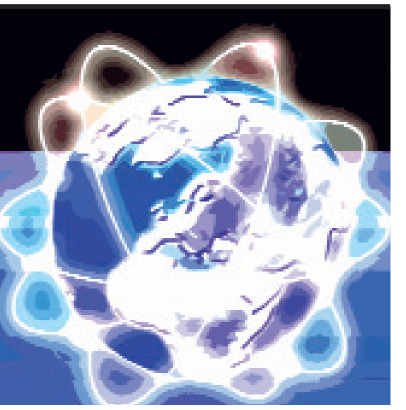
LF and VLF Converter



Raymond Haigh

Simple practical circuits for exploring the lower reaches of the electromagnetic spectrum

FOLLOWING on from the popular series on *Practical Radio Circuits* (June '03 to Jan '05), a number of readers have asked for a further article dealing specifically with reception on low (LF) and very low frequencies (VLF). This additional material has been prepared in response to their request and, as before, the emphasis is on practical circuits for experimenters.

The simple converter unit outlined here will allow a high performance receiver to tune into transmission from below 10kHz to 350kHz. Also, alternative aerial systems are described.

What's There?

Britain, Ireland, France, Germany and Russia, operate high-power broadcast transmitters in what is known as the long-wave band, covering 150kHz to 350kHz. An amateur band is centred on 136kHz and various other transmissions are radiated from 150kHz to below 10kHz. In the 1kHz to 20kHz region whistlers or howlers can be found – these are a natural electromagnetic phenomenon caused by distant lightning.

Longwave broadcasting did not take hold outside Europe. In the Americas, Canada, Australia and New Zealand, frequencies below 550kHz are allocated for time signals, military, government and commercial data, and marker beacons used primarily by the aviation industry.

As the frequency is lowered, electromagnetic waves penetrate water and earth to an increasing depth. Frequencies below 10kHz are used by the military for communicating with submarines. On a more peaceful note, localized communications with cavers or potholers are achieved on a frequency of 874Hz (the Molefone).

Whistlers

Natural electromagnetic phenomena, known as whistlers or howlers, occur at frequencies between 1kHz and 20kHz. Electromagnetic waves, caused by distant lightning, are distorted as they travel around the earth, and this produces a whistling or howling sound at the receiver. Greatest activity is usually during the summer months, between sunset and dawn.

Whistler receivers are no more than sensitive audio amplifiers connected to a short aerial. They incorporate filtering to exclude higher radio frequencies, and to curtail the response of the amplifier to mains hum and its harmonics. Despite these measures, whistler receivers must be battery powered and operated some distance from mains wiring and power lines.

Listening In

Receiving signals radiated at low (LF) and very low frequencies (VLF) presents no major difficulties, and the add-on circuits described here will extend the coverage of the two high performance receiver designs, Regenerative and Superhet, included in the *Practical Radio Circuits* series.

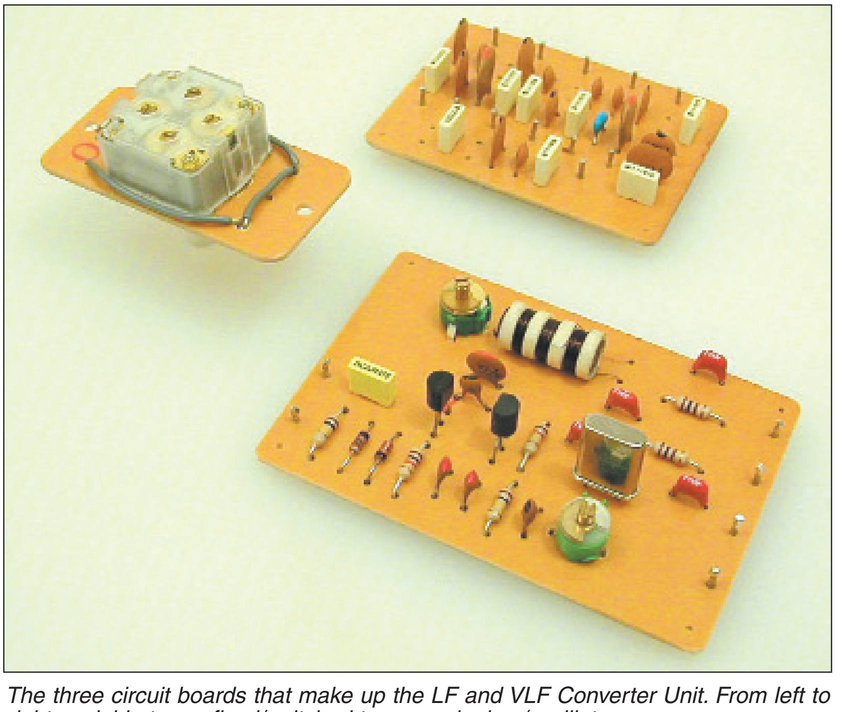
Serious listeners often use commercial communications receivers, again with add-on units to extend coverage and/or improve performance. The circuits presented in this article are equally suitable for equipment of this kind.

The tuning circuits must, of course, contain much more inductance and capacitance to resonate at the lower frequencies. Wire aerials, even when physically quite long, are only a small fraction of a wavelength. Because of this, they terminate at a high impedance which needs to be matched to the receiver.

Man-made and natural electrical disturbances result in comparatively high noise levels at low frequencies. The problem is inevitably worse in urban areas, and is often the limiting factor in resolving very weak signals.

Converter Unit

Some communications receivers can be tuned to the lowest reaches of the spectrum, but most end their coverage at or above 100kHz. Many incorporate broadband input filters, and performance deteriorates at low frequencies. Even if the receiver has fully variable front end tuning, there is



The three circuit boards that make up the LF and VLF Converter Unit. From left to right: variable tuner, fixed/switched tuner, and mixer/oscillator

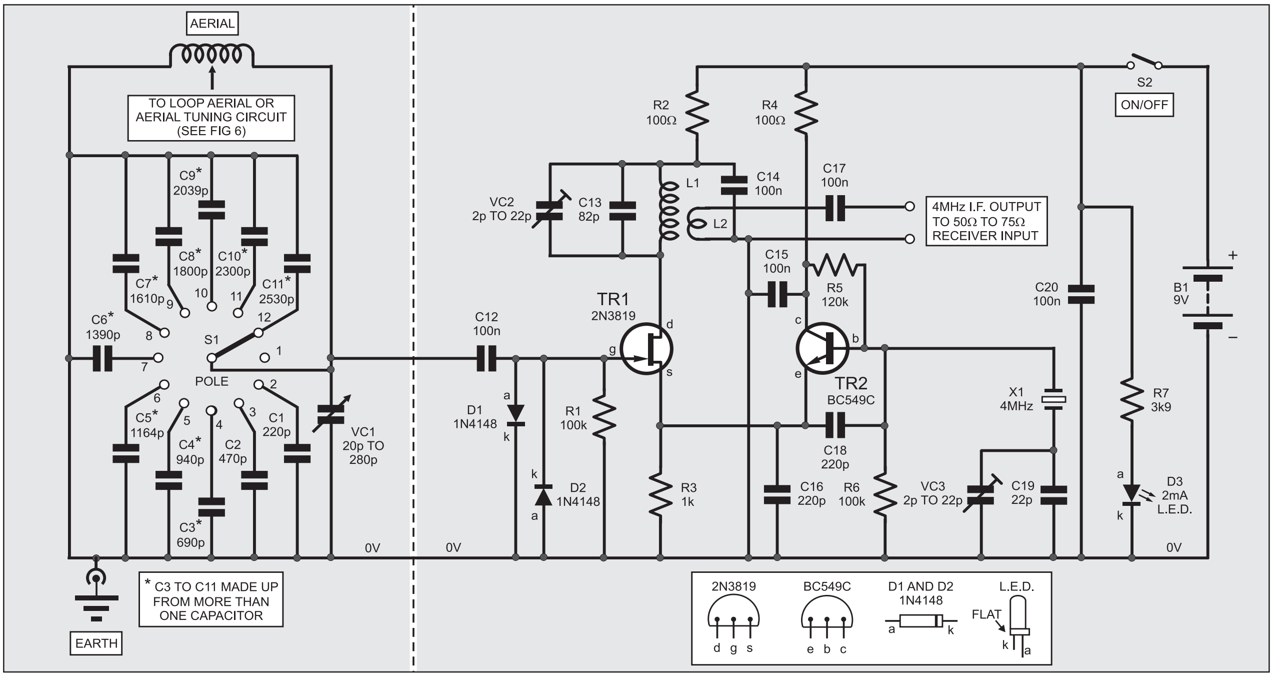


Fig.1. Full circuit diagram for the LF/VLF Converter. The circuit is split in two sections; tuning and mixer/oscillator

often a considerable mismatch to the aerial on longwaves, and signal transfer is less than optimum.

