Construction project:

# Regenerative Radio with Varicap Tuning

*Step back in time and build this simple regenerative radio receiver. Using only three transistors, it is not only fun to build, but educational as well.*

**by MARK CHEESEMAN**

Back in the early days of radio, when men were real men, transistors were still in nappies, and *Electronics Australia* was called *Radio & Hobbies,* a favourite project for experimenters was to build a regenerative radio receiver. The design presented here is based on this old concept, however some concessions have been made to modern technology.

A regenerative receiver, in common with most receivers of the time, had a tuned front end consisting of a capacitor and inductor in parallel. Tuning could theoretically be accomplished by altering the value of either the inductor or the capacitor, to vary the frequency of resonance. It was usually easier to adjust the value of the capacitor, by physically moving the plates closer together (for increased capacitance) or further apart (to reduce it), and this became the usual method for tuning a radio.

Of course, a signal had to be coupled into this resonant circuit in order to get anything out of it, and this was achieved by either a tap on the inductor winding, or a smaller and completely separate winding wound on the same former. In the latter case, the coupling to the tuned circuit was magnetic rather than electrical.

In order to increase the level of the signal presented to the detector, an RF (radio frequency) amplifier stage was inserted after the tank circuit, both to buffer the signal (in order to avoid loading the circuit too much), and also to amplify it.

Two important specifications of any receiver are sensitivity and selectivity. *Sensitivity* describes the ability of the radio to detect weak signals and present them to the audio stage with as little noise as possible. *Selectivity* is the ability to separate the desired signal from others which are close in frequency, particularly if the desired signal is from a distant station, and a strong local signal exists on a nearby frequency.

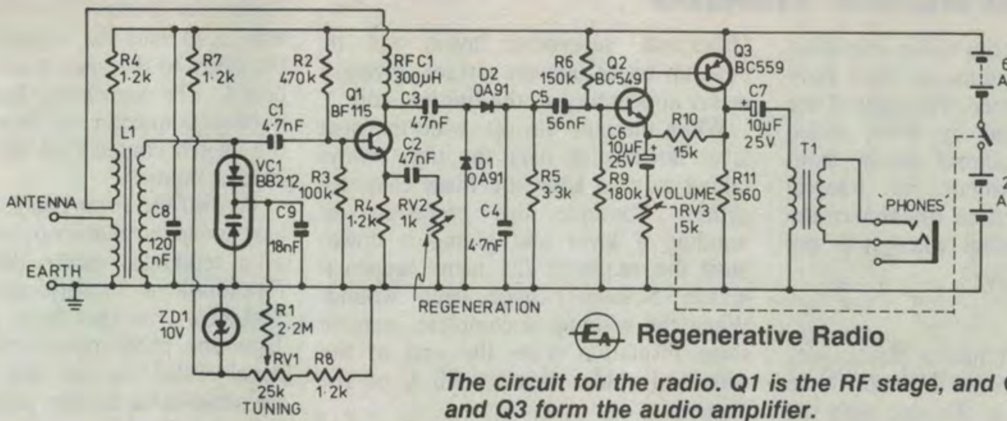
One day some bright spark figured that if he carefully coupled some of the signal from the RF amplifier back to its input with the right polarity (which turned out to be *positive* feedback), he could increase the level of the signal coming out of the amplifier — and also reduce the level of the unwanted signals nearby. That is the basic idea behind regeneration, and although one can't amplify the signal by an unlimited amount, it effectively increases the quality factor (Q) of the circuit, improving both the selectivity and sensitivity of the tuned circuit simultaneously.

All that was necessary then was to convert this RF signal back to the original audio program which was fed to the transmitter. The most direct way of doing this was to half-wave rectify the output from the RF stage, and filter out the RF component. This left behind the 'envelope' of the received signal, which was in fact the original audio from the program source.

The audio signal was then ready for amplification, after which it was fed to a speaker or pair of headphones.

