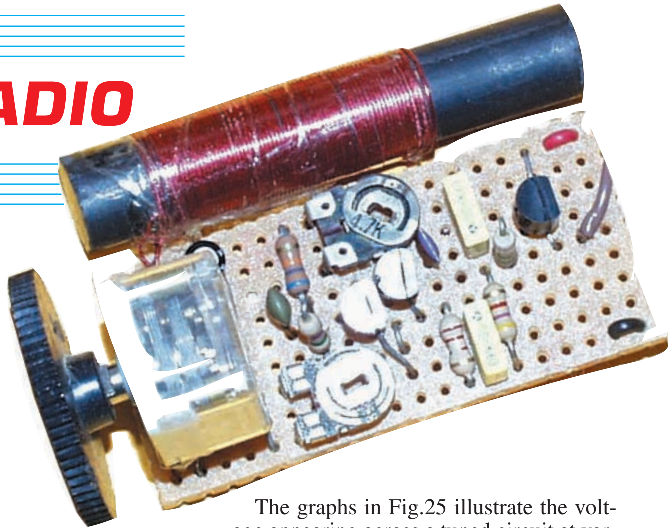
MEDIUM WAVE RADIO



No series about transistor circuits would be complete without a simple radio circuit and, although better performance is obtainable using integrated circuits, simple radios are still fun to build and use and have been popular since the first transistors were introduced, well over 50 years ago.

RADIO RULES

Before describing the operation of this circuit, it may be useful to review a few basic principles which govern radio transmission. Aerials (both transmitting and receiving) are much more efficient when their length is comparable to the wavelength of the signal to be used.

Since wavelength is inversely proportional to frequency, it is clear that lower frequencies require longer aerials. It is, therefore, impractical to try to transmit audio signals directly as this would require aerials several hundred kilometres long, so most radio transmissions are restricted to higher frequencies, above a few hundred kilohertz.

CARRY ON

To transmit any useful information (e.g. speech or music) this high frequency, which is called the *carrier frequency* must be modulated and various schemes exist for doing so. Frequency modulation (f.m.), where the frequency of the carrier is varied by the audio signal, is the most widely used for hi-fi transmissions, although amplitude modulation (a.m.) is still popular where lower quality is acceptable.

This is probably due to the ease with which an a.m. radio signal can be *demodulated* and the audio signal recovered. The use of a carrier also has the great advantage of permitting simultaneous transmission by a large number of radio stations, each on a different frequency, while still allowing the listener to tune into one particular station.

In Fig.24 is shown a high frequency carrier which is amplitude modulated by a low frequency signal. In this case it is a sine wave, although it would more likely be a complex speech or music waveform. To receive this, a circuit that responds only to the carrier frequency (or a small range of frequencies around it) is required and here the tuned circuit, which we illustrated in the *Metal Detector* project (Part 2, March '03), can be used.

TUNED CIRCUIT

A tuned circuit has a low impedance at all frequencies except its resonant frequency (which is determined by the value of the inductor and capacitor used) so that all signals appearing at the aerial will be short circuited to earth, except the frequency to which the circuit is tuned.

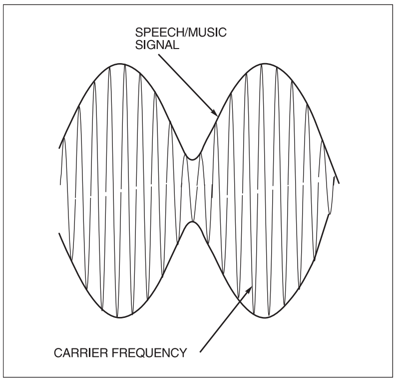


Fig.24. The make-up of an amplitude modulated (a.m.) radio signal.

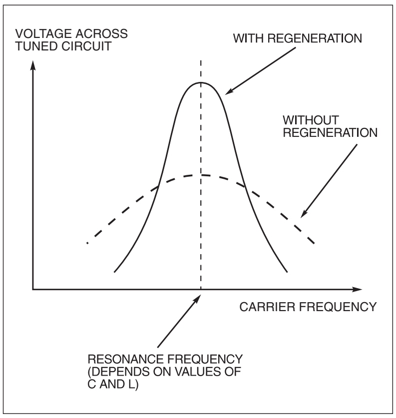


Fig.25. Frequency response of a tuned circuit.

