with some 16 associated resistors, are fabricated on a monolithic silicon chip and packaged as a "black box" microcircuit. As a result, for a small TRF radio receiver the components required in addition to the microcircuit are so few that the construction becomes extremely simple and straightforward.







The idea of a TRF radio is as old as the notion of radio itself. Basically you have a tuned resonant circuit consisting of an inductor and a capacitor and for a radio application it is typically tuned by a variable capacitor.

The frequency range tuned for many AM radio projects of course was the medium wave band (MW) typically from 530kHz to 1600kHz, but sometimes to 1700kHz too.

The reason for this tuning range is that many commercial broadcast stations once existed in this range and any radio enthusiast, who wanted to build a home made radio in the era from the 1920's to now, can easily make such a tuned circuit.

In the most basic form of a TRF radio, it was called the "Crystal Set". In this case the tuned circuit's output was simply rectified by a diode to recover the amplitude modulation of the transmitted radio carrier. That audio signal could drive a simple earphone or a crystal earpiece to obtain a signal that was quite useable. Or, the signal level could be amplified up to drive a speaker.

Of course multi-stage TRF radios were designed with high selectivity and then Superhet radios came along with excellent selectivity and took over, but these are not the subject of this article.

Recently I wanted to revisit the design of a one gang variable capacitor tuned TRF circuit, perhaps because I built these as a boy and had good success with them, inspiring my interests in electronics.

I had built a number of Superhet radios as an adult, including those based on PLL's (phase locked loops) and some FM radios too.

So, over time, I had moved well away from the idea of a radio with a single gang variable capacitor and a single gang radio frequency stage. However, maybe just for nostalgia's sake or other reasons, I decided to revisit the idea since it must be over 40 years since I had built a radio with a single tuned RF stage.

Part of this interest was inspired by the article in Electronics Australia April, 1969, which detailed a radio called the "MICRO-ONE" with a single tuned stage based on the interesting and now uncommon IC, the National Semiconductor LM372.

The LM372 was not designed to be used to make an AM medium wave band TRF radio, but it was pressed into service for this application. It was intended as an IF amplifier with AGC. Of note, other MW band "single IC radios have been based on the ZN414 IC. Also single IC FM radios came along using the Phillips TDA7000 which were popular radio kits and sold at Dick Smith in the 1990's era.

THE LM372 :

Reading the Electronics Australia article from April 1969, I was quite surprised by the specs of the LM372. The LM372 has 3 internal functional blocks:



The gain stage typically is 2,360 or 67dB while the precision detector stage has a gain of 3 times, or 10dB.

So a 50uV signal input, modulated to 80% will produce an audio output of around 280mV rms, or 800mV PP.

The AGC stage has an enormous control range of 60dB with a threshold of 50uV. Therefore, with this IC, used as the basis of a TRF AM radio, the output level would be expected to be fairly constant even if the signal level increased from 50uV to 50mV. This would mean that tuning across the MW band, weak and strong signals would appear with a fairly uniform volume, which would be interesting and unusual.

Because of the internal design of this IC and those specs, it seemed irresistible to try one of these IC's as the basis for a TRF radio. I found 4 of these IC's for sale on Ebay so I snapped them up.

This IC though has an input impedance of around 3k. Unlike the ZN414 that is very high. So when used in this application, unlike the ZN414, it requires a tap on the main resonant circuit, or a small coupling coil, to avoid damping the main tuned circuit.

DESIGNING & BUILDING THE RADIO:

The first move in building any radio is to decide on the Engineering materials and the basic physical format of the design. How to power it and what sort of power audio output and speaker it might use.

I had quite a lot of 10mm thick brown phenolic material left over from other projects and some white insulating material called Bramite (once use on household fuse boxes in AU). Also I had a vintage 40 Ohm speaker and a 32 Ohm speaker to try and some perforated aluminium mesh and some metal AA battery holders. Also a vintage National tuning dial made in 1943. The phenolic material will also take a coarse screw thread (UNC) quite well and is easy to tap, which is helpful.

Once thee materials and basic design is settled on it pays to draw everything out with the dimensions so there are no errors in the construction work.

For a small battery operated radio it is always important to consider the power consumption, in the interests of battery life.

For the audio stages, I decided to go with a vintage Fairchild 741H (with a similar appearance to the LM372) to provide a voltage gain of 10 and simply use a complimentary follower output stage. Also I decided to settle for a modest power output at 150 to 180mW (depending on a 32 or 40R speaker), so that the output transistors did not require heat sinks.

The schematic of my version of this radio is shown below:



The physical bodies of the metal TO-5 cased 2N3053 and 2N4036 transistors act as the "heat sinks" for the transistor crystals inside them. They are better than epoxy cased transistors in this respect. The temperature rise, of each transistor body, at full continuous sine wave output power, just below clipping, is 10 to13 degrees C above ambient. In normal use with listening to the radio, they never get noticeably warm.

The two 47R resistors in the LM372 circuit were not recommended by the manufacturers, but reading the Electronics Australia article, they had some difficulty with HF stability with the LM372, so I decided to add these as a precaution and also paid a lot of attention to the design of the pcb tracks around the input pins of the LM372 and use double RF bypassing on the supply rail with excellent quality 0.1uF axial ceramic capacitors.

Of note the 1N5819 diode is used in the event of somebody installing the batteries in reverse and destroying the LM372 and LM741.



The pcb itself was simply made with iron on film and an etch with ferric chloride. Eyelet tags were used where the wires would connect, and 0.9mm gold plated pin and single connectors used to couple in the signal from the ferrite rod's coupling coil. I removed the tags in the end and just used the eyelet part for the connections to the pcb.