## Modern approach

At first glance, our new circuit may look a little different from the description above; however in reality it is exactly the same. The coil consists of three windings, the largest of which is the main tuned winding. The two smaller windings serve to couple the antenna signal into the tuned circuit, and to couple some signal back from the output of the RF amplifier into the tuned circuit in order to perform the




**Regenerative Radio**

***The circuit for the radio. Q1 is the RF stage, and Q2 and Q3 form the audio amplifier.***

regeneration function.

Mechanical tuning capacitors with a suitable range of capacitance are becoming harder to obtain, and are also quite pricey. For these reasons we have chosen to use a varicap diode instead of the more conventional mechanical type. This is basically a reverse-biased diode, which has a capacitance that varies according to a DC control voltage applied to it. For more details, see our explanatory box. The BB212 in fact contains two varicaps back-to-back, in the same package.

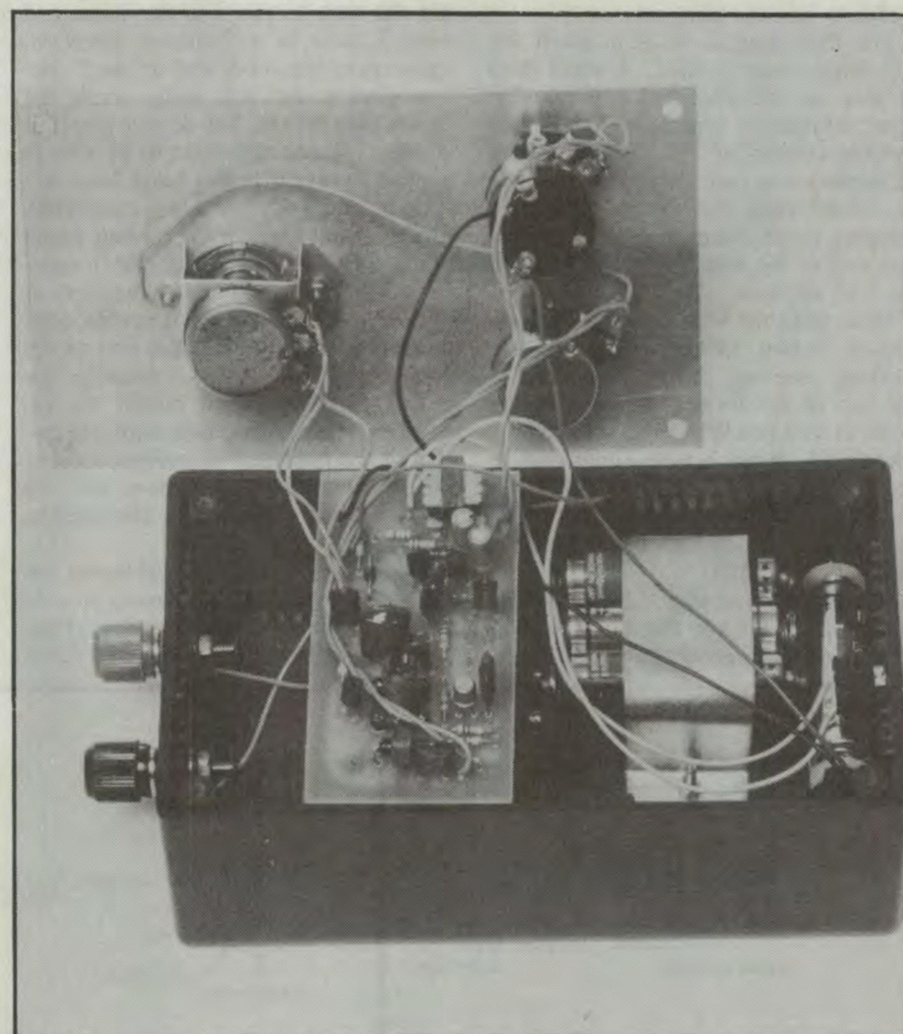
Since the capacitance of the varicap increases as the reverse bias voltage is reduced, and the resonant frequency of the circuit reduces as the capacitance of the varicap is increased, the net effect is that the frequency to which the radio is tuned increases with increasing voltage. This effect is not linear, however, as the characteristic of the varicap is approximately logarithmic, and also because of the inverse square relationship between capacitance and frequency.

