RADIO & ELECTRONICS CONSTRUCTOR

OCTOBER 1978
Volume 32 No. 2

Published Monthly
(3rd of preceding Month)
First Published 1947

Incorporating The Radio Amateur

Editorial and Advertising Offices
57 MAIDA VALE LONDON W9 1SN

Telephone 01-286 6141
Telegrams Databux, London

Annual Subscription: £7.00, Overseas £8.00 (U.S.A. and Canada $15.00) including postage. Remittances should be made payable to "Data Publications Ltd". Overseas readers, please pay by cheque or International Money Order.

Technical Queries. **We regret that we are unable to answer queries other than those arising from articles appearing in this magazine nor can we advise on modifications to equipment described.** We regret that queries cannot be answered over the telephone; they must be submitted in writing and accompanied by a stamped addressed envelope for reply.

Correspondence **should be addressed to the Editor, Advertising Manager, Subscription Manager or the Publishers as appropriate.**

Opinions **expressed by contributors are not necessarily those of the Editor or proprietors.**

Production.—**Web Offset.**

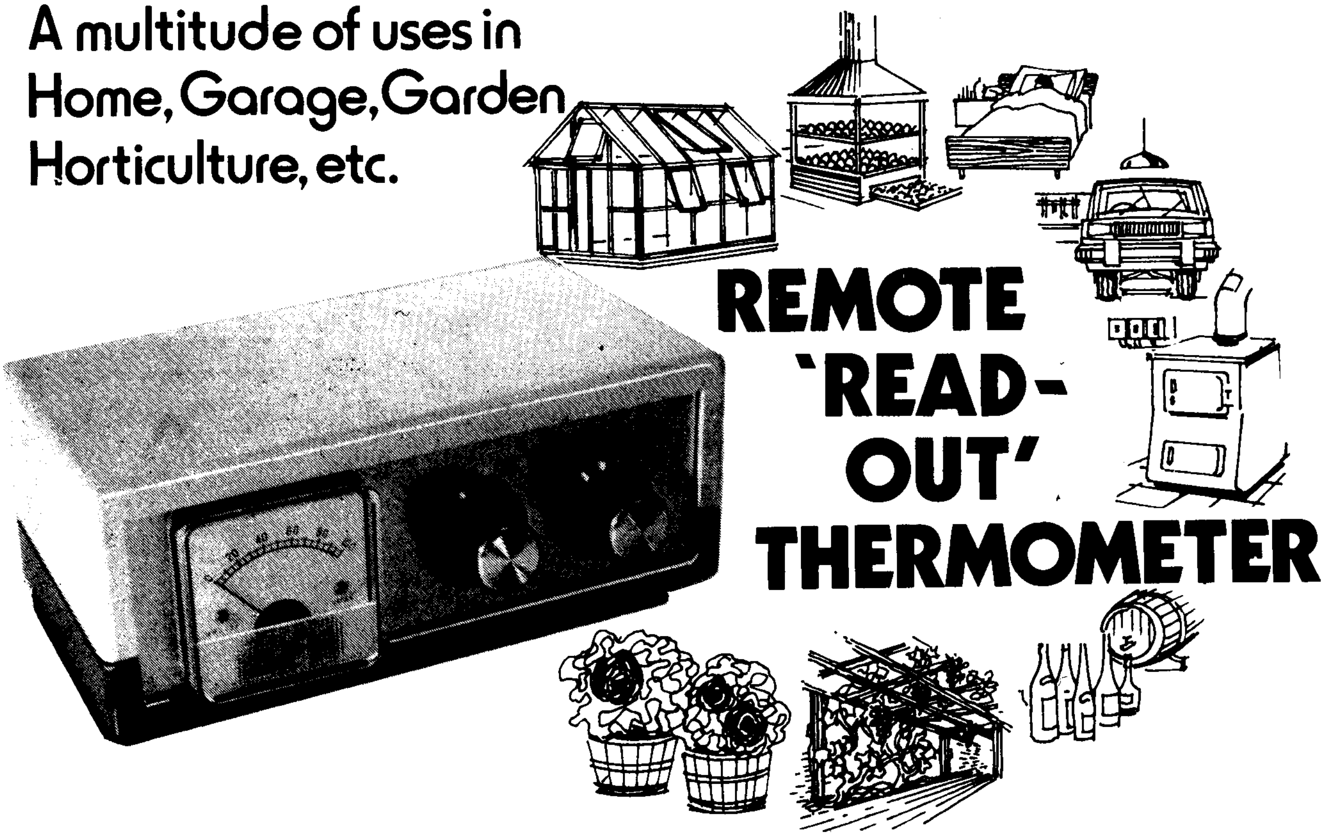
Published in Great Britain by the Proprietors and Publishers, Data Publications Ltd, 57 Maida Vale, London W9 1SN

The ***Radio & Electronics Constructor*** is printed by Swale Press Ltd.