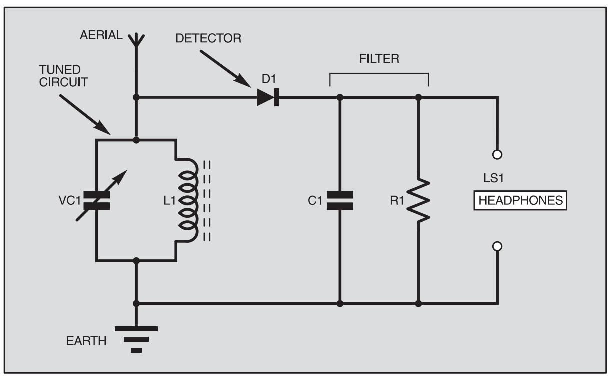


Fig.26. Basic radio receiver circuit.

The graphs in Fig.25 illustrate the voltage appearing across a tuned circuit at various frequencies. It will be seen that the voltage falls away gradually as the applied carrier frequency differs from the resonant frequency of the tuned circuit. Thus if all transmissions on all frequencies had an equal amplitude, the one coinciding with the resonant frequency would produce the largest output.

This is, of course, not the case as some transmitters radiate at lower power or are further away, resulting in a lower voltage at the receiver. For the best results it is clear that the peak response should be as "sharp" as possible to achieve maximum suppression of unwanted signals. This is governed by losses inherent in the tuned circuit and the smaller these are, the sharper will be the response.

BASIC CIRCUIT

A simple radio receiver circuit diagram is shown in Fig.26. The tuned circuit is formed by an inductor, L1, and a variable capacitor, VC1. The latter enables a range of frequencies to be tuned in.

Assuming the transmitted signal is that in Fig.24, the signal appearing across the tuned circuit will be identical. To recover the audio signal, the received signal must be demodulated. This can be done with a single diode, D1, which allows only the positive portion of the signal to pass. It is followed by a simple filter, consisting of capacitor C1 and resistor R1, which removes the high frequency carrier signal, leaving only the audio signal, which can be listened to via suitable headphones.

Given a long aerial and a good earth connection, together with very sensitive headphones, you may just about be able to receive a strong local a.m. station using this circuit. For a portable radio, however, it is useless, but it gives an idea of what is required to make a radio.

IMPROVEMENTS

Aerial signals smaller than the forward voltage of the diode (about 0·6V for a silicon diode) will not be passed to the headphones so the sensitivity of the circuit must be improved to allow weaker stations to be received.

The problem with using only one tuned circuit is that its response is too "flat" and with today's crowded wavebands, it is difficult to select only one station and stronger stations transmitting on an adjacent frequencies to that required can interfere with reception. To improve the selectivity, commercial receivers use many more tuned circuits, but this leads to other problems that need much more complex circuits to resolve.

SENSITIVITY

The sensitivity of the radio can be improved simply by amplifying the aerial signal before it is fed to the detector, while to improve the selectivity, the losses inherent in the tuned circuit must be minimised to sharpen its response. As a first step, any impedance connected across the tuned circuit must be made high to load the tuned circuit as little as possible. Consequently the input impedance of the amplifier must be high.

The tuned circuit is coupled to the base of transistor TR1 by capacitor C1. The latter prevents the d.c. conditions from being upset by the low resistance of L1. The input impedance of this stage is high due to the large value bias resistor R2 and the resistance in the emitter circuit, provided by preset potentiometer VR1, so that the tuned circuit is only lightly loaded.

The circuit around transistor TR1 is very reminiscent of that used in the Metal Detector referred to earlier, in which the first transistor operated as an oscillator. Potentiometer VR1 is adjusted so that there is *just* insufficient positive feedback to sustain oscillation.

As the frequency to which the circuit is tuned increases, this feedback also increases but since the input impedance falls, the losses in the tuned circuit increase so that the circuit remains stable and VR1 should not need to be constantly re-adjusted.