A 10V reference voltage is developed by R7 and ZD1, which prevents the tuning from drifting as the battery discharges. RV1 delivers a variable voltage from this, which is used to bias the varicap via R1. The value of R1 is high enough not to significantly load the AC resonant circuit, yet the reverse current of the varicap is almost zero, so the DC voltage drop across this resistor is insignificant.

In order to make the tuning control more precise, without the need for a fine tuning control, we have incorporated a planetary reduction drive. This is mechanically connected to RV1 and gives a reduction of approximately four to one.

The RF amplifier stage is based around a BF115 transistor, which is specifically designed for this sort of application. The gain of this stage is varied by RV2, which varies the emitter degeneration (negative feedback). The load for the transistor consists of the series combination of the feedback winding of the coil, R4 and L5 (a 300uH RF choke). As the gain of the stage is increased, so is the amount of positive feedback, or regeneration, applied to the tuned circuit.

D1 and D2 form a voltage-doubler detector, with C5 and R6 filtering the output to remove RF and provide some attenuation of higher frequency audio signals. This improves the signal to noise ratio somewhat, and also helps to separate signals in a crowded band.



***The inside story. The PCB slides into the pair of slots closest to the left of the box, with the component side facing to the right.***

# Regenerative Radio

Q2 and Q3 form the audio amplifier, which drives the headphones via a 1k:8-ohm audio transformer. The gain of the amplifier is adjusted by RV3, which forms the volume control on the front panel. This pot contains an integral switch which is used to disconnect the power from the circuit when it is not being used.

## Construction

The radio is built into a plastic jiffy box measuring 95 x 158 x 50mm. Note that the type used is the one with the metal front panel, as this provides shielding of the circuit against the effects of hand capacitance when tuning.

The best place to start the assembly of the radio is to wind the coil. While this may seem to be a tedious procedure at first, you should resist any temptation to rush it. A small investment in time at this point will save much tearing of hair and gnashing of teeth when the time comes to turn the thing on.

The first thing to do is to insert the coil former into its base. A small drop of glue on the joint will help prevent their subsequent separation. The main winding consists of 225 turns of 34B&S enamelled wire, and is the first coil to be wound onto the former. Begin by scraping about 10mm of insulation from one end of the wire, and solder this to pin 1 on the base.

Now, wind the wire in a clockwise direction (when looking from above), working your way from the bottom to the top of the former — counting the turns as you go. When the first layer is completed, apply a little super-glue to the coil while holding it in place. Be careful not to glue your fingers to it, as you will need these for the rest of the assembly procedure!

Ideally, the glue should be as fluid as possible, so that not too much remains on the surface of the layer of wire. Otherwise, successive layers will be built up on as uneven surface, giving a messy appearance to the finished coil.

When the glue has set, wind the next layer downwards over the top, always taking care to keep the turns close together. Continue this procedure of winding a layer and gluing it down, until the required 225 turns (approximately 5 layers) have been wound. When the winding is complete, remove some insulation from the end of the wire and solder this to pin 6 of the base.

Next, wind the antenna winding over the last layer of the main winding. Starting at the base again, solder the wire to pin 3 of the base, and wind 10 turns in a clockwise direction, soldering the other end to pin 4. Again glue this into position, and allow it to set in place.

Finally, wind the regeneration winding just above the antenna winding. Solder the wire to pin 2 of the base, and wind 5 turns in a clockwise direction, terminating the other end at pin 5. Before placing the coil aside, screw the ferrite slug into it, but do not glue this in place, as you will need to be able to move it to set the tuning range later on.

Once the coil has been completed, turn your attention to the printed circuit board. The PCB (coded 88tr1) measures 42 x 88mm, to fit in the slots in the case. Mount the lower profile components such as the resistors and diodes first, making sure you polarise the diodes correctly. Then mount the capacitors, again taking care with orientation of the polarised electrolytic variety. Finally mount the transistors and the varicap diode according to the orientation shown on the overlay.

Taking note of the internal layout, attach suitable lengths of hookup wire to the PCB to connect to the three front panel controls, and also for the headphone socket and input terminals. Also solder the positive lead from one battery snap and the negative lead from the other to the appropriate pads on the board. The remaining lead from each battery connector is then soldered to the switch contacts on the back of the volume control.