THE NOVEMBER ISSUE WILL BE PUBLISHED ON 3rd OCTOBER

A multitude of uses in Home, Garage, Garden Horticulture, etc.

REMOTE 'READ-OUT' THERMOMETER



by
R. A. Penfold

DIRECT READINGS FROM 0 TO 100 DEGREES CENTIGRADE.

The subject of this article is a simple electronic thermometer which has a measuring range of 0 to 100 degrees Centigrade. The temperature is indicated on a 0-100μA moving-coil meter and, as the scaling of the thermometer is linear, there is no need to bother with the difficult problem of recalibrating the meter scale.

An electronic thermometer has the advantage, over more conventional forms of instrument, of being capable of making measurements with the temperature sensor remotely located from the meter read-out and accompanying circuitry. Thus, for example, the unit can be used to monitor the temperature of a greenhouse, cellar or water tank from any convenient point inside the premises.

Of course, the unit is also suitable for the many applications where the remote read-out facility is of no consequence. The accuracy of the unit is equal to that of most ordinary wide range thermometers.

DIODE SENSOR

The obvious choice as the sensor for a unit of this type would be a thermistor, but these devices generally have comparatively poor temperature-resistance linearity, especially when used over a wide temperature range. The poor linearity would make it necessary either to accept a relatively poor accuracy or to individually calibrate all the temperature gradations on the meter scale.

An alternative and in some respects better form of temperature sensor is a forward biased silicon diode fed from a constant current generator, as shown in Fig. 1(a). As many readers will be aware, when forward biased a silicon diode operates rather like a zener diode, but with a voltage across it of only about 0.65 volt. The precise voltage will depend upon the current fed to the diode, the type of diode employed and its junction temperature.

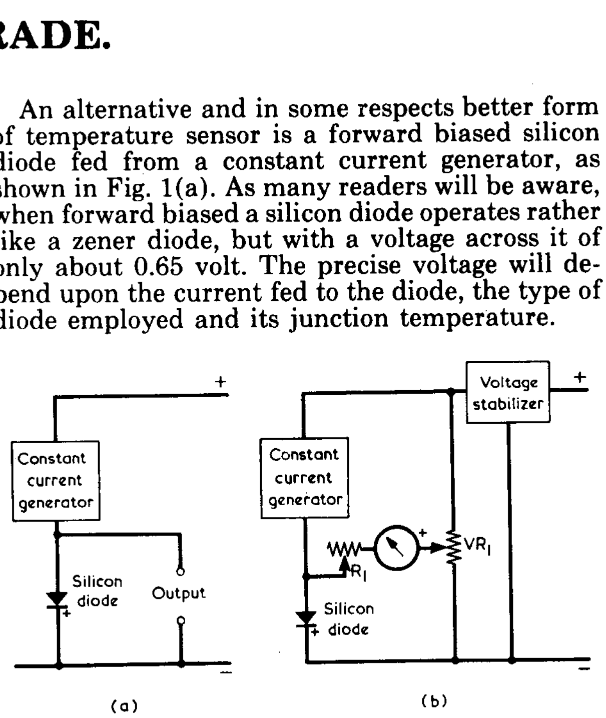


Fig. 1(a). In this circuit the voltage across the silicon diode varies in linear fashion with the diode temperature

(b). Using the varying voltage across the diode to make up an electronic thermometer

Since the current fed to the diode is constant, for any particular device the exact voltage appearing across it will be only dependent upon its temperature. The voltage will fall with increasing temperature and will rise with falling temperature. The voltage change is quite small. Most silicon diodes produce a voltage change of only about 2mV per degree Centigrade, and no diodes produce a change of more than some 3mV per degree Centigrade.

However, the voltage change per degree Centigrade remains virtually constant over a very wide range of temperatures and it would be an easy matter to amplify the voltage swing if this should prove to be necessary. But for a thermometer having a wide temperature range it is by no means essential to use any amplification at all since a voltage change of 2mV per degree Centigrade over a 100 degree range corresponds to a total voltage swing of some 200mV, which is more than adequate to drive a moving-coil meter.

