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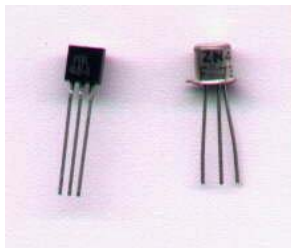
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ZN414 AM Receiver IC



T092 package at left used for ZN414Z, YS414, MK414 and TA7642. T018 package at right is used for the original ZN414.

History.

This TRF radio IC, well known to European and Australasian constructors of radio receivers, was developed in the early 1970's by Ferranti in the UK. Originally, it came in a TO18 package, like a BC108 transistor, but the last of the IC's were made in a T092 plastic case, as the ZN414Z. There are only three connections; input from a ferrite rod aerial, earth and audio output. The circuit is a TRF type with all gain at the received frequency. The IC also incorporates a detector and AGC circuit. Supply is a nominal 1.5V at 300uA and audio output is sufficient to drive a crystal earphone. Needless to say, it became very popular for matchbox size radios in the 1970's. So popular was the ZN414 in the UK, that it eventually killed off the one and two transistor reflex circuits which used to regularly appear in their constructional magazines. I'm sure Clive Sinclair would have been delighted if such an IC was around when his keyring Micro Matic (two transistor AM reflex) receivers were being developed.

In Australia, the first project description of a ZN414 receiver was in Electronics Australia, May 1974. It drove low impedance headphones via a transformer. Then in August 1979, they presented a circuit driving a low impedance earphone via a transistor. In the following issue was a two transistor audio amplifier add on. Around the late 1970's, a one off magazine, "Easy Electronics" described a similar set, again using a BC108 to drive a low impedance magnetic earphone.

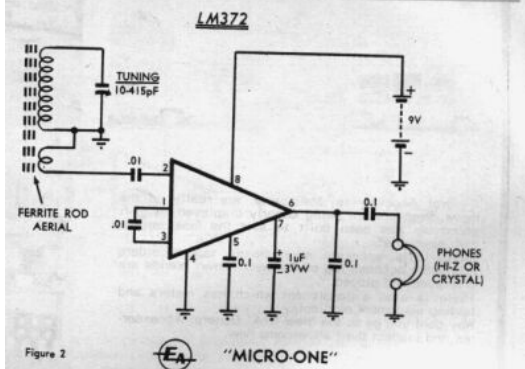
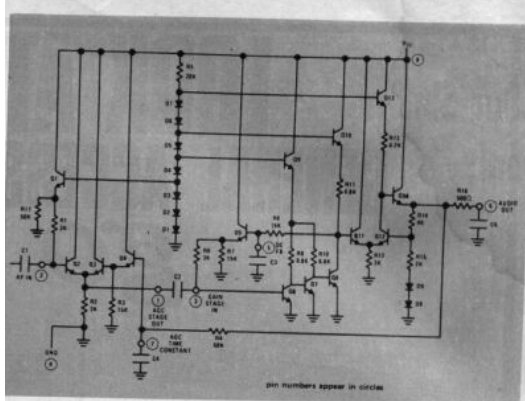
In the 1980's, two more versions of the IC appeared in an 8pin DIL package. These were the ZN415 and ZN416 and were simply a ZN414 with an audio stage capable of driving low impedance headphones. No doubt these versions were developed as the Walkman style of headphones were now in vogue. Apart from being much more comfortable, the sound quality and hygiene aspects far surpass the single magnetic or crystal earphones which until now had been standard with transistor radios.

Eventually, Ferranti went the way of many semiconductor companies and the ZN414/ZN415/ZN416 were no longer being produced.

However, all was not lost as the Asian manufacturers had cloned it under a number of different types. First was the YS414 and then came the MK484, LMF501T, TA7642, and various other xx7642 types. The MK484 and TA7642 are the most common types these days.