To drill the front panel, it is probably best to use a photocopy of the artwork as a template, rather than the actual Dynamark material (formerly known as Scotchcal), as this tears rather easily. Tape the photocopy to the aluminium panel of the box, and drill the appropriate sized holes for the regeneration and volume pots.

Cutting the hole for the reduction drive may be accomplished in one of many ways, depending upon the facilities available to you. If you have access to chassis punches, drill a hole that will clear the thread of the punch, and then use a 20mm diameter punch to make the hole. Alternatively, drill as large a hole as you can, and then file or ream it to the correct size.

Now, using a scrap of aluminium, fashion a bracket according to Fig.1. This will support the tuning pot below the reduction drive when the two are connected together. Using the reduction drive as a template, drill two small holes in the front panel with which to mount the tuning pot assembly. Now, *carefully* countersink the holes by hand, using a large drill bit. Do not use a machine to do this, as any slip-up here will render the panel virtually useless. Only countersink the holes just far enough to ensure that the heads of the screws sit flat with the aluminium panel.

Place two 12mm long countersunk 6BA screws in these holes, and secure these with shakeproof washers and nuts. These nuts should be tightened securely, as their heads will ultimately be covered by the Dynamark panel, making access to them impossible. The label should now be carefully affixed to the

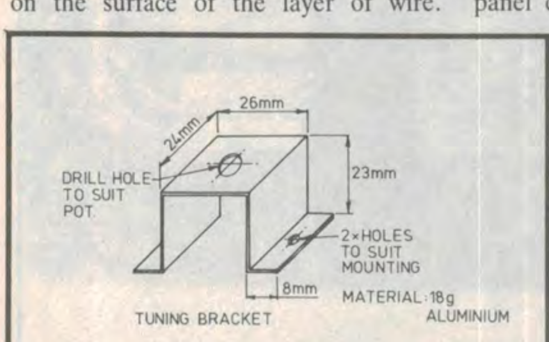



**Fig.1: The pattern for the bracket which supports the tuning pot.**

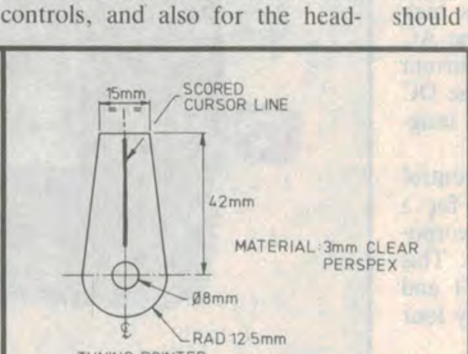



**Fig.2: The dimensions for the Perspex tuning cursor.**

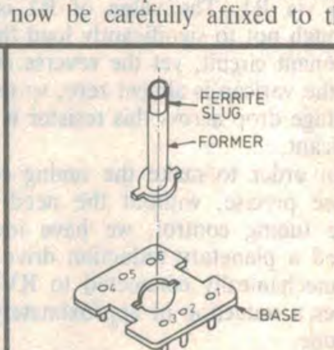



**Fig.3: Note that the pin spacing is not uniform.**

panel, and the holes cut with a sharp knife.

Using a piece of clear Perspex, fashion a pointer according to the dimensions given in Fig.2. Do not remove the protective paper from the surface of the Perspex, as these will prevent accidental scratching. When cutting this material, use a hack-saw with a fine-toothed blade to avoid chipping the surface, and take your time. Also, when drilling, use a high drill speed and proceed slowly, drilling a pilot hole first, followed by the correct sized drill.

Now, mark the center-line on the protective paper, and without removing the paper, score along this line with a sharp knife. This forms the mark on the pointer to indicate the position of the tuning control. When you have completed this, remove its protective paper, using some acetone if the glue proves to be a little tenacious.

The tuning pot should now be attached to its mounting bracket, and tightened as much as possible. Using washers as spacers, mount the reduction drive on the two screws previously attached to the panel. The bracket is then mounted directly behind the drive, and the nuts tightened onto the screws.