A step-up converter, which changes the frequency of incoming signals to, say, 4MHz, overcomes the problem of coverage. With appropriate input circuits, signal losses due to broad tuning and aerial mismatch can be reduced significantly.

All Change

Frequency changing, which is fundamental to superhet receivers, was covered at length in the "Radio" series (June'03 to Jan'04). In brief, a locally generated oscillation is combined with the incoming signal in a mixer stage, and the difference between the two, known as the intermediate frequency, is selected by a tuned circuit connected to the mixer's output port.

The intermediate frequency (i.f.) is usually fixed, and the receiver tuned by altering the oscillator frequency and adjusting the input circuits. When only a narrow band of frequencies has to be covered, it is often more convenient to fix the oscillator frequency and tune the system by varying the intermediate frequency instead.

The entire VLF/LF spectrum is located within a band of frequencies no more than 350kHz wide, and a single 4MHz i.f. transformer, "damped" by the mixer and the feeder to the receiver, will tune broadly enough to accommodate it. The precise i.f. is varied by sweeping the communication receiver's tuning from 4MHz to 4·350MHz, which gives a signal frequency coverage from zero to 350kHz.

LF/VLF Converter Circuit

The circuit diagram for the LF/VLF Converter is shown in Fig.1, where the fixed tuning capacitors, C1 to C11 are selected by rotary switch S1. The switched increments of capacitance are smaller than the maximum value of the variable tuning capacitor, VC1, and the arrangement thus provides a continuously variable capacitance swing of around 20pF to 2800pF.

Details of an inductor (coil), which completes the tuned circuit, are given later, together with details of a Loop Aerial.

Front panel controls of the Converter

Mixer

The received signal is applied, via d.c. blocking capacitor C12, to the gate (g) of the field-effect transistor mixer stage TR1. High impedance at the gate minimizes damping on the input tuned circuit.

Diodes D1 and D2 shunt signals in excess of around 0·6V and protect the transistor against static damage. (Long wire aerials and high value tuning inductors increase the vulnerability of the unit).

The gate (g) of TR1 is connected to the 0V rail via resistor R1 in order to ensure correct biasing.

Oscillator

Transistor TR2 is configured as a Colpitt's oscillator. The operating frequency is fixed, with a high degree of accuracy and stability, by quartz crystal X1.

The crystal is loaded by capacitor C19 and trimmer VC3: the latter permits the frequency of oscillation to be set at precisely 4MHz. Readers who do not require the main receiver's dial reading to be very precise can delete VC3 (the dial readings will still be accurate enough for all but the most demanding applications).

Positive feedback, from TR2 emitter (e), is injected via capacitors C16 and C18, and resistors R5 and R6 set the bias on the base (b) of TR2. The oscillator output is developed across emitter resistor R3. This component also acts as the source bias resistor for transistor TR1, and the local oscillation is thereby injected directly into the mixer.

The stage is decoupled from the supply rail by resistor R4 and capacitor C15.

I.F. Output

The tuned circuit formed by coil L1, trimmer capacitor VC2 and capacitor C13, selects the 4MHz i.f. output (it passes a band of frequencies from 4MHz to 4·350MHz, see earlier). Matching to the low impedance input of the communications receiver is achieved by coil L2, and C17 acts as a d.c. blocking capacitor (some receivers can have d.c. voltages on their input circuitry).

The mixer stage, TR1, is decoupled from the supply by resistor R2 and capacitor C14.

Powering Up

Current drain is very modest, around 4mA plus the current taken by the optional l.e.d., D3, On indicator and its ballast resistor, R7.

A PP3 type battery is, therefore, an appropriate and convenient means of powering the Converter. Switch S2 connects power to the circuit and bypass capacitor C20 ensures stability and consistent operation as the battery ages.

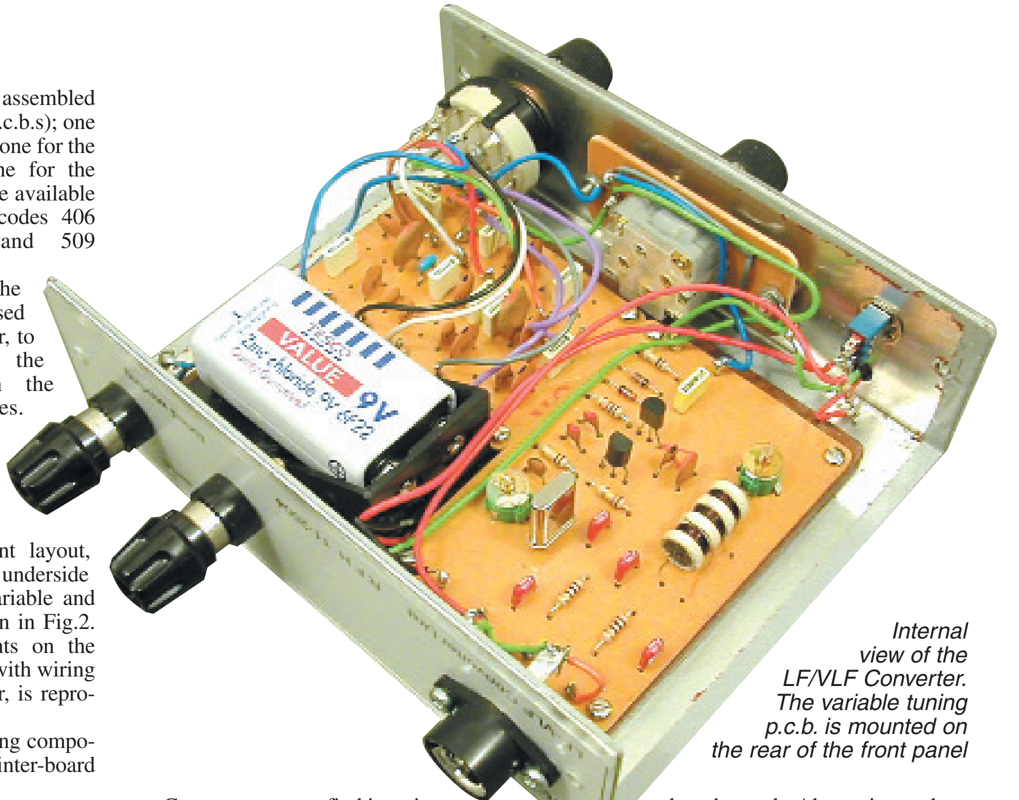
Construction

The LF/VLF Converter unit is assembled on three printed circuit boards (p.c.b.s); one for the variable tuning capacitor, one for the fixed tuning capacitors and one for the mixer/oscillator. These boards are available from the *EPE PCB Service*, codes 406 (Tun.cap), 508 (Fix.cap) and 509 (Mix./Osc) respectively.

This arrangement permits the tuning capacitor system to be used with the simple Buffer Amplifier, to be described later, or with the Regenerative Receiver from the *Practical Radio Circuits* series. Further, readers who have air-spaced tuning capacitors in their spares boxes can substitute them for the polythene dielectric types.

The topside p.c.b. component layout, interwiring details and full-size underside copper track masters for the variable and fixed capacitor boards are shown in Fig.2. The arrangement of components on the mixer/oscillator board, together with wiring details and full-size track master, is reproduced in Fig.3.

General guidance on assembling components on the boards, and the inter-board wiring, is given later.



Internal view of the LF/VLF Converter. The variable tuning p.c.b. is mounted on the rear of the front panel

I.F. Transformer

Intermediate frequency transformer, L1/L2, is produced by winding 36s.w.g. (32a.w.g.) enamelled copper wire onto an 18mm (3/4in) long former, cut from a piece of scrap 6mm (1/4in) diameter plastic potentiometer spindle. Full details of the coil winding and construction are given in Fig.4.

Constructors may find it easier to wind the coil on the end of a longer spindle off-cut and then remove the unwanted material after completing the coil construction.