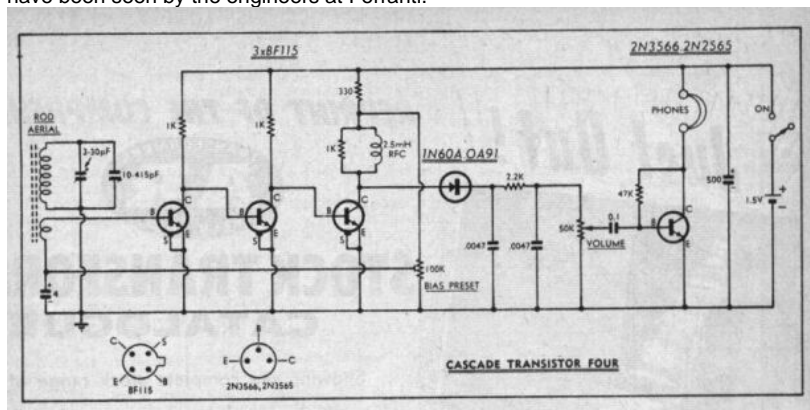
It would be interesting to know the development of the ZN414. I can guess the idea came from one of two places. In the U.S, National Semiconductor had their LM372 in the late 60's.

This is a very similar IC and does the same job. However, it has a low input impedance, requiring a tapping on the aerial coil, and runs off a higher supply voltage. The LM372 has a gain of about 60dB (slightly less than the ZN414), is in a different package, and has more of its internal circuitry connected available to the outside world. It was intended to be used as an IF amplifier/detector, but Electronics Australia published a circuit with it operating in the broadcast band fed from a ferrite rod aerial, as one would with a ZN414.



Was National Semiconductor's LM372 a source of inspiration for Ferranti? This circuit was described in Electronics Australia, April 1969.

The other possible source of inspiration was a circuit published in Wireless World, and presented locally by Electronics Australia. This used a chain of directly coupled transistors fed from an aerial coil. I suspect this to be the more likely option as this circuit ran off 1.5V and would have been seen by the engineers at Ferranti.



This circuit, originally from Wireless World, October 1966, and shown here in an article from Electronics Australia, November 1966, bears more of a resemblance to the internal workings of the ZN414, and also works from 1.5V. Incidentally, this circuit has been tested and works well. An extra transistor will give good volume into an 8R speaker.

It would seem odd that it had taken about 35 years for this IC to really take off. Until recently it was one of these IC's like the TDA7000 (and its clones) that never seemed to be used in commercially made equipment. One would only see them in the pages of electronics magazines or in kits. The thing that has revived it, and the TDA70xx FM IC's, has been the proliferation of very cheap miniature radios. These are the type of pocket radio you see in \$2 shops and typically run off 2 AAA cells. Some have an internal speaker, but most are earphone only. Obviously, someone along the way had realised that it would be far cheaper to produce radios using these IC's which had been used by hobbyists for so long, rather than a whole heap of discrete components and IF transformers. The alignment procedure is also dispensed with, further lowering costs.

About the ZN414 and its clones.

At this point it is worthwhile downloading the data sheets. Search for data on not just the ZN414, but the other clones as well.

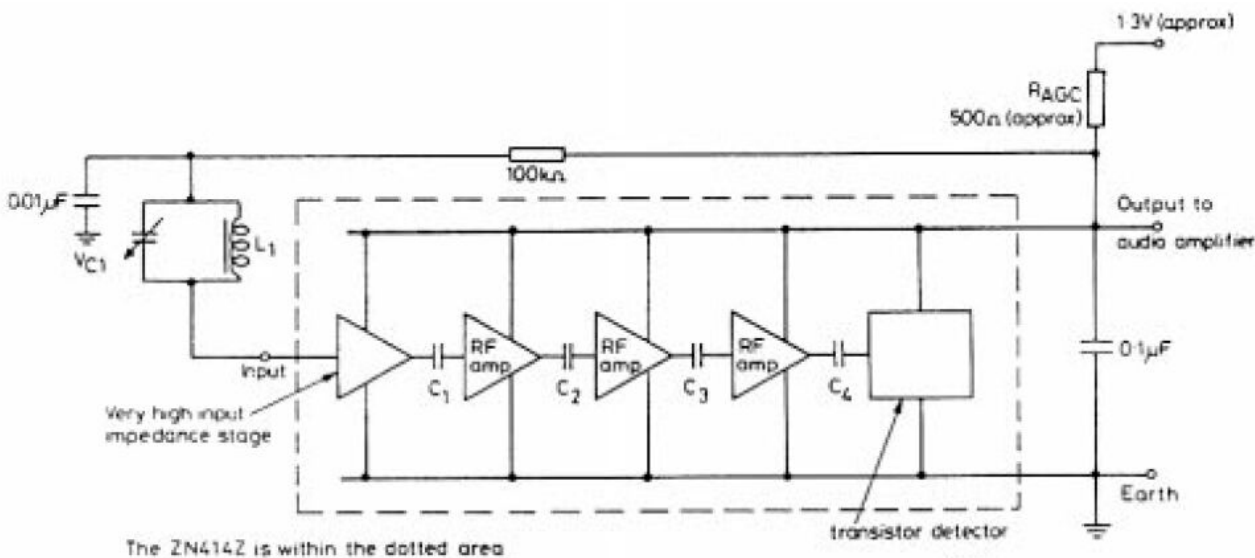
One of the Ferranti sheets is available [here on the Jaycar site.](#)