Provided the meter has a full-scale deflection sensitivity which is reasonably low in comparison with the diode current, the simple bridge arrangement outlined in Fig. 1(b) works very well. With the diode at a temperature of zero degrees Centigrade the potentiometer VR1 is adjusted so that the voltage at its slider is exactly the same as the voltage at the anode terminal of the diode. There is then no voltage developed across the meter and it reads zero in consequence.

COMPONENTS

Resistors
(All fixed values $\frac{1}{4}$ watt 5% unless otherwise stated)
R1 3.3k Ω
R2 4.7k Ω
R3 560 Ω
R4 100k Ω 2%
R5 2.2k Ω pre-set potentiometer, 0.1 watt, horizontal
R7 820 Ω
R8 220 Ω pre-set potentiometer, 0.1 watt, horizontal
R9 56 Ω R6 220Ω

Capacitors
C1 0.1μF type C280 (Mullard)
C2 0.1μF type C280 (Mullard)

Semiconductors
IC1 μA78L05WC
TR1 BC179
D1 1N914

Switches
S1 2-pole 2-way rotary (see text)
S2 s.p.s.t. rotary

Meter
M1 0-100μA moving coil (see text)

Miscellaneous
Case (see text)
Materials for probe (see text)
3.5mm. jack socket
3.5mm. jack plug
2-way cable
9-volt battery type PP3 (Ever Ready)
Battery connector
Veroboard, 0.1 in. matrix.
2 control knobs
Bolts, nuts, wire, etc.

With the diode at a temperature of 100 degrees Centigrade, variable resistor R1 is adjusted to produce f.s.d. in the meter. The desired range of zero to 100 degrees Centigrade is thus provided, and as there is a linear relationship between temperature change and voltage change across the diode the unit will have a linear scale.

Note that negative meter terminal is connected to the diode anode so that, when this point in the circuit goes negative with increasing temperature, the required positive deflection of the meter needle is produced. The supply to the circuit must be very well stabilized as a voltage change of only a few millivolts at the slider of VR1 due to a fluctuation in supply potential would obviously significantly upset the accuracy of the unit.

THE CIRCUIT

Fig. 2 shows the full circuit of the thermometer, and this is very much along the lines of the arrangement in Fig. 1(b).

The diode used in the prototype is a 1N914, but other silicon diodes that were tried, such as the 1N4148, also worked satisfactorily. All the 1N914 and 1N4148 devices that were checked had rather low but adequate sensitivity. Various cheap surplus silicon diodes that were tried experimentally seemed to be better in this respect. No silicon diode that was used failed to operate satisfactorily in the circuit, and this has been given wide adjustment ranges so that it can be set up to suit any normal diode.

The diode sensor, D1, is fed with a constant current from TR1 collector. TR1 is used in a quite conventional constant current generator mode, with R1 and R2 biasing its base a little more than 2 volts below the positive supply rail. With approximately 0.6 volt being dropped across the base-emitter junction of TR1 this produces about 1.5 volts across R3, and with the specified value for this component an emitter current of a little less

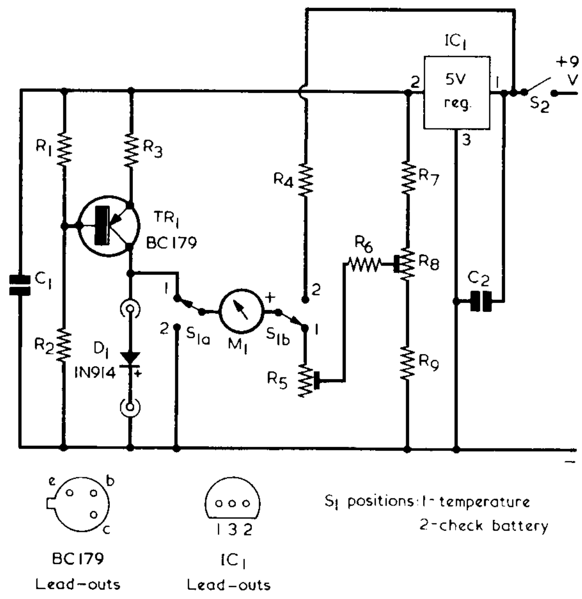
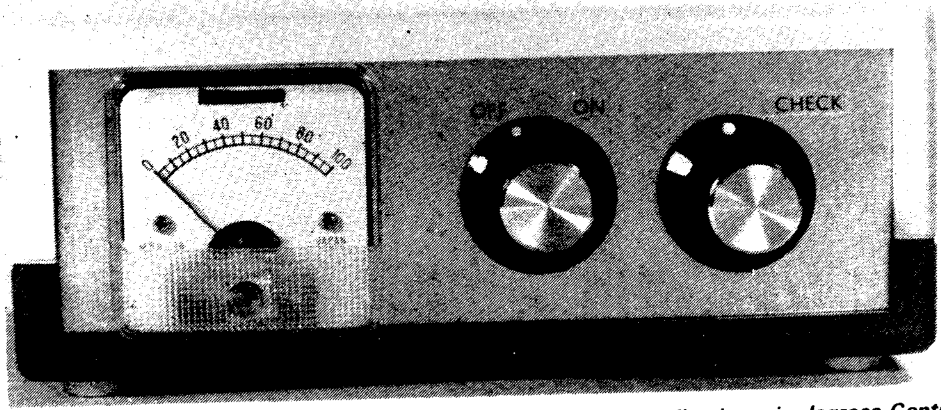