Alternative I.F.s

Some receivers may not tune to 4MHz, and the intermediate frequency will need to be changed. Alternative values for fixed capacitor C13 are also given in Fig.4 to enable coil L1 to be tuned to other crystal frequencies within the range of 4MHz to 10MHz.

The precise value of the crystal is not important, but the use of a "round figure" unit makes it easier to relate dial setting to reception frequency.

COMPONENTS

CONVERTER

Resistors

- R1, R6 — 100k (2 off)
- R2, R4 — 100Ω (2 off)
- R3 — 1k
- R5 — 120k
- R7 — 3k9

All 0·25W 5% carbon film or better

See SHOP TALK page

Capacitors

- C1 — 220p low-k ceramic
- C2 — 470p low-k ceramic
- C3 — 690p low-k ceramic (220p plus 470p)
- C4 — 940p low-k ceramic (470p plus 470p)
- C5 — 1164p (1000p polyester plus 82p plus 82p low-k ceramic)
- C6 — 1390p (1000p polyester plus 390p low-k ceramic)
- C7 — 1610p (1000p polyester plus 390p plus 220p low-k ceramic)
- C8 — 1800p (1000p polyester plus 470p plus 330p low-k ceramic)
- C9 — 2039p (1000p plus 1000p polyester plus 39p low-k ceramic)
- C10 — 2300p (2200p polyester plus 100p low-k ceramic)
- C11 — 2530p (2200p polyester plus 330p low-k ceramic)
- C12 — 100n polyester
- C13 — 82p low-k ceramic
- C14, C15, C17, C20 — 100n ceramic (4 off)
- C16, C18 — 220p low-k ceramic (2 off)
- C19 — 22p low-k ceramic
- VC1 — 20p to 280p 4-gang a.m./f.m. polyvaricon tuning capacitor
- VC2,VC3 — 2p to 22p min. film dielectric trimmer (2 off)

Semiconductors

- D1, D2 — 1N4148 signal diode (2 off)
- D3 — 2mA low current l.e.d., red
- TR1 — 2N3819 *n*-channel field-effect transistor
- TR2 — BC549C *npn* transistor

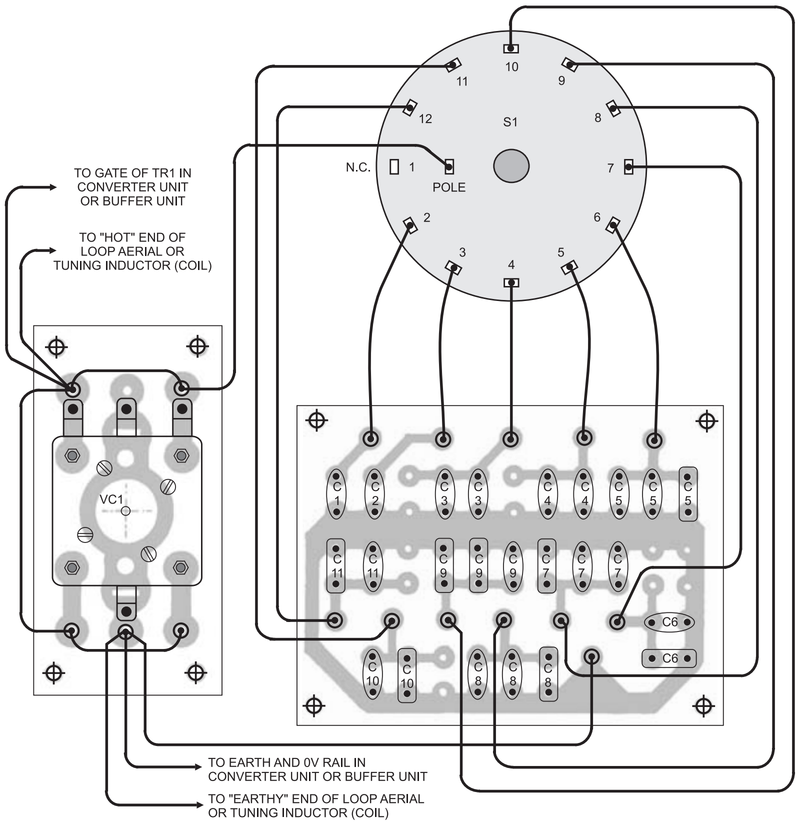
Miscellaneous

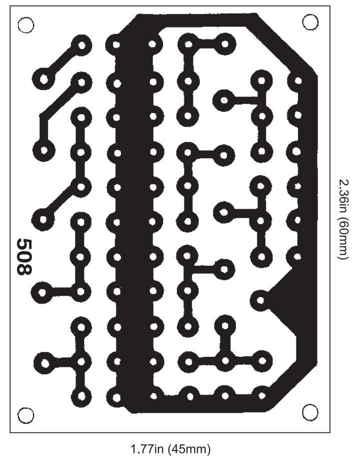
- L1/L2 — 2 metres (6ft) 36s.w.g. (32a.w.g.) enamelled copper wire. Masking tape and short length of 6mm (1/4in) diameter plastic spindle off-cut (see text)
- X1 — 4MHz crystal unit in HC49/U or U4 style case
- S1 — 1-pole 12-way rotary switch
- S2 — single-pole, single-throw toggle switch
- B1 — 9V PP3 type battery, with clips

Printed circuit boards available from the *EPE PCB Service* codes 406 (Tune Cap), 508 (Switch Cap) and 509 (Mix/Osc); aluminium case, size 133mm (5.25in.) x 102mm (4in.) x 38mm (1·5in.); coaxial socket; screw terminal (2 off); plastic knob (2 off); l.e.d. holder; battery holder; multistrand connecting wire; p.c.b. stand-off pillars (10 off); self-adhesive feet (4 off); card and thin Perspex sheet for case front panel; spindle extender for polyvaricon capacitor; nuts; bolts; washers; solder pins; solder etc.

Approx. Cost Guidance Only £25 excl case hardware & batts

LF/VLF TUNING AND CONVERTER BOARDS





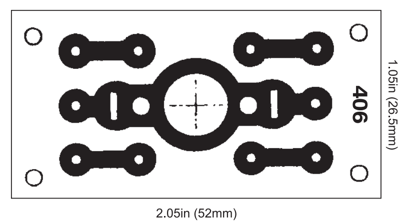
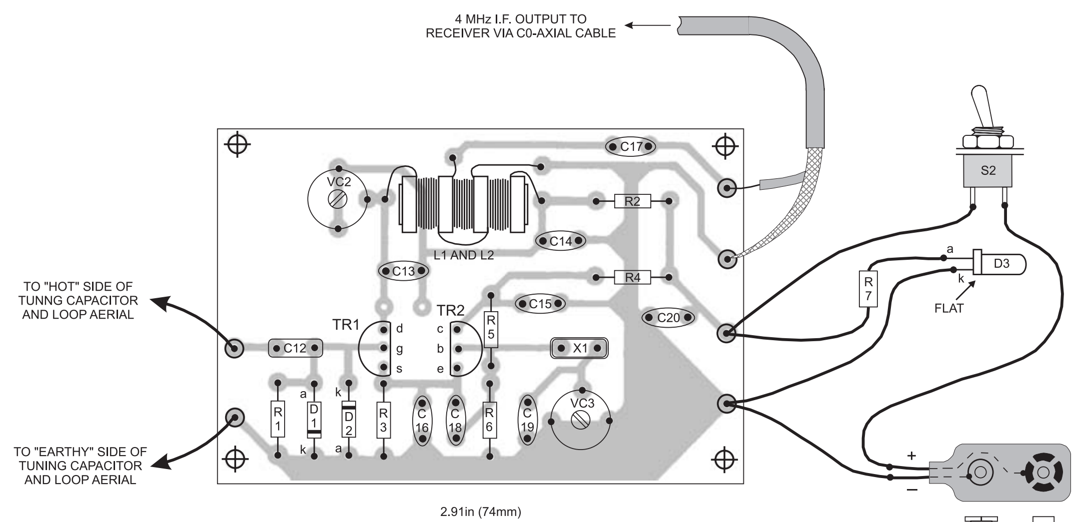


Fig.2. Printed circuit board component layouts (above) and full-size copper track masters (above right) for the variable and switched tuning circuits