Briefly, the tuned circuit is fed straight into the IC. There is no need for a tapped coil due to the 4M input impedance. Looking at the internal diagram of the TA7642, we can see this is a result of using an emitter follower at the input pin. Four stages of amplification and an active detector result in a gain of about 72dB which is high enough to give good results with no external aerial. In fact, gain is not too far off an average superhet using the same size aerial rod. The .1uF at the output pin is for RF bypassing, and in conjunction with R_{agc}, determines the audio bandwidth. The data sheet shows how this capacitor value is calculated. Apparently, the higher the value, the more gain can be had. This would make sense as RF bypassing would be improved with an increase in capacitance value.

The DC at the output pin varies with signal strength and this is used for AGC. The 100K and .01uF are the usual time constant to remove audio fluctuations. In addition, the .01uF is also the RF bypass for the earthy end of the aerial coil and tuning condenser. Gain of the IC is thus controlled by the DC at the input pin.

I have seen some circuits incorrectly drawn, particularly with the LMF501T clone, where the 100K has been connected directly to the input pin, along with the .01uF for DC isolation of the aerial coil. While it would work to a degree, and the DC conditions are correct, the problem is 100K is effectively shunted across the aerial coil and will result in loss of gain and selectivity.

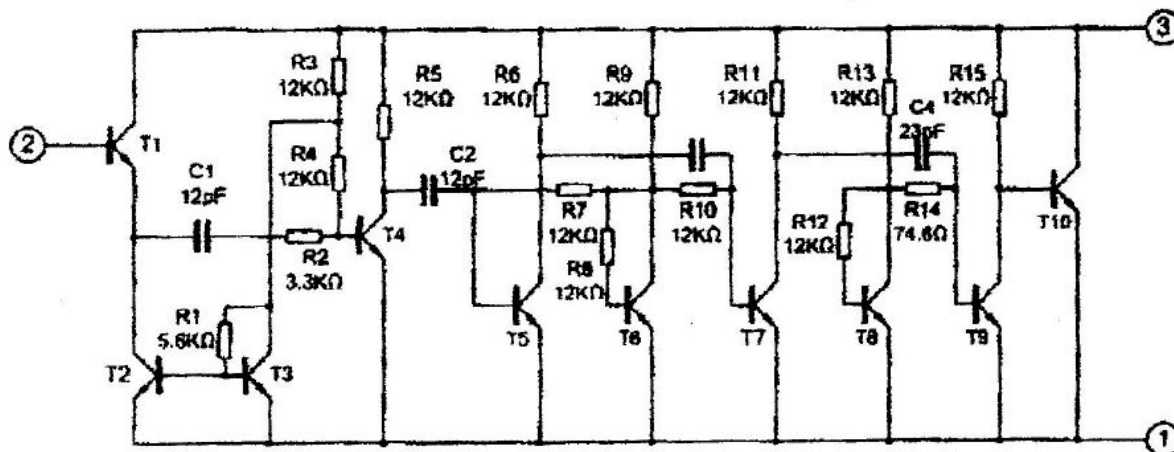
It is important that the tuned circuit is the only thing connected to the input pin.



Basic connections for the ZN414.