Fig. 2. The circuit of the remote read-out thermometer. In the lead-out inset for IC1 the leads are pointing at the reader



Front panel layout of the thermometer. The meter gives direct indications, in degrees Centigrade, of the temperature of the remote sensor

than 3mA is produced. The BC179 used in the TR1 position is a high gain transistor, and its emitter and collector currents are virtually equal. A constant current of a little less than 3mA is therefore fed to D1.

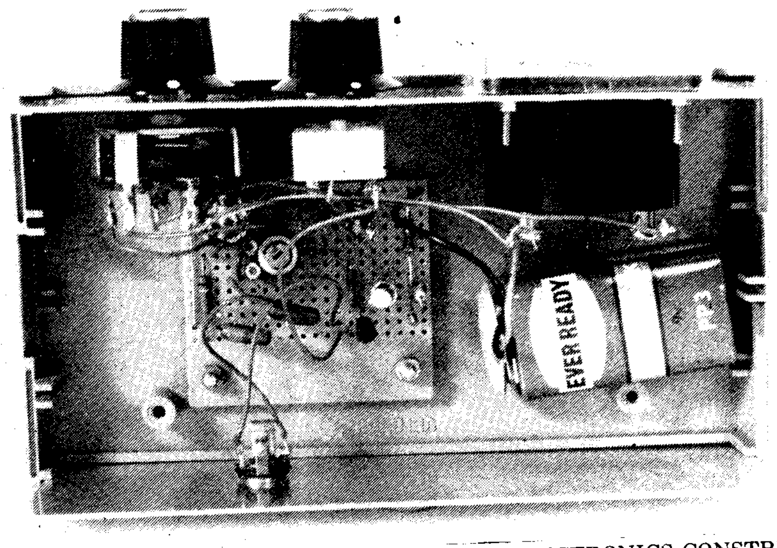
R7, R8 and R9 form a potential divider network across the supply rails so that the meter, M1, can be nulled when the sensor is at zero degrees Centigrade. R5 permits the meter circuit sensitivity to be adjusted to the correct level.

The meter employed in the prototype unit ia Henelec type with a 42mm. square front. This has a nominal internal resistance of 900 Ω which means that 90mV is dropped across it at full-scale deflection. Henelec panel mounting meters are not as readily available as they were several years ago, but any other 0-100μA meter movement with an internal resistance not greater than 1,000 Ω can be employed in its place. Meters with internal resistances well below 1,000 Ω will be quite satisfactory. It should be noted in passing that a multimeter switched to a 0-100μA range will not function in the circuit; multimeters have universal shunt range switching circuits which necessitate the provision of voltages much higher than 100mV for full-scale deflection on the current ranges.

As was mentioned earlier, it is important to have a well stabilized supply so that there is no significant variation in the potential at the positive meter terminal. The constant current generator also relies on a stabilized supply as any variation in the supply voltage will affect the base and emitter voltages of TR1, and will therefore alter the level of current applied to D1. A small 5 volt regulator i.c. stabilizes the supply voltage for the circuit, and it provides a very high level of performance. Varying the input supply voltage over a range of 9.5 to 7.5 volts, which is the range of potentials offered by a 9 volt battery during its operating life, causes a just barely perceptible movement of the meter needle. C1 and C2 are needed to ensure that the regulator i.c. does not become unstable. The regulator i.c. is available from Maplin Electronic Supplies.