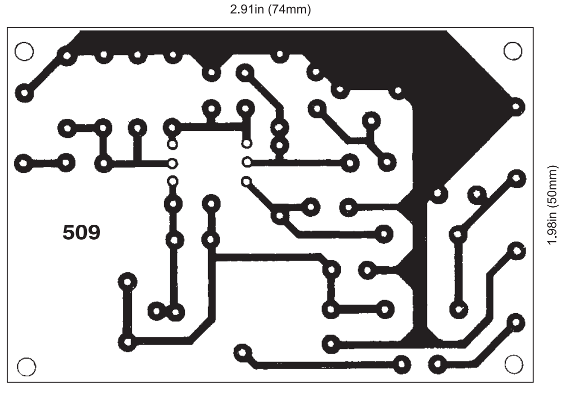
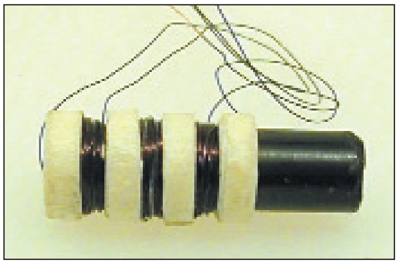


Fig.3. Printed circuit board component layouts, wiring details and full-size copper track master for the mixer/oscillator circuit



Completed i.f. transformer. The excess plastic spindle should be trimmed back to the bobbin cheek

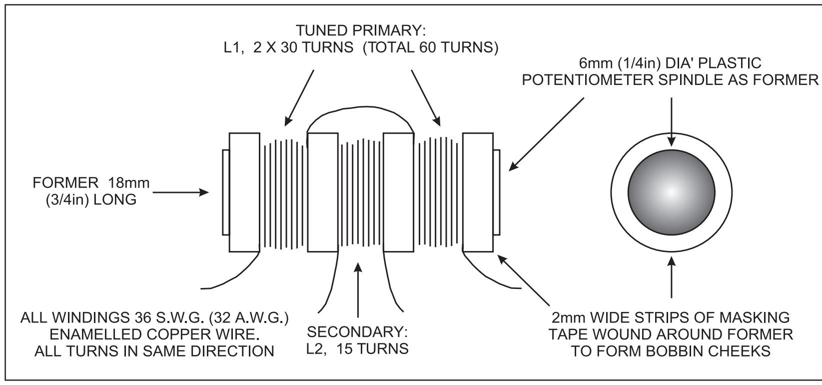


Fig.4. Converter i.f. transformer construction and winding details. Wind the central secondary section first to permit loop-over between the two primary sections. Primary is tuned with a 2p to 22p trimmer plus a fixed capacitor – see Fig.1. Fixed capacitor values for various i.f. frequencies are as follows: 4MHz 82p; 6MHz 39p; 8MHz 10p; 10MHz nil

Table 1: LF/VLF Tuning Inductor Coil
Measured Inductance Values

Tapping No	*No of Turns*	*Inductance mH*
1	100	1·3
2	200	3·9
3	300	7·7
4	400	12·8
5	500	19·9
6	600	27·2
7	700	36·0
8	800	44·8
9	900	54·6
10	1000	64·4
11	1100	74·7
12	1200	85·5
13	1300	95·2

Notes:
(1) See Fig.6 for details of coil.
(2) Inductance values will be slightly lower if unused windings are shorted out.

TAPPED INDUCTOR – YOU WILL NEED

Reel (50g – 2oz) of 36s.w.g. (32a.w.g.) enamelled copper wire; plastic overflow pipe for coil former, length 125mm (5in.) with 21mm (7/8in) outside diameter; ferrite rod, 9mm (3/8in) diameter × 125mm (5in) long; thin card (postcard); masking tape; Durofix adhesive, or similar; small pieces of plywood or MDF; 19-way tagstrip (see Fig.6); screws.

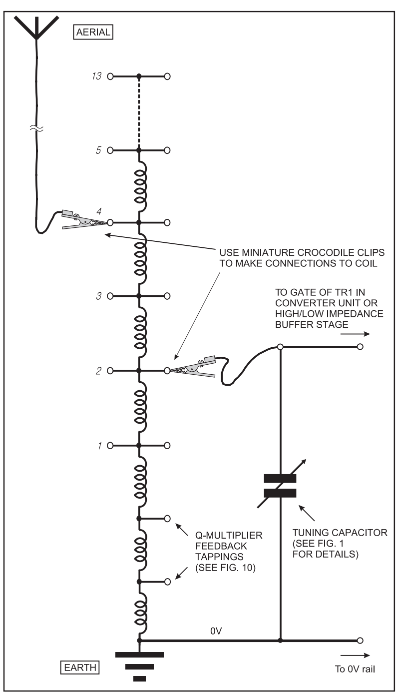


Fig.5. Circuit schematic for a tapped inductor coil to help match the aerial to the receiver. See Table 1 for schedule of inductance values

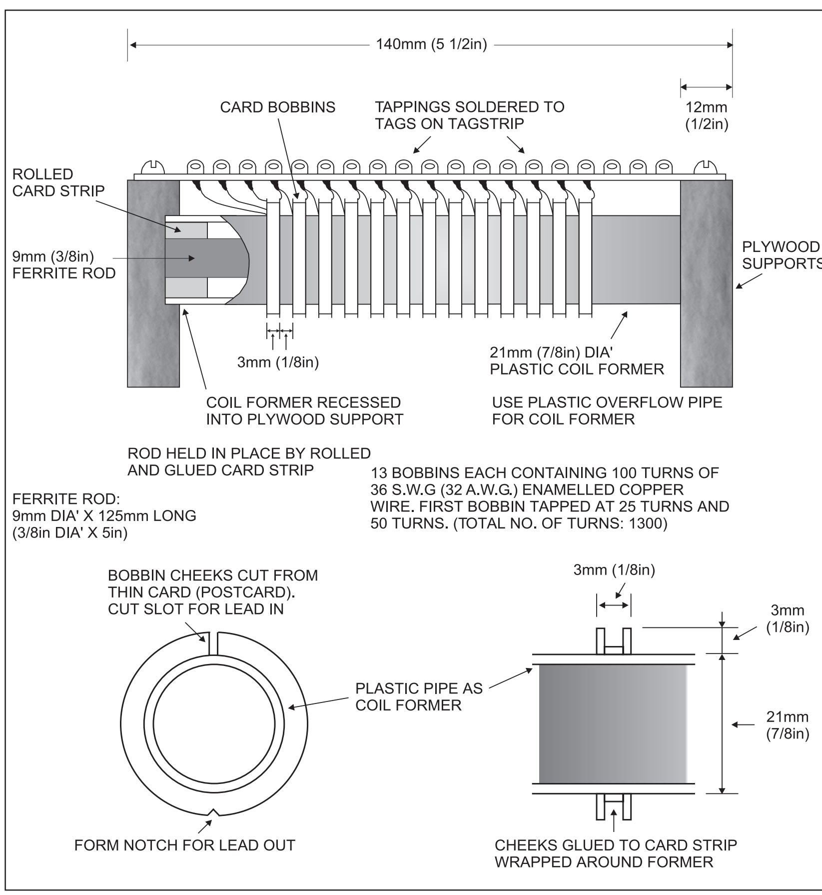


Fig.6. LF/VLF tuning inductor coil construction details. See Table 1 for coil winding turns information. Tappings at the start of the coil are for injection of positive feed-back to produce Q-multiplication (see text)

Tuning Inductors (Coils)

The formulae relating inductance, capacitance and frequency in a tuned circuit are given in the accompanying panel. They have been expressed in the units normally encountered at these frequencies. If the value of the inductance is known, it is a simple matter to calculate the capacitance required to tune it to a desired frequency, and vice versa.