COMPONENTS

See SHOP TALK page

Resistors

R1	68k
R2	4M7
R3	2k2
R4	1M5
R5	4k7

Potentiometers

VR1	1k skeleton preset
VR2	47k skeleton preset

Capacitors

C1	47p ceramic
C2	100p ceramic
C3, C4	100n polyester (2 off)
C5	10µ radial elect. 25V
VC1	15p to 165p variable capacitor

Semiconductors

TR1, TR2	2N3904 *npn* transistor (2 off)
TR3	BC558 *pnp* transistor

Miscellaneous

L1	Ferrite rod, 50mm x 10mm, with coil (see text)
LS1	high impedance earpiece

Stripboard, 19 holes x 9 strips; PP3 9V battery; PP3 battery clip; plastic case to suit; 28swg enamelled copper wire; solder, etc.

Approx. Cost Guidance Only **£5**
excl. case, earpiece and battery

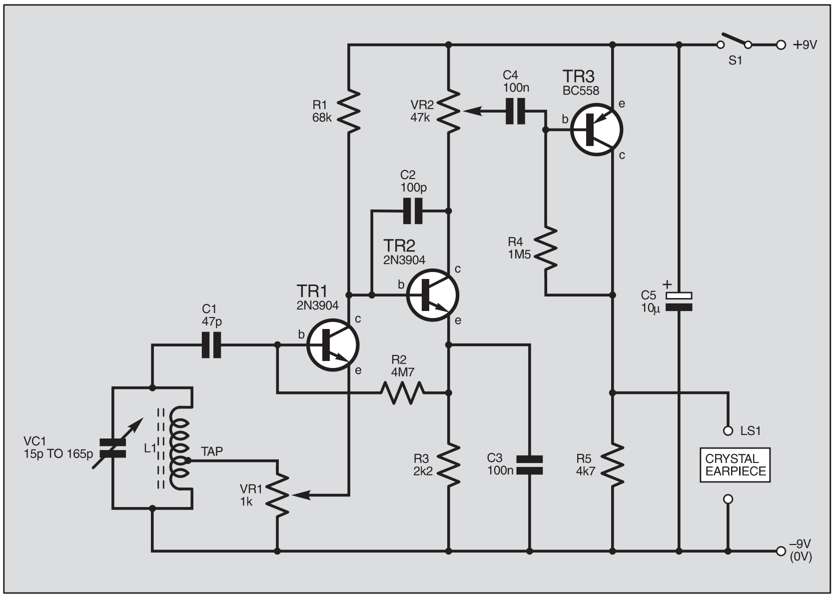


Fig.27. Practical circuit diagram for the Medium Wave Radio.

Another thing that can be done is to try to replace some of the tuned circuit losses by using positive feedback. However, this can lead to oscillation, and so the feedback level must be closely controlled. It is found that the selectivity is greatly improved if the circuit is just on the verge of oscillation.

Most circuits using this technique (which was called *regeneration* in old valve receivers) have a separate control to do this, but which is tricky to use, having to be adjusted for each station and is the reason why no modern commercial radios use it. With careful adjustment, though, it is possible to do away with this control and ensure that once set up, no further adjustment is required.

PRACTICAL CIRCUIT

The circuit diagram for a suitable receiver is shown in Fig.27. As in Fig.26, the tuned circuit is formed by inductor L1 and variable capacitor VC1. The coil acts not only as an inductor but also an aerial and the directional properties of the ferrite rod on which it is wound can also be useful to help eliminate unwanted stations from interfering with reception.

Transistor TR1 amplifies the signal appearing across the tuned circuit, boosting the sensitivity of the circuit and eliminating the need for an earth connection. No separate detector diode is used in this design as this function is carried out by the collector (c) of TR1.

Transistor TR2 further amplifies the signal but the gain at high frequency is very low due to the presence of capacitor C2, so that only the audio signal is amplified while the residual radio frequency carrier signal is suppressed. Using d.c. negative feedback via R2 stabilises the operating point of the two transistors, while capacitor C3 bypasses TR2's emitter resistor, R3, so increasing the gain of this stage at audio frequencies.