The last step in the assembly of the tuning control is to screw or glue the Perspex pointer to the reduction drive. Its orientation is not important at this point, as the pot has not yet been locked to the reduction drive. Now mount the headphone socket and the two binding posts as shown in the photos.

The two battery holders may also be secured as illustrated, using a bracket fashioned from a scrap of aluminium to hold the larger of the two in place. The smaller holder is held between the larger one and the side of the case. The two separate battery holders are necessary to fit the battery in the small space available in the box.

Now the final assembly may be completed, by soldering all the trailing wires to their relevant controls or connectors. A wire is also connected from the earthy side of the regeneration control to the front panel, to allow the panel to shield the circuitry from the effects of hand capacitance. This is most easily attached to one of the mounting screws of the tuning assembly.

Before screwing the front panel in place, it is necessary to adjust the position of the slug in the coil in order to set the tuning calibration. The most accurate way to do this is with an RF signal generator. However, if you do not have access to one of these, simply tune into a known station at the high end of the dial, and adjust the slug (and retune the tuning control) until it appears at the correct place. Now, tune in a station at the low end of the dial and check whether of not it appears in the correct place.

If the indicated frequency is lower than the known frequency of the station, reduce the value of R8 slightly (perhaps by shunting it with a higher value resistor) until the station lies in

## The VARICAP or VARACTOR DIODE

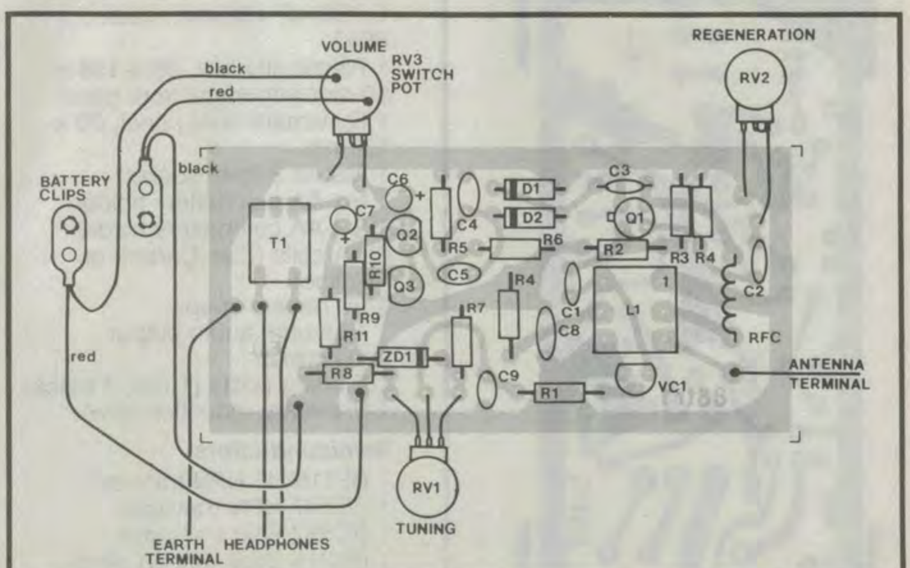
A capacitor usually consists of two electrodes or plates, separated by some form of dielectric material. The actual capacitance of the component is a function of the surface area of the plates, their mutual separation and the properties of the dielectric material separating them. Examination of a typical P-N junction reveals that it is essentially the same thing.

A varicap diode is constructed in a similar way to most diodes, with a piece of silicon which is doped so as to make it N-type at one terminal and P-type at the other. However, special care is taken during construction to minimise any series resistance and inductance in order to keep the Q of the varicap as high as possible.