FORMULAE RELATING RESONANT FREQUENCY TO THE INDUCTANCE AND CAPACITANCE IN A TUNED CIRCUIT

When inductance (**L**) is measured in millihenries (**mH**), Capacitance (**C**) is measured in microfarads (**μF**), and frequency (*f*) is measured in kilohertz (**kHz**), the following formulae apply:

$$f = \frac{5{\cdot}033}{\sqrt{LC}} \qquad L = \frac{25{\cdot}33}{f^2C} \qquad C = \frac{25{\cdot}33}{f^2L}$$

$0{\cdot}001\mu\mathbf{F} = 1000\mathbf{pF}$ $\qquad$ $1\mathbf{mH} = 1000\mu\mathbf{H}$

Example:

What value capacitor is required to tune a 3mH inductor to 200kHz?

$$C = \frac{25{\cdot}33}{200 \times 200 \times 3}$$

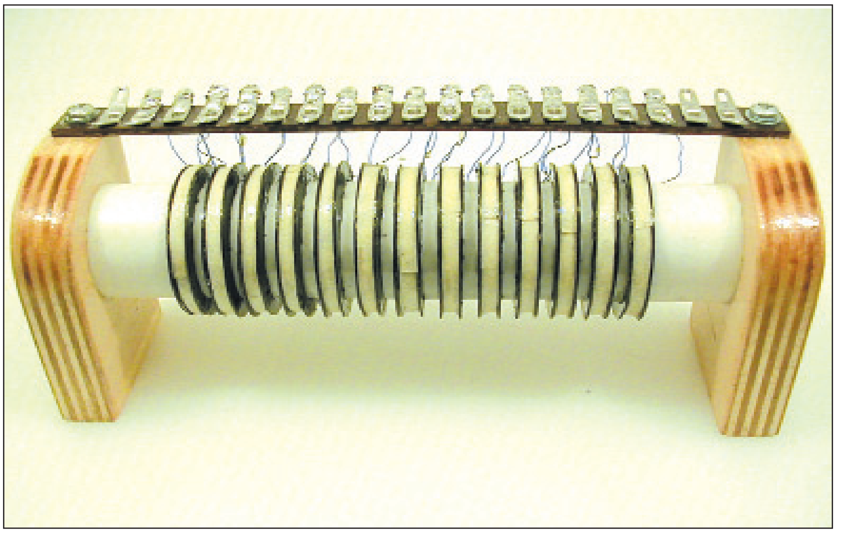
$$= 0{\cdot}000211\mu F$$

$$= 211 pF$$

The only commercial coils currently available to home constructors are those manufactured by Toko. A CAN1A350EK longwave aerial coil, with both windings connected in series and the ferrite core screwed fully down, presents an inductance of 4·4mH. Teamed with the tuning capacitor unit already described, this will permit coverage down to 45kHz.

A longwave ferrite loop aerial coil, placed at the centre of its rod, will have an inductance of approximately 5mH, and the capacitor arrangement will tune this down to 42kHz. If the medium wave winding (usually part of the rod aerial) is placed in series with it, and both are located centrally on the ferrite rod, the combined inductance will increase to around 7mH, permitting tuning down to 36kHz.

From the foregoing, it will be appreciated that suitable inductors (coils), with tappings for the injection of positive feedback, are not difficult to find. The addition of more capacitance will, of course, tune them to lower frequencies.



Assembled LF/VLF aerial-to-receiver matching tapped inductor coil

Ratios

A reasonable ratio between capacitance and inductance has to be maintained, however, or performance will suffer. Large values of capacitance should not be placed in parallel with a low value of inductance to tune to the desired frequency.

A very rough rule of thumb is to try and keep the inductance, expressed in microhenries (μH), equal to or more than the capacitance, expressed in picofarads (pF).

Aerial Matching

Long wire aerials, connected to Earth via the receiver's input circuitry, become resonant when they are a quarter of a wavelength long. They then present a low impedance. A quarter of a wavelength at 100kHz is 750 metres (approximately 2500ft). Few readers will have the space (or the inclination) to erect so much wire, but impedance increases as length reduces below this ideal.

Under these conditions, signal transfer and performance can be improved by connecting an inductance in series with the aerial. This has the effect of lengthening the wire electrically, and the amount required is best determined by trial and error.

Tapped Coil

An inductor which can be tuned down to a low frequency, and which assists in the matching of aerial to receiver, is illustrated in Fig.6 and its circuit schematic diagram is shown in Fig.5.

Thirteen sections (coils) are connected in series, and there are additional tapping points at the "earthy" end for the injection of Q-multiplying positive feedback, should this be required. The aerial and receiver are connected to the coil tappings by miniature crocodile clips and, unless the aerial is comparatively long, feeding the aerial to a "higher" tapping point than transistor TR1's gate will usually improve signal transfer and selectivity (see Fig.5).

Combining the coil with a simple buffer amplifier results in the signal input to the receiver being increased by some 20dB.

Inductance values at the various coil tapping points are given in Table 1. Using half of the coil (36mH) and the capacitor described earlier, tuning can be extended down to 16kHz. The remaining sections of the coil can be used to improve matching to an electrically very short aerial.

Coil Construction

The inductor coil sections are wound between card bobbins spaced along a former cut from a length of 21mm (7/8in.) diameter plastic overflow pipe. The inductance and Q-factor are increased by the use of a 9mm (3/8in.) dia. × 125mm (5in.) length of ferrite rod as a core.

Full details of the inductor coil construction are given in Fig.6, and little needs to be added. A modeling knife is useful for cutting out the card cheeks, and Durofix, or a similar quick setting adhesive, is best for sticking the cheeks to card strips, wrapped around the former, to construct the bobbins.

Dip the bobbins in cellulose or shellac to harden them after the glue has set. The windings can be protected by a thin strip of masking tape, but they should not be impregnated.

Loop Aerial

A tuned (resonant) loop aerial has much to commend it for low frequency reception. Provided its diameter is greater than one metre (3ft), signal pick-up usually exceeds that from the 20 metres (65ft) or so of wire that can be accommodated in most gardens.

More important, a loop exhibits a pronounced null in pick-up when its axis is pointing towards a noise or signal source. This property can be used to almost completely eliminate local interference.

Loop Construction

A suggested design for a 104cm (41in) diameter loop aerial is given in Fig.7. The completed loop is shown in the accompanying photographs.

Eight radial arms support the windings, which are spaced and held in place by horizontal comb pieces. Although a little more difficult to construct than a simple square, the octagon is closer to the ideal circular form, and the increased number of supports is desirable for the sixty-turn winding.

Again, little needs to be added to the information given on the drawing. Materials and methods of construction are not hard and fast, and readers will have their own ideas for assembling the support framework. A plastic stand from an old typist's chair makes an ideal base if the castors are removed.

The gauge and type of wire used for the loop windings are not critical, but the specified weight of 24s.w.g. enamelled copper wire will be enough for 60 turns with a little to spare.

LOOP AERIAL – YOU WILL NEED

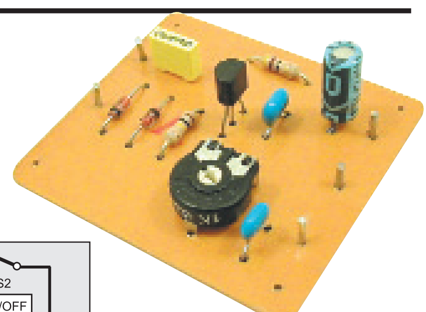
Reel (500g – 1lb) of 24s.w.g. (23a.w.g.) enamelled copper wire (NB 1lb is tight at the thicker a.w.g., and American readers might wish to play safe and purchase 1lb of their slightly thinner 24a.w.g.); softwood strip, 31mm × 21mm (1 1/4in. × 3/4in.), 6 metres (20ft); sheet of 6mm (1/4in.) plywood for plates and combs, 1000mm × 600mm (3ft × 2ft); softwood, 150mm × 18mm (6in. × 3/4in.) 1500mm (48in.).

Plastic waste pipe, 41mm (1 1/2in.) outside diameter; glue; screws; rubber feet; nylon ball from deodorant bottle; tag strip.

Completed home-brewed loop aerial

The measured inductance of a half winding (30 turns) is 1·65mH and of the full winding (60 turns) around 4·74mH. The calculated self-capacitance of the full winding is 60pF, and this should be taken into account when estimating the capacitance needed to tune to higher frequencies within the band.

Buffer Amplifier



Readers who have a communications receiver that can be tuned below 100kHz, or who wish to use a regenerative receiver, will need a simple buffer amplifier to match the tuned circuits just described to the aerial input terminals on their sets.

Circuit Details

The circuit diagram for a Simple Buffer Amplifier is shown in Fig.8. Field-effect transistor TR1 is configured as a source follower (common drain) stage.

Its high input impedance minimizes damping on the signal-frequency tuned circuit, and its low output impedance ensures a good match to the receiver's input circuitry. There is no voltage gain, but the impedance transformation results in some power gain.

The output is developed across source load preset potentiometer VR1. Making this a variable preset enables the output to be reduced to avoid overloading the receiver. If desired, a standard rotary potentiometer can be substituted as a front panel control, but the leads to the printed circuit board, if longer than 75mm (3in), must be screened.