The power supply is one of the most attractive features for portable or miniature receivers. Only one 1.5V cell is required, and in its most basic form driving a crystal or high impedance earphone, current consumption is only 300uA. This makes operation from even the smallest

cell possible. Voltage is however critical and R_{agc} may need to be changed for best results. Typically, 500R to 1.5K are shown on most circuits. Various stabilised and adjustable supplies are shown on the data sheets for use when the receiver needs to be powered from other sources; e.g. 9V.



Internal circuit of the TA7642 which presumably is the same or very similar to the ZN414. Note the emitter follower input allowing direct connection to an aerial coil without tappings.

The official operating frequency of the ZN414 and clones is 150Kc/s to 3Mc/s. From articles in the English magazine, Radio and Electronics Constructor, it appears the gain falls off in the longwave band. It was recommended only if Radio 2 (BBC long wave transmitter in the UK) gave a good signal in the area where the radio was to be used. However, both Electronics Australia (July 1985) and Silicon Chip (September 1994) described radios for the reception of the long wave weather beacons located at various Australian airports. This, and my own experiments seem to infer the ZN414 does a good job below the broadcast band.

As for the upper frequency limit, while 3Mc/s is the official cut off, many stories exist of reception higher into the SW bands, up to around 6 Mc/s. This cannot be guaranteed, and would be dependent on individual IC's and signal strength.

Of course, it doesn't have to be an aerial coil that feeds the input of the ZN414; it can just as well be the secondary of an IF transformer.

This means that by using the ZN414 as an IF amplifier/detector, normal superhet techniques can be used to cover frequencies well outside the 150Kc/s-3Mc/s band. Examples are given in the data sheets on how to do this.

I have also seen circuits with regeneration applied. Given that the RF bypassing at the output pin is not perfect, some of the RF can be fed back into another winding on the aerial coil.

Other circuits show an external Q multiplier.

My use of the ZN414.

My interest had been rekindled of late as Dick Smith was selling MK484's at half price. Knowing that they are slowly getting rid of components, I went and stocked up with a lifetime supply. I have known about the ZN414 for years; for a long time the Dick Smith catalog had provided a circuit (EA May 1974) in the back of their catalog.

The ads for the device proclaimed such virtues as "equivalent to a ten transistor radio". Ten transistors it may have, but it actually has only four stages of RF amplification. This is about the practical limit before instability would set in. The other transistors are used for the detector, AGC, impedance matching, and stabilisation.

The first time I actually used the ZN414 was with the Funway kits back in 1981. In the Funway 1 volume was the "Beer Powered Radio" which was the standard ZN414 circuit driving a crystal earphone but powered from a homemade battery using beer as the electrolyte. A modification was shown to run the circuit from a 9V battery instead, which needless to say is the version I built. In Funway 2 was the "Pocket Transistor Radio" which drove a magnetic earphone and ran off a 9V battery. Its performance was very poor for two reasons. Firstly the method of obtaining the supply for the ZN414 was a bodge and resulted in instability, and secondly, the 9V battery pressed up against the ferrite rod ruined the signal pickup. This particular circuit was the same as EA's August 1979 design, except for the modification for 9V operation.

During the mid to late 80's when I was learning about solid state, I experimented with many different ZN414 circuits and associated audio amplifiers. I used to demonstrate to some of my fellow students a ZN414 receiver with a two transistor amplifier driving a speaker that I'd build on a breadboard from time to time. I recall listening to 2SM during one of our programming classes on such a set. Soon after, I went off listening to AM as a result of changes to formats and stations migrating to FM. So, the ZN414 became dormant in my designs until recently, now that I'm mainly listening to AM again.

Also was the fact I'd accumulated a few of the \$2 shop radios using the ZN414 clones.

Selectivity.

Being a TRF circuit with selectivity determined only by the one tuned circuit, sound quality is excellent. It is certainly up to the standard for feeding into a hi fi amplifier and decent speaker system. As I've said elsewhere on the site, if people heard wideband AM through a good sound system, it wouldn't have the poor reputation it has unjustly suffered.