One thing that helps significantly with a pcb design is to lay it out in the drawing software over an exact size 2.54mm grid. This helps to keep everything as orderly as possible and helps select spacings for the pads, whether they are axial lead, or radial lead components. For this radio I stuck with all axial lead parts to help give it a vintage theme.

It also pays to be mindful of the quality and appearance of the components. For example the green coloured 0.1uF 100V rated ceramic capacitors used in this radio are super high quality vintage parts made by the Corning Glass Works. Some Tropical fish capacitors were used to throw in a "splash of colour " and high quality IC and transistor sockets with gold plated pins were used. It is a shame to have to solder to the pins of a very rare part like the LM372, or a vintage 741 for that matter.

MECHANICAL CONSTRUCTION:

In making an original or unique radio, ideally you want it to "look good" and you want it to be long lasting. So with that in mind I never scrimp on materials and spend a lot of time to ensure that cut edges are smooth & polished and all the holes are in the correct positions with perfect counter-sinking so the screw heads sit flush, where CS screws are used. All the hardware in this set is either stainless steel or nickel plated brass. The hookup wire is Teflon covered.

All drill holes are carefully marked on the cross hair location (created by the micrometer edge lightly marking the surface) with a hand held spike and then initially started by hand with a 1mm drill in a hand pin chuck, before drilling with pilot 1.5mm holes and everything checked to fit together properly. To this end and to help avoid errors, it is best to create a set of diagrams first which contain the dimensions and use a dial micrometer to help mark the holes.



It is good to have a basic overview of where everything is mounted. So I have included in this article just some of the diagrams I drew to help in the process.

To ensure the CS screws which attach the front panel to the base and sides are all in the correct position, the assembly was made initially with some small dots of weak glue and the holes in the panels used as a template to start the drill holes into the 10mm thick phenolic material so they all remain in perfect registration.







PHOTOS DURING CONSTRUCTION:

The front panel is made of Bramite, a unique Australian insulating panel once used on household fuse boxes here. It is practically unobtainium now. It is fantastically heat resistant, incredibly strong and machines well. The brown material is 10mm thick phenolic insulating panel which I buy from the markets at Akehabara in Tokyo. A local plastics company helped with the Bramite panel and planed it down from about 7mm thick to 5.5mm.













As can be seen from the above a metal strap was made to prevent the batteries falling out of their holders. The holders are made by Keystone and these are far superior to the usual Nylon AA battery holders that often stretch, harden or crack over time. The holders are retained by 4-40 UNC machine screws, with threads tapped the full thickness of the 10mm thick Phenolic base.

The rubber feet are door stoppers. A spacer was machined to length from1/4 brass tube to fit inside them and again these are retained to the base with a 6-32 UNC that passes into the threaded base plate the full thickness.



The variable capacitor is mounted on two nickel plated brass spacers which attach it directly to the pcb. The vintage 40R loudspeaker was rusty and required rubbing down, treating with Fertan and re-painting with Holts auto spray.

When the V/C is fully meshed and the coil on the rod positioned to tune 530kHz, at the high end the radio tunes to 2MHz. The 365 pF Japanese made V/C and does not have an additional trimmer capacitor on it and there is nothing directly loading that point to add any capacitance there. The V/C was made by the Japanese for the American market and has a ¼" shaft and its body holes pre-threaded with 6-32 UNC holes, rather than the usual metric threads seen on Japanese parts.



The image above with the ruler gives the size of the radio which is 200mm wide and about 150mm tall including the rubber feet.



PERFORMANCE OF THE TRF-ONE RADIO & SOME OTHER DETAILS:

It is well known that the main issue with a radio such as a single tuned circuit type is the reduced selectivity compared with a Superhet or a TRF type with more tuned stages.

In this radio, this issue is offset to some extent by the very high Q ferrite rod coil and the low loading on this by the coupling coil that was also spaced away a little from the earthy end of the main tuned circuit. (The input resistance of the LM372 is around 3k).

Also, unlike most TRF radios, this radio has a very high gain and a phenomenally effective AGC. Weak and local stations appear with a similar volume. Therefore, in use, the performance is apparently super lively with many stations coming in at a similar volume. And hiss heard between the stations often heard in a multi stage high gain radio .The Rod antenna is also deaf to noise in the electric field. I used #30 awg wire for the Rod's coil. I also tried Litz wire, but I could not detect any difference in the Q compared to the #30 awg wire. The large sized high permeability rod means there are fewer turns on the coil (46 turns only) than most MW transistor radio coils.

In addition, due to the absence of transformer coupling in the audio stages, the frequency response of the audio circuit is flat, being about 3dB down at 50Hz (not that the small speaker could reproduce this well). By 18kHz, the first change that is noted in the amplifier's output waveform, rather than amplitude loss, it is slew rate limited by the 741. The sine wave simply becomes triangular and the amplitude drops after that as the frequency rises further.

This radio could perhaps almost be regarded as a "Hi-Fi" AM receiver. The radio required a tone correction capacitor for a balanced sound to roll off the higher audio frequencies a little. An 820pF capacitor (across the 100k feedback resistor) was found with a listening test to give the good result. While there are better modern OP amps than the 741wth output stages which can swing closer to the supply rails so as to gain more power output before clipping, the internal frequency compensated 741 is totally deaf to radio frequencies and very stable too, so for the application I'm very happy with the 741.

Using the radio in an outdoor patio area the 150mW audio is plenty of power and it easily received many AM stations with loud crystal clear output with the volume control at about ½ or less, for example one station 100km away on 693 KHz with no discernable background noise when tuned in. The radio exceeded my expectations for an AM radio based on a single tuned circuit. It is a very pleasant radio to listen to and I find myself using it most days. And it was a fun exercise to design & build.