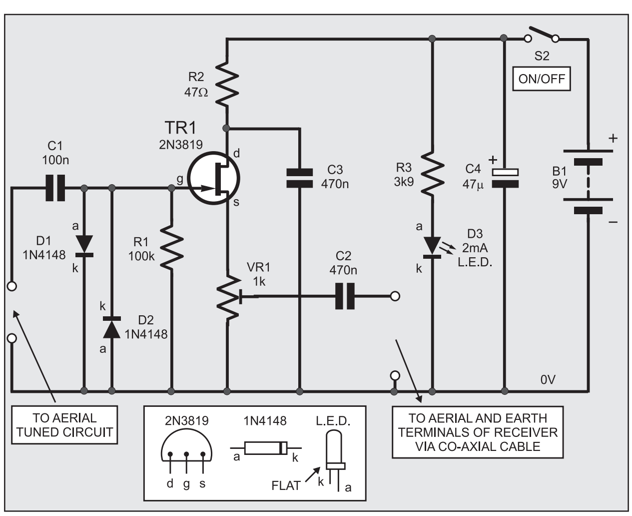


Fig.8. Circuit diagram for a high/low impedance Buffer Amplifier. This will match high impedance LF/VLF tuned circuits to the low impedance aerial input of a communications receiver

Together with preset VR1, gate resistor R1 ensures the correct biasing of transistor TR1; C1 is a d.c. blocking capacitor and diodes D1 and D2 protect TR1's gate (g) from high voltages. The stage is decoupled by R2 and C3, and C2 functions as a d.c. blocking capacitor in the output feed.

The l.e.d. On indicator, D3, with its dropping resistor R3 is optional. Stability with ageing batteries is ensured by capacitor C4, and switch S1 connects the battery to the circuit.

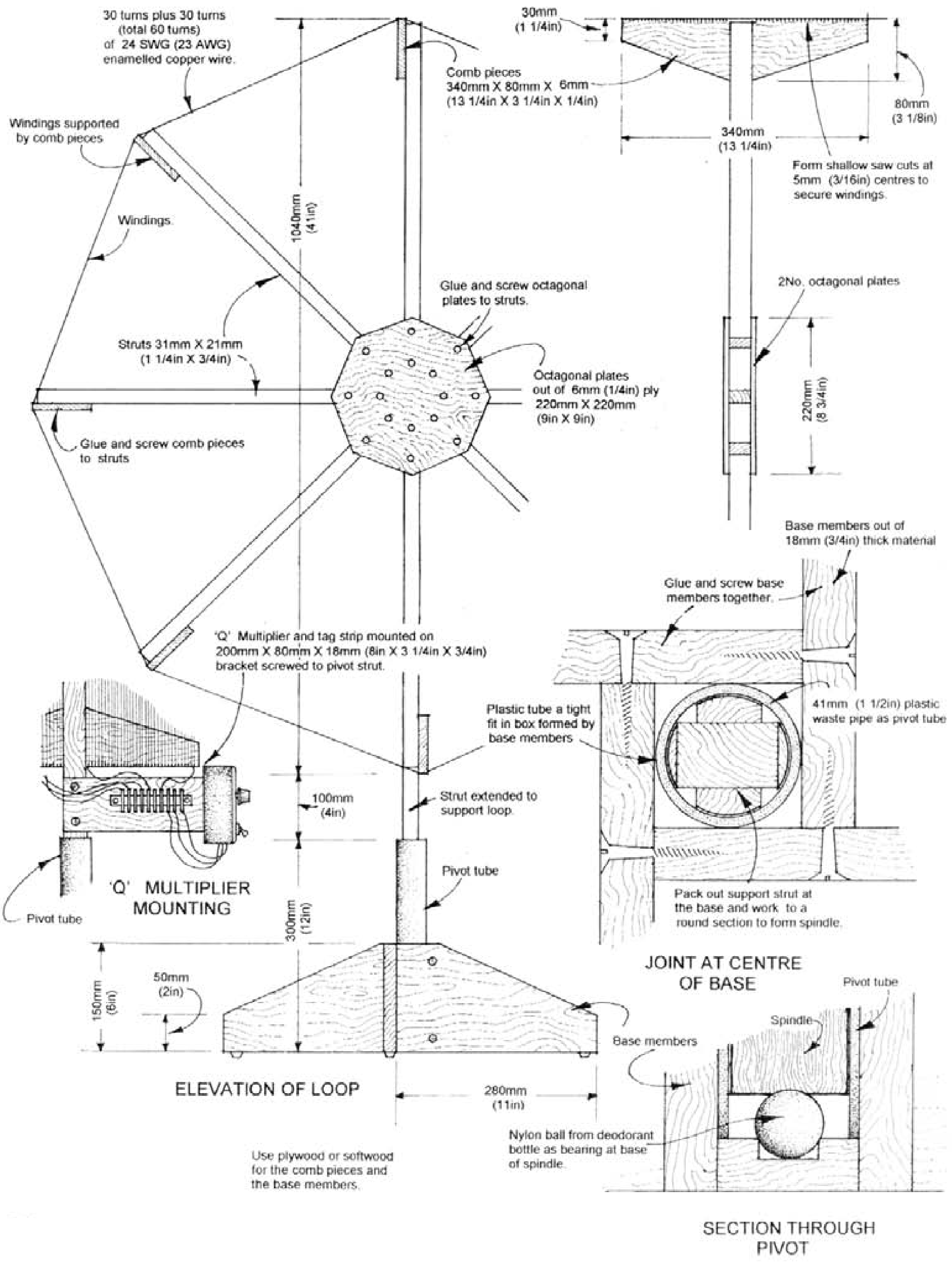


Fig.7. Constructional details for an LF/VLF Loop Aerial with optimal Q-Multiplier. Eight radial arms support the 24s.w.g. enamelled copper wire windings

These drawings are not to scale.

Construction

With the exception of l.e.d. D3, R3 and S1, the various components are assembled on the small printed circuit board as illustrated in Fig.9. Details of the off-board wiring and a full-size copper track master are also included in this diagram.

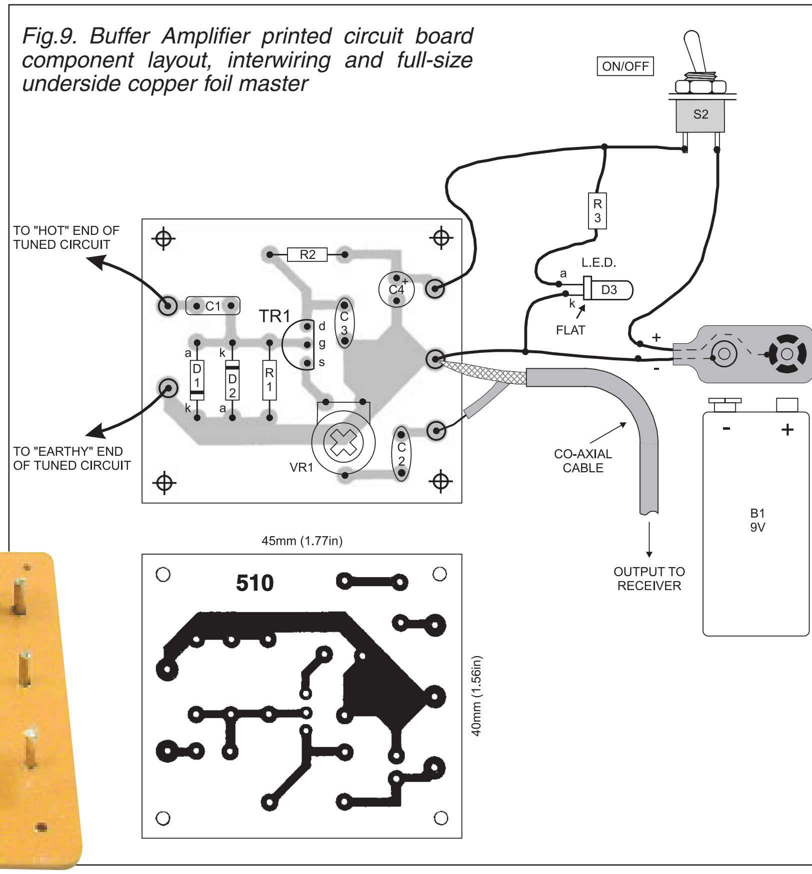


Fig.9. Buffer Amplifier printed circuit board component layout, interwiring and full-size underside copper foil master

COMPONENTS

BUFFER AMPLIFIER

Resistors
R1 100k
R2 47Ω
R3 3k9
All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers
VR1 1k enclosed preset, horiz.