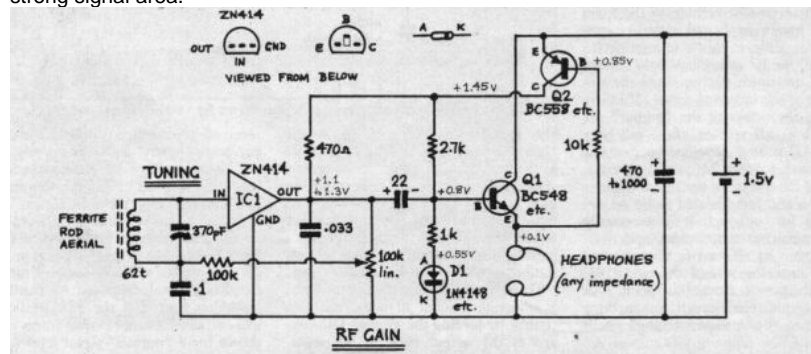
However, this and the limited AGC can be a problem in strong signal areas. Here, selectivity becomes poor. When I was still living in Sydney not too far from the transmitters, I had difficulty receiving 2WS on 1224 as it was a weak western suburbs station. The problem was 1170 2CH and 1269 2SM being much more powerful in my area. So, a DX receiver it was not! Nevertheless, I did try a ZN414 receiver in a car and bus with good results.

The problem was the AGC system cannot cope with strong signals. One can of course attenuate them by using a smaller ferrite rod (compromise) or by turning the receiver away from the interfering stations (may not be convenient). At home in the mid Blue Mountains, about 70km away from the AM transmitters at Homebush, performance is very good with selectivity about the same as a valve TRF set. I can receive 2LT (Lithgow) without any interference from 2GB(Sydney) and yet the stations are only 27Kc/s apart. At night, the usual interstate stations are received.

Many designs allowed the supply voltage to be adjustable as this is actually quite critical and has a large effect on receiver performance. This was done either by making R_{agc} partially variable or by adjusting the supply to the usual fixed R_{agc}. This helped but wasn't as good as the breakthrough developed by Technicraft in their article printed in Electronics Australia for February 1986. Technicraft was a short lived kit company whose fame was a series of reproduction 1920's radio kits. Their one valve "Unidyne" is probably their most well known. They did do a few modern kits, and their "AM3" based around the ZN414 was one of these.

Performance Breakthrough.

Technicraft had examined the limitations of the IC and its AGC system with strong signals, when they were designing their AM3 kit, and developed a method for obtaining a greater range of control. The circuit was an instant success when I tried it and all subsequent ZN414 circuits in Electronics Australia (September 1987 - Switched tuned receiver in cassette box) and Silicon Chip (September 1994 -Weather Radio) have used it. Surprisingly, outside Australasia the new circuit is still unknown, and the rest of the world battles on with the limitations of the original circuit oblivious to the improvement possible. Having said that, the original circuit is acceptable provided you're not in a strong signal area.

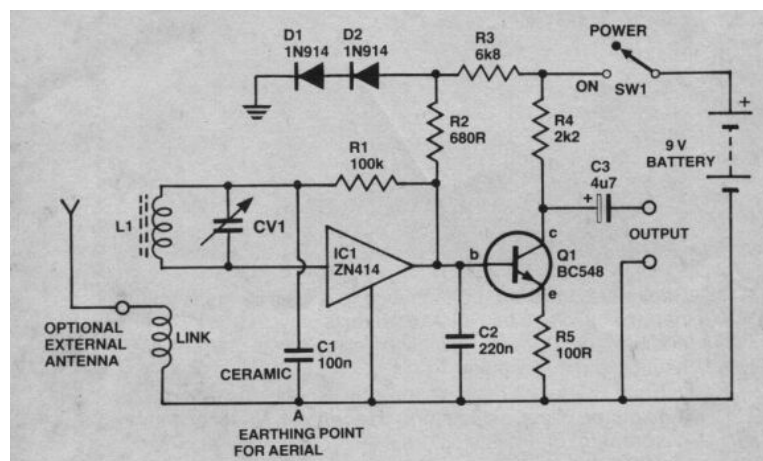


From Electronics Australia, February 1986, this circuit shows how to obtain complete control over the ZN414 when the range of AGC is insufficient. The 100K pot is not critical, and can be as low as 10K. Q2 is the power switch that detects whether or not the headphones are plugged in. D1 is for temperature stabilisation.

Projects.