The collector load consists of potentiometer VR2, which forms a volume control enabling the signal level to TR3, the earpiece driver, to be varied.

CONSTRUCTION

The circuit is constructed on stripboard, as shown in Fig.28. Care must be taken to ensure that stray capacitance is minimised by keeping component leads as short as possible.

Aerial coil L1 is made by winding 10 turns of 28s.w.g. enamelled wire onto a

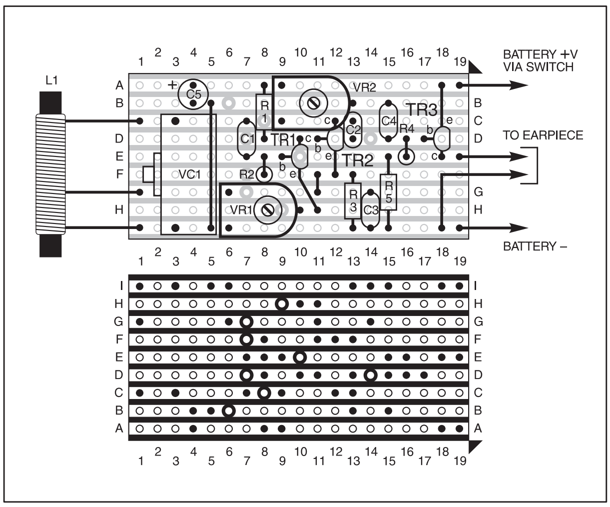
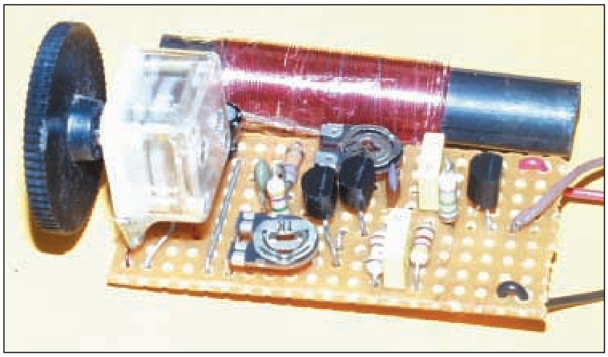


Fig.28. Radio stripboard component layout, wiring and details of breaks required in the underside copper tracks.



Completed radio showing the ferrite rod aerial.

Starting Next Month . . .
. . . RADIO CIRCUITS

Intended to dispel the mysteries of radio, this short series of articles by Raymond Haigh features a variety of circuits for the set builder and experimenter.

This new series will view the technology in an historical perspective and try to dispel its mysteries. The main purpose, however, is to present a variety of practical circuits.

You will be able to build a wide range of receivers, everything from a crystal set to a superhet.

piece of ferrite rod, 50mm long and 10mm in diameter. This forms the feedback winding and should be followed by a further 60 turns to form the main coil.

Each turn should be made adjacent to the previous one and the whole winding should be secured to the ferrite rod with insulation tape. The final number of turns may need to be adjusted (up or down) depending on the actual capacitance range of variable capacitor VC1, which is used to obtain the required medium waveband coverage.

Since it is easier to remove turns than to add them once the wire has been cut to length, it is preferable to initially wind slightly more turns than required.

A miniature tuning capacitor was used in the prototype for VC1, with a value range of 15pF to 165pF. The actual range is not too critical as most values can be accommodated by varying the number of turns on the coil, as just said, and/or connecting fixed capacitors across VC1 to adjust the range span.

TUNING CHECKS

Once construction is finished, VR1 and VR2 should be turned fully clockwise and a battery connected. Adjust VC1 until a station is heard and then adjust the signal amplitude using VR1. If the circuit oscillates (which is heard as a high pitched whistle in the earpiece) turn VR1 back slightly.