Capacitors
C1 100n polyester
C2, C3 470n ceramic (2 off)
C4 47µ radial elect. 25V

Semiconductors
D1, D2, 1N4148 signal diode (2off)
D3 2mA low current l.e.d., red
TR1 2N3819 *n*-channel field-effect transistor

Miscellaneous
S1 single-pole, single-throw toggle switch.
B1 9V PP3 type battery, with clips

Printed circuit board available from the *EPE PCB Service*, code 510; l.e.d. holder; battery holder; screw terminal (2 off); coaxial socket; multistrand connecting wire; p.c.b. stand-off (4 off); nuts, bolts and washers; solder pins; solder etc.

NB. This unit would be normally be mounted in a metal case, together with the tuning capacitor arrangement.

Approx. Cost Guidance Only **£9** *excl case & batts*

Q-Multiplier

The relationship between the Q-factor and tuned circuit magnification was discussed in Parts One and Two of the *Practical Radio* series mentioned earlier. In brief, the Q-factor is a figure of merit that defines the ability of a tuned circuit to resonate sharply, and to magnify signal voltages at its resonant frequency. Put simply, and assuming resonance, a signal of 10mV applied to a tuned circuit with a "Q" of 100 will be magnified to 1V.

The "Q" of a tuning coil can be increased by the application of positive feedback, and a simple Q-Multiplier and Loop Aerial circuit is shown in Fig.10. Field-effect transistor TR1 functions here as a Hartley oscillator. Its gain, and hence the amount of positive feedback, is controlled by potentiometer VR3, which varies the voltage on its drain (d) terminal. Bypass capacitor C2 decouples the stage and eliminates potentiometer wiper (moving contact) "noise".

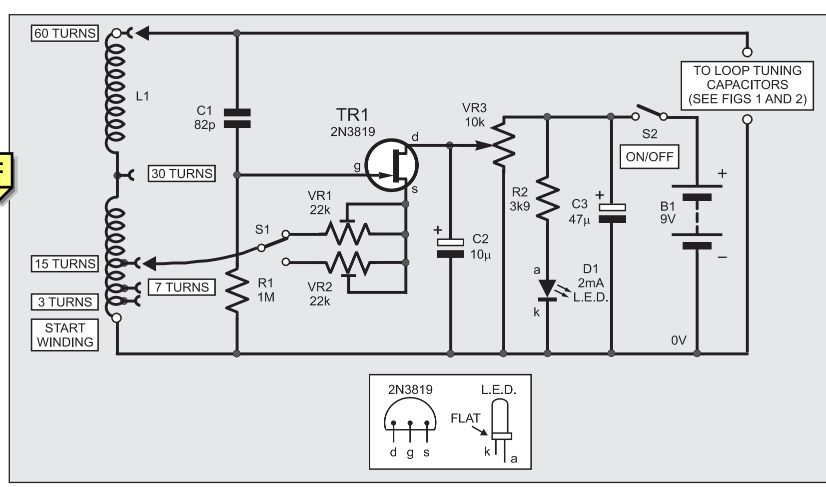
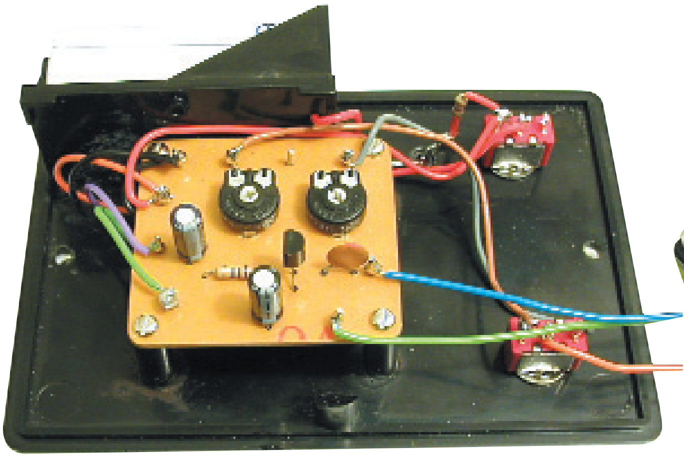


Fig.10. Circuit diagram for the Q-Multiplier and Loop Aerial. The Q-Multiplier can be used with any LF/VLF turning coil and ferrite-cored loops



Q-Multiplier circuit board mounted on the lid of the case

Front panel layout of the Q-Multiplier

The multiplier is connected to the "hot" end of the tuned circuit via capacitor C1. Resistor R1 ensures the correct biasing of the transistor.

Feedback is preset by selecting the required tapping on the coil and by adjusting TR1's source (s) presets VR1 and VR2, wired as variable resistors. One or other of these presets is switched into circuit by switch S1. This arrangement ensures the smooth operation of the Q-Multiplier control VR3 at all settings of the switched tuning capacitor p.c.b.

The purpose of the remaining components will be evident from earlier circuit descriptions.

Construction

The printed circuit board component layout, off-board component interwiring details and a full-size underside copper foil master pattern for the Q-Multiplier are shown in Fig.11. This board is available from the *EPE PCB Service*, code 511. Also shown are the lead-off wires to the loop or tuning coil, including the feedback tapping lead.

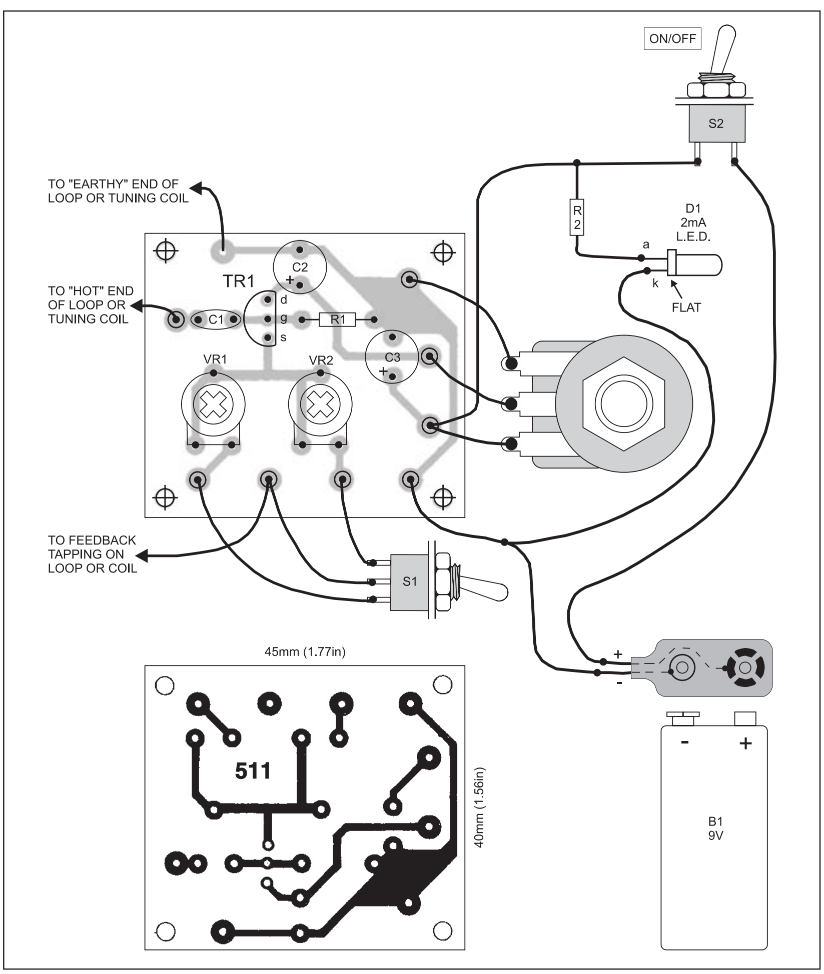


Fig.11. Q-Multiplier printed circuit board component layout, wiring to off-board components and full-size copper foil masters

COMPONENTS

Q-MULTIPLIER

Resistors
R1 1M
R2 3k9
All 0·25W 5% carbon film

See SHOP TALK page

Potentiometers
VR1,VR2 22k enclosed preset, hor. (2 off)
VR3 10K rotary carbon, lin.