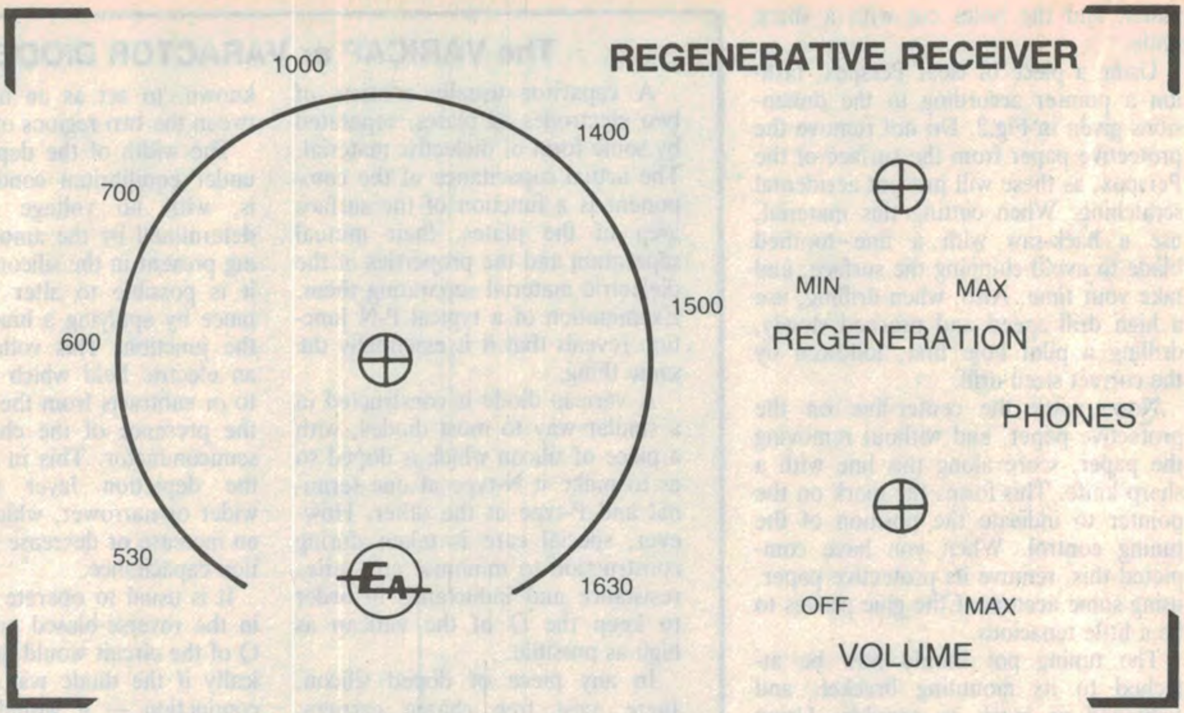
In any piece of doped silicon, there exist free charge carriers, which are either electrons (in an N-type material) or holes (in a P-type). At the junction of P-type and N-type material, some of these charge carriers diffuse into the other piece of material, causing charge cancellation to occur in the region of the junction. This causes the resulting depletion layer, as it is known, to act as an insulator between the two regions of charge.

The width of the depletion layer under equilibrium conditions (that is, with no voltage applied) is determined by the amount of doping present in the silicon. However, it is possible to alter this capacitance by applying a bias voltage to the junction. This voltage sets up an electric field which either adds to or subtracts from the one due to the presence of the charge in the semiconductor. This in turn causes the depletion layer to become wider or narrower, which results in an increase or decrease in the junction capacitance.

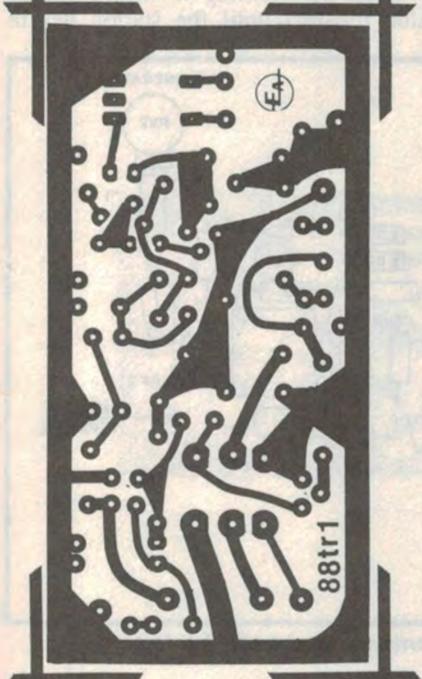
It is usual to operate the varicap in the reverse-biased mode, as the Q of the circuit would drop dramatically if the diode was biased into conduction — it would appear to have a low value of resistance in parallel with it. The signal in the tuned circuit is also much smaller than the voltage necessary to make a significant change to the capacitance of the device, so it may be assumed that the capacitance does not oscillate in time with the signal in the tuned circuit.