First point of call on the internet is to look at European sites, particularly British and European ones; use google.co.uk and google.de. Search under all the different type numbers. From Japan (google.jp), LMF501T, MK484, and TA7642 will provide more search results than ZN414. This is a good [German site](#) with many links. Use the Google Translator if sites are not in your preferred language. In the U.S, the ZN414 went largely ignored, along with just about every other European semiconductor. In recent years a few kits and designs have started to appear there, no doubt as a result of being sourced from Asia where the later clones are popular, but U.S suppliers still regard it as an unusual component.

The ZN414, or more often now, the MK484 appears in many beginners kits, often with an LM386 to drive a speaker. Dick Smith is still selling the Funway kits, almost 30 years on, so this at least guarantees a supply in Australia.



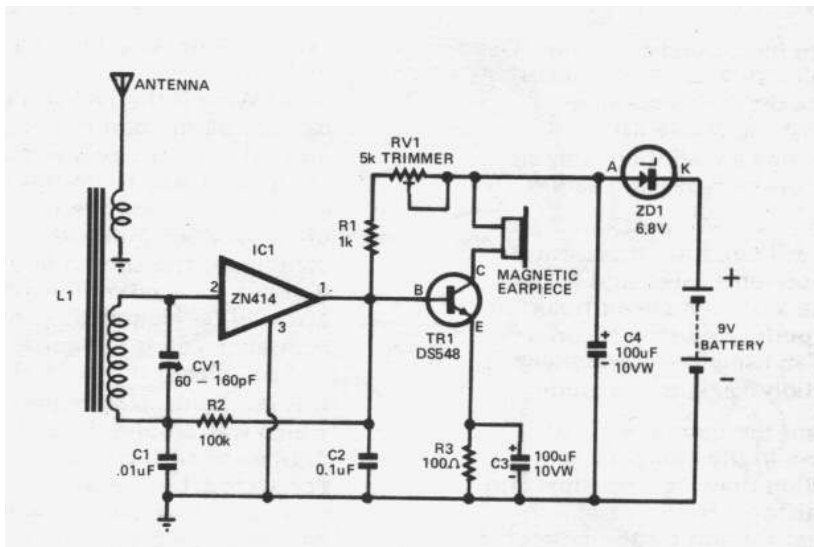
This circuit is from one of ETI's spin offs; Hobby Electronics, July 1981. This is the one [shown here](#) in the prototype photo. I can receive interstate stations on this at night with no external aerial or earth. The only limit to performance is the quality of the tuned circuit. Note the method used to obtain the 1.4V supply. My unit actually uses a YS414.

The only project I've seen using the ZN416 in Australia was an ETI design from March 1987 which was a portable headphone radio.

Funway 2 "Pocket Transistor Radio".

This ZN414 receiver is one of the kits in the DSE Funway series; a publication well known to electronics enthusiasts in this part of the world.

Back in 1981 when I built this kit, I had very little idea what was going on so merely followed the instructions and built up the radio as described.



Circuit of the Funway 2 radio circuit. Unfortunately, it's a bodge and performance is poor. Once modified, it became an excellent little receiver.

Apart from the zener diode and 9V battery, the circuit is conventional and commonly used. The ZN414 is connected as per the data sheet. Output at pin 1 then feeds a DS548 (BC548) transistor as a class A earphone driver. TR1 bias comes from the voltage at pin pin 1 as it's DC coupled. Collector current will therefore depend on the setting of the 5K pot, signal strength, and R3. Current is $[V_{pin1} - .6]/100$. C3 reduces audio degeneration and loss of gain. I have seen some circuits on the internet which are similar, but the transistor base is AC coupled and biased with a single resistor from the collector. The emitter resistor retained in these circuits is pointless, (unless it is unbypassed for reducing audio gain) as there is no resistor from base to ground. It's amazing how many badly designed circuits abound on the internet and other places.