Capacitors
C1 82p low-k ceramic
C2 10µ radial elect. 25V
C3 47µ radial elect. 25V

Semiconductors
D1 2mA low current l.e.d. red
TR1 2N3819 *n*-channel field-effect transistor

Miscellaneous
S1 single-pole, double-throw toggle switch
S2 single-pole single-throw toggle switch
B1 9V PP3 type battery, with clips

Printed circuit board available from the *EPE PCB Service*, code 511; small plastic case, size 102mm(4in.) x 76mm (3in.) x 40mm (1.57in.); l.e.d. holder; plastic knob; battery holder; multistrand connecting wire; p.c.b. stand-off (4 off); card and thin Perspex sheet for front panel; nuts, bolts and washers; solder pins; solder etc.

NB. When used with the Aerial Loop, this unit is mounted on the frame pivot and wired directly to the loop tag-strip.

Approx. Cost Guidance Only **£10** *excl case & batts*

Components

Almost any *n*-channel junction field-effect transistor should be suitable for these circuits. But check base connections as some are bound to vary. Similarly, almost any small-signal *npn* bipolar transistor should function as the oscillator, TR2, in the Converter unit. However, reliable oscillation and a decent input to the mixer will be ensured by the use a device with good h_{fe} and f_T figures, especially if the i.f. frequency is increased to 10MHz.

Close tolerance polystyrene capacitors are the preferred components for the switched tuning system. High value examples are, however, expensive and bulky. With this in mind, low-k ceramic capacitors have been specified for values up to 470pF, and polyester components for the 1nF and 2·2nF units. Do not use high value ceramic capacitors. Their "Q" factor and stability can be low, and they are unsuitable for use in tuned circuits.

All four sections of an a.m./f.m. polyvaricon tuning capacitor are connected together to produce the 20pF to 280pF capacitance swing required for the variable tuning element. Most small polyvaricons will have maximum capacitance values of this order, and some greater.

Assembly

Almost all of the components for the LF and VLF Converter are mounted on small printed circuit boards. Solder pins, inserted at the lead-out points, will simplify off-board wiring, and they should be inserted into the board first.

When populating the Converter p.c.b., mount the i.f. transformer, L1/L2, next, after inserting the solder pins. It can be secured to the board by a drop of Superglue (cyanoacrylate adhesive).

Follow this with the resistors, then the capacitors, smallest first. The semiconductors and the crystal should be soldered onto the board last in order to avoid the repeated heating of these components. It is good practice to use a miniature crocodile clip as a heat shunt when mounting the field-effect transistor.

The optional l.e.d. On indicators, and their dropping resistors, are wired between the On/Off switch and/or the appropriate pins on the boards.

Setting Up and Testing

Check all the printed circuit boards for poor soldered joints and bridged tracks. Double-check the placement of components on the p.c.b.s and the orientation of semiconductors and electrolytic capacitors. If all is in order, proceed as follows:

Converter Unit

Starting with the Converter Unit, connect a fresh 9V battery. Current consumption should be approximately 4mA (excluding the current drawn by any l.e.d. indicator).

Connect the unit to the Receiver via a short (no more than 1 metre or 3ft) length of coaxial cable and set the dial of the receiver to 4MHz (4000kHz) plus the frequency of some powerful longwave transmitter. BBC Radio 4 on 198kHz is ideal in many parts of the UK, and this would require a receiver dial reading of 4198kHz.

Connect an aerial to capacitor C12 (the input is not tuned for this initial test). The chosen station should now be heard. Adjust the i.f. transformer tuning capacitor VC2 for highest reading on the receiver's signal strength meter.

Note that provision is made, on the p.c.b., for the insertion of an additional fixed capacitor in order to refine the tuning of coil L1. If the coil is constructed as specified, it should come to resonance with trimmer VC2 at about mid-swing, and the need for an additional, or two smaller capacitors, is most unlikely.

Tuning Capacitors

The 10 per cent tolerance of the larger capacitors in the switched bank tuning board can exceed the overlap between the ranges. If the constructor has some means of measuring capacitance, the continuity of change should be checked. A check carried out on the prototype, which was assembled without selecting capacitors, revealed a short-fall of 20pF between the penultimate and the highest range.

With up to 2800pF in circuit at this point, the short-fall is not particularly serious. However, constructors who can carry out a check will no doubt wish to do so, and the p.c.b. has provision for the insertion of addition capacitors, on most of the higher ranges, in order to refine values.

Connect the capacitor tuning bank across a suitable inductor (coil), and connect the resulting tuned circuit to the converter. Tune in a weak signal on the receiver (remember, the receiver dial setting is 4000kHz plus the frequency of the wanted station). Connect an aerial and adjust the variable and fixed capacitors to tune the input circuits to the chosen longwave station. The receiver's signal strength meter should reveal the effects of tuning the input.

Inductors (Coils)

Readers who have some means of measuring inductance may wish to establish the inductance of the tapped coil and the loop aerial. Otherwise, all that can be done is to carry out a continuity and resistance check.

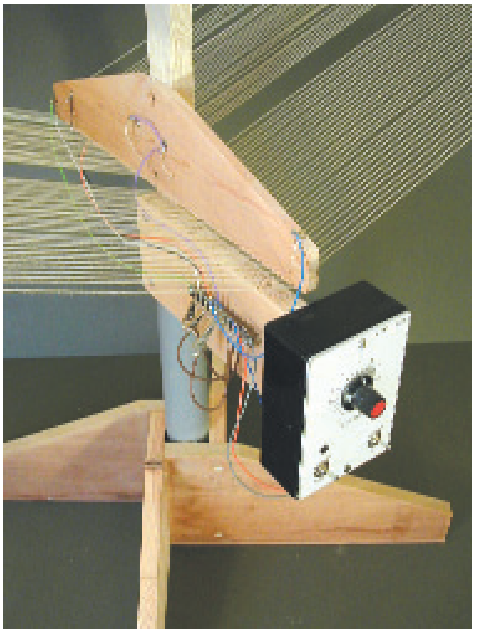
The measured resistance of individual sections of the prototype tapped coil is around 7·4 ohms, and the resistance of the entire winding totals 96 ohms.

Loop Aerial

Tuning capacitors are sometimes mounted directly on the loop aerial and the loop connected to the receiver via a low impedance coupling winding. With this design, the tuning capacitors are enclosed with the Converter or Buffer Amplifier, and the loop is connected to them via separate and short (no more than 600mm or 2ft) unscreened leads. This makes for easier operation of the system.

If any interference is encountered, rotate the loop to null it out. Orientation for strongest signal is quite broad, but the position for deepest null is critical.

Readers seeking the deepest possible nulls on distant stations should consider a gimbal mount so the loop can be tilted, as well as turned. With additional tuning capacitance, the loop performs well down to 14kHz.



Q-Multiplier mounted on the LF/VLF Loop Aerial

Buffer Amplifier

Turning to the Buffer Amplifier, connect a 9V battery and switch on. Current consumption should be approximately 2mA, (excluding any l.e.d. indicator).

Set preset VR1 for maximum output (fully clockwise), and connect the buffer to the receiver via a short (not more than 1 metre or 3ft) length of coaxial cable (see Fig.9). Connect a tuned circuit and an aerial to the buffer input, and set the receiver tuning to a weak station.

When the buffer stage tuning has been correctly adjusted, the rise in signal strength at the receiver should be very apparent. If strong signals overload the receiver, VR1 can be backed-off to reduce the output from the Buffer.

Q-Multiplier

Connect the Q-Multiplier across a tuned circuit formed by the fixed capacitor board and the coil or loop aerial already described. The tapping point for the feedback connection should be spaced between ten and twenty-five percent of the total number of turns up from the "earthy" end of the winding. The Multiplier is, of course, used in conjunction with, not in place of, the Converter or the Buffer Amplifier.

Connect a 9V supply to the circuit board. Current consumption, excluding any l.e.d. indicator, should be in the region of 2mA.

Set the Q-multiplier control, VR3, to mid-travel, tune in a station, and advance preset VR1 or VR2 until the stage almost oscillates. Refine the tuning, which should now be quite sharp. The receiver's signal strength meter should show a dramatic rise: up to 40dB on weak transmissions.

Spend some time adjusting the tapping point and presets VR1 and VR2. With care, the operation of the Q-Multiplier control can be made smooth and completely free from backlash at all settings of the tuning capacitor. □