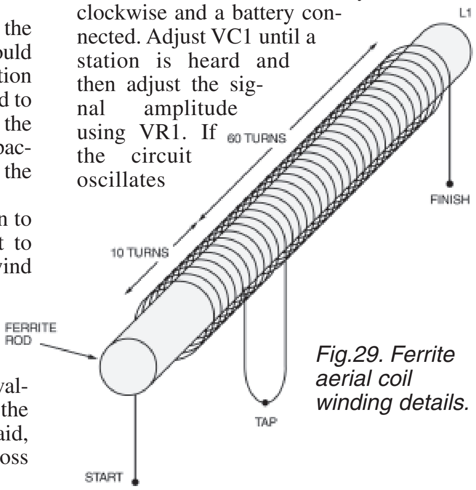


Fig.29. Ferrite aerial coil winding details.

Turn VC1 fully clockwise and check that no oscillation occurs on other stations, re-adjusting VR1 if required. The circuit should now not oscillate, irrespective of which station is tuned in.

The circuit will draw about 2mA, so an on/off switch is required. Alternatively, a 3·5mm stereo jack socket can be fitted for the earpiece with the tip terminal connected to TR3's collector, the centre terminal connected to the circuit's 0V line (marked as Battery –V). The battery negative itself is then connected to the outer terminal.

Inserting the earpiece plug will short out these last two terminals, switching on the power to the circuit. The principle is similar to that in Fig.7 of Part 1, Feb. '03.

In the concluding part of this series, next month, we describe a Twilight Switch, and a simple circuit for that most fascinating of all musical instruments – the Theremin.

SHOP TALK
with David Barrington

Super Motion Sensor

Nearly all of the "miniature" light-dependent resistors we looked up in various components catalogues seem to be within the specification required for the *Super Motion Sensor* project. A suitable l.d.r. should certainly be stocked by many of our component advertisers.

The 12V relay used for this project **must** have switching contacts rated for the appliance it is going to be controlling. This may mean that it will not sit directly on the circuit board so you will have to mount it separately and "hard wire" the relay to the p.c.b.'s appropriate copper pads. The Telecom type, mentioned by the author, should be widely available, but do not forget to check the contact ratings before purchase.

The TL071 low noise, low distortion op.amp is a popular device and should not present any buying problems. It was selected particularly for its high input impedances, which are necessary for this circuit. The 4066 quad bilateral switch i.c. is another popular widely-stocked device.

The Sensor printed circuit board is available from the *EPE PCB Service*, code 391 (see page 359).

Back-To-Basics 4 – Live Wire Detector/M.W. Radio

Some readers may experience problems with a couple of parts for the *Medium Wave Radio*, one of this month's *Back-To-Basics* projects.

Most components suppliers carry a 100mm length by 10mm diameter ferrite rod, which means readers will have to cut it to size. One problem, ferrite is very brittle and great care will be needed when cutting this material. One suggestion is to score around the rod diameter, at the required length, and then give it a "gentle" tap to snap it apart. We see that **WCN Supplies** (☎ ***023 8066 0700***) are currently "advertising" a 140mm x 10mm ferrite rod, with an unwanted tuning coil, at a reasonable price.

The specified tuning capacitor is normally found listed as a miniature "transistor radio" type. However, the favourite value is 20pF to 126pF, which should be OK for this simple radio. One was found listed by **ESR Components** (☎ ***0191 251 4363*** or ***www.esr.co.uk***), code 896-110.

No component problems should be met with the *Live Wire Detector*, the second simple project this month.

Door Chime

The audio amplifier i.c. chosen for the *Door Chime* project is the TDA7052 power amp chip which, in fact, contains two amplifiers in a single 8-pin d.i.l. package. This device is widely held and should not present any buying difficulties. You should certainly give ***Cricklewood Electronics*** (☎ ***020 8452 0161***) a call as we understand they have stocks.

The rest of the components are standard "off-the-shelf" items. Your local DIY superstore should have a suitable front doorbell pushswitch, if you do not already have one, of course. The small printed circuit board is available from the *EPE PCB Service*, code 390 (see page 359).

PLEASE TAKE NOTE

Earth Resistivity Logger *(April '03)*

Page 292. The wrong operating frequency for the crystal X1 is listed in the Components box. This should be 3·6864MHz. The circuit diagram Fig.5 and text are correct.

Shoptalk *(April '03)*

We regret that we gave an incorrect telephone number for Farnell and that it should be 0113 263 63**11**. You can also use 0870 1200 200.