Having assembled the kit, performance was unacceptable. I seem to recall instability and poor volume. Back then, I didn't understand zener diodes and thought the power supply was a bit strange. I did know the ZN414 was meant to run on 1.5V, however. So, I tried powering it off an AA cell instead and that immediately cleared up the instability. My suspicion was right; something funny with the 9V battery and the zener diode. In retrospect, there's two faults with the design. As it is, there will actually be 2.2V across C4, not 1.5V. And this will be even higher with a new 9V battery. Definitely outside the ZN414 ratings! Assuming we got the correct 1.5V across C4 by using a 7.5V zener diode instead, there are still two remaining deficiencies. First, it's incredibly wasteful. Given the cost of 9V batteries, 5/6 of what you're paying for is going up as heat from the zener diode and contributing nothing. Five out of the six cells are effectively being wasted. The second fault is that battery life will be much less than when a single 1.5V cell is used to power the circuit. Why is this so? As we know, battery voltage starts dropping as soon as we start using it. As a rule of thumb, something designed for a 9V battery should work down to about 7.5V, giving an acceptable life. If we apply that principle here, we will see that it won't take long for this kind of drop in battery voltage to kill off the supply altogether. Yet, the individual cells in the 9V battery would still be capable of powering the radio directly.

The reason for this bodge? Back in 1980, Dick Smith did not sell single AA or AAA battery holders, and a 9V battery was the only thing with a connector that would fit in the preferred box.

The 9V battery approach could have actually been done to advantage. Firstly, the ZN414 should have been powered as per the Hobby Electronics circuit with a series resistor and shunt regulator diodes. The 9V battery will last a very long time with this configuration; probably longer than if one of the individual cells was used directly. Secondly, the full 9V could have been used for the audio stage, and with a transformer to match the earphone impedance. This would provide more gain and volume.

For my version of this project, I eventually installed a AAA battery, of which the holder only just fits the box. The low volume was, not surprisingly, a result of an 8R earphone being provided with the kit. As I dislike those white low impedance earphones provided with transistor radios up until the 1980's, I installed a 3.5mm stereo socket for proper 32R Walkman headphones. Most ZN414 circuits that use these recommend the earphones be connected in series to increase the impedance to 64R instead of 16R which is what you'd get connecting them in parallel. While the higher impedance allows greater volume, the problem is that the two transducers are out of phase giving a peculiar and unnatural sound. I prefer the correct in phase connection instead despite loss of gain. It is true that you could connect them in series and in phase by cutting off the plug and accessing the individual transducer connections.

I have a few sets of these headphones, but two of which I discovered are of higher impedance (about 250R per transducer). These are the headphones provided in aircraft for passenger use. With a set of my Qantas headphones plugged in, this receiver really became alive with good volume and excellent bass response. With the normal 32R headphones, the Sydney stations were just audible 80km from their transmitters, but with the 250R units, volume became acceptable. Near the centre of Sydney, about 10km from the transmitters, there is more than enough volume on all stations. I would be hesitant to recommend speaker use without further stages.

The other modification I did to the kit was replace the 5K trim pot with a panel mounted switch pot. This gives a good range of adjustment for the AGC. DSE's idea of only needing to set the pot once shows how unfamiliar the kit designer was with the ZN414. Additionally, the 1K resistor was reduced to 470R as this is the value shown in the data sheets, and 1K just did not allow full performance to be attained. Maybe ZN414's are not all the same, and some would have been satisfactory with 1K.

The performance of this radio has been drastically improved with these mods. Even in Sydney, I can receive some interstate stations at night, and the old 1224 2WS transmitter (now 2RPH) at Prospect can now be received without interference from 1170 2CH or 1269 2SM.

Using the ZN414.

Considering the amount of gain, it is a forgiving IC as far as construction methods go. It is possible to build ZN414 circuits on a solderless breadboard and get good results, but like any RF circuit, performance will be better if component leads are kept short, a ground plane is used, etc. One point mentioned in the data is that the output bypass condenser (C2 in the above diagram) should be as close as possible to the IC. It is interesting to note that although the data sheets show the AGC bypass (C1 in the above diagram) as .01uF, many circuits have used .1uF, possibly as a result of incorrectly reading the data sheet. The increase in AGC time constant would not be noticeable, and if anything, the RF bypassing would be better.

While the typical ferrite rod and plastic dielectric tuning condenser as used in modern radios work well enough, an aerial coil wound with Litz wire and an air dielectric tuning condenser will improve Q and selectivity. Also, a longer ferrite rod improves signal pickup and directional qualities. Don't mount the ferrite rod near anything metallic, and make sure any metallic clamps for the aerial coil don't form a shorted turn. A large open loop aerial would probably provide quite spectacular performance.

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