*The printed-circuit overlay. Note that the antenna and earth leads are soldered to the back of the board.*




**Right: the front panel artwork, actual size. Below: the PCB artwork, again actual size.**




the correct place. Conversely, if the dial reads high, R8 needs to be increased. Some slight interaction between the slug position and the value of R8 may be expected, so it would be wise to re-adjust the slug at the high end of the band whenever you alter R8. Once the tuning is correct, a little wax on the coil slug will ensure that it stays in place, yet allow further adjustment if this is ever desired.

This radio requires an external aerial and earth to be connected to the binding posts on the left-hand end of the box. The easiest type of aerial to arrange is probably a long-wire type, as long as you can manage, up to about 6 or 7 metres in length, and mounted as high up as possible. If you make the aerial too long, it may start to load the tuned circuit too much, making it impossible to obtain sufficient selectivity.

In this case, you will need to reduce the coupling of the antenna to the tuned circuit. There are two ways in which this may be achieved. The first is to remove turns from the antenna winding of the coil until selectivity is recovered. Alternatively, if you don't want to play with the coil (or you have already glued the winding in place), you can try connecting a discarded tuning capacitor in series with the aerial terminal. If the capacitor is of the multiple-ganged type, connect the various gangs in parallel, and then connect this parallel combination in series with the antenna. Adjust this capacitor for the best compromise between sensitivity and selectivity.

The earth should ideally be attached to a metal stake driven into the ground,

*Continued on page 173*

## Parts List

1 PCB 42 x 88 mm, coded 88tr1
1 Plastic jiffy box, 95 x 158 x 50 mm with metal front panel
1 Dynamark front panel, 90 x 153mm
1 Stereo 3.5mm socket
1 6 x AA cell battery holder
1 2 x AA cell battery holder
8 AA cells (Zinc-Carbon or Alkaline)
2 9V battery snaps
1 1k:8 ohm audio output transformer
2 Binding posts (1 red, 1 black)
1 Planetary reduction drive

***Semiconductors***

1 BF115 HF NPN transistor
1 BC547 NPN transistor
1 BC557 PNP transistor
1 BB212 Dual varicap diode
2 OA91 germanium diodes
1 10V zener diode

***Resistors*** (all 1/4w, 5%)

4 x 1.2k, 1 x 470k, 1 x 150k, 1 x 100k, 1 x 15k 1 x 180k, 1 x 560Ω, 1 x 2.2M, 1 x 33k.
1 25k lin pot
1 5k log switch-pot
1 1k lin pot

***Capacitors***

2 10uF/25VW electros
2 47nF metallised polyester
2 4.7nF metallised polyester
1 220nF metallised polyester
1 56nF metallised polyester
1 18nF metallised polyester

***Inductors***

1 Neosid F16 coil former
1 base for above
1 slug for former
34B&S enamelled wire
1 330uH RF choke

***Miscellaneous***

Nuts, screws and washers.
Aluminium for brackets.

**Radio** *Continued from page 80*

or a metal water pipe which travels underground at some point. The soil should be reasonably conductive, otherwise it will be difficult to obtain a good connection. However, if this is not the case, there is probably not much that you can do about it anyway.

A few notes with regard to operation of a regenerative radio are perhaps in order here, as this type of receiver is something of an oddity these days. Begin with the regeneration control set about mid-range, and adjust the tuning control until the desired station can be heard. If the radio squeals, back off the regeneration until it stops. Conversely, if you don't hear anything at all, or if it is very weak, advance the regeneration control until *just before* the onset of oscillation.

Best performance is achieved when the radio is just on the verge of (but not quite) oscillating. If the volume is too loud, do not back-off the regeneration, as this will reduce the selectivity and introduce interference from other stations. Use the volume control instead. The oscillation may not always be audible, but instead may manifest itself as severe distortion of the audio output.

Have fun with your new radio!