S1 enables the meter to be connected across the supply lines via R4, whereupon this resistor and the meter form a 0-10V voltmeter. Operating S1 thereby enables the battery condition to be checked. S2 is the on-off switch. The current consumption of the unit is about 14mA at 9 volts. As the thermometer will presumably not be switched

Construction is relatively simple, with most of the components being assembled on a Veroboard module



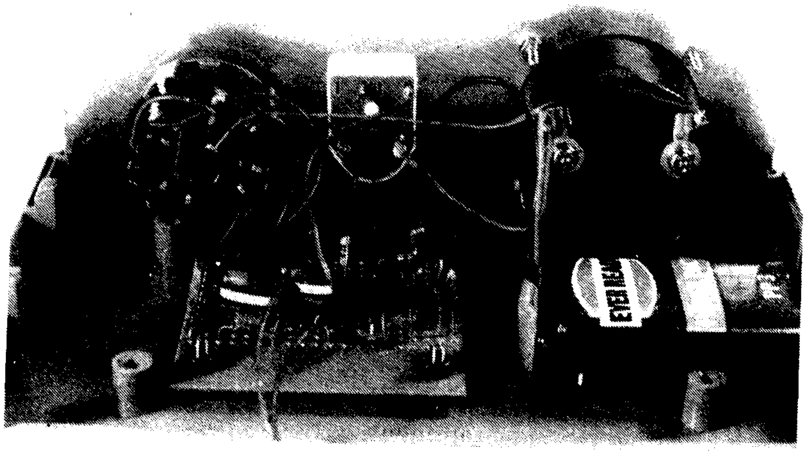
on for long periods but will only be turned on when a reading is to be taken, a small 9 volt battery such as a PP3 is a perfectly suitable power source for the unit.

Incidentally, in the same way as the voltage produced across D1 varies with applied temperature the voltage dropped across the base-emitter junction of TR1 does as well. However, a variation of a few millivolts or so at TR1 emitter, which is all that is likely to occur with normal changes in room temperature, has no noticeable effect on the circuit whatever. In fact, quite large changes in the temperature of TR1 have no significant effect. The regulator i.c. is largely unaffected by changes in temperature, and there is no problem with self heating of the sensor as D1 consumes a power of only about 2mW.

Most of the components are assembled on a 0.1 in. matrix stripboard panel which has 16 copper strips by 20 holes. Details of this panel are provided in Fig. 3. Start by cutting out a panel of the correct size and then file up any rough edges that are produced. The two mounting holes are then drilled 6BA or M3 clear, and the single break in the copper strips is made using either the special Vero tool or a small hand held drill bit. The various components can then be soldered into position

The completed panel is wired up to the rest of the unit and then it is mounted on the base panel of the case behind S1 and S2 by means of 6BA or M3 bolts and nuts. Spacing washers are required on the bolts to space the board underside away from the bottom surface of the case. The point-to-point wiring is all illustrated in Fig. 3.

The Veroboard assembly couples to the front panel components by way of thin flexible wires



CONSTRUCTION

The prototype, with its Henelec meter, is housed in a Verobox type 75-1238D, which measures 154 by 60 by 85mm. deep. Any other instrument case capable of taking the parts and the particular meter to be employed can, of course, be used. The meter is mounted at the left hand side of the front panel and will require a circular cut-out. The cut-out diameter depends on the meter, but with most small types will be 38m. (1½in.) The cut-out can be made using a fretsaw or a needle file. There will also be four small mounting holes, whose positions can be found with the aid of the meter itself.

S2 is mounted towards the centre of the front panel and S1 is situated to the right of S2. The connection to the diode sensor, which is mounted in a separate probe, is made by way of a 3.5mm. jack socket mounted on the rear panel of the case. The jack socket is wired so that the sleeve contact is common with the diode cathode and the tip contact is common with the diode anode. (The jack socket was inadvertently wired incorrectly when the photographs of the unit interior were taken.) S1 is a 2-way 4-pole rotary switch with 2 poles unused, or alternatively a 3-way 4-pole rotary switch with adjustable end stop set for 2-way operation.

PROBE

The diode sensor is soldered to a twin lead of the desired length and then it is mounted in some form of container to protect it against moisture and any liquid in which it is to be immersed. The prototype uses a small test tube as the housing for the probe, with its cork stopper drilled to take the connecting wire. Any other small glass or plastic container capable of being immersed in hot water should be equally suitable. It is advisable to use some silicone grease or a substitute to fill the gaps between the diode and the sides of the tube. This will help to provide a good thermal contact between the outside of the container and the diode, so that the latter responds reasonably quickly to temperature changes.

A 3.5mm. jack plug is fitted to the other end of the lead connecting to the probe. Make sure that the diode connects to the main circuit with the correct polarity. Should it be connected incorrectly, excessive current can flow through the meter. If the twin lead to the diode is to be relatively long it should consist of fairly low resistance wire, such as 5 amp lighting flex. The twin lead should be in circuit between the main thermometer unit and the diode sensor during the setting-up of R8 and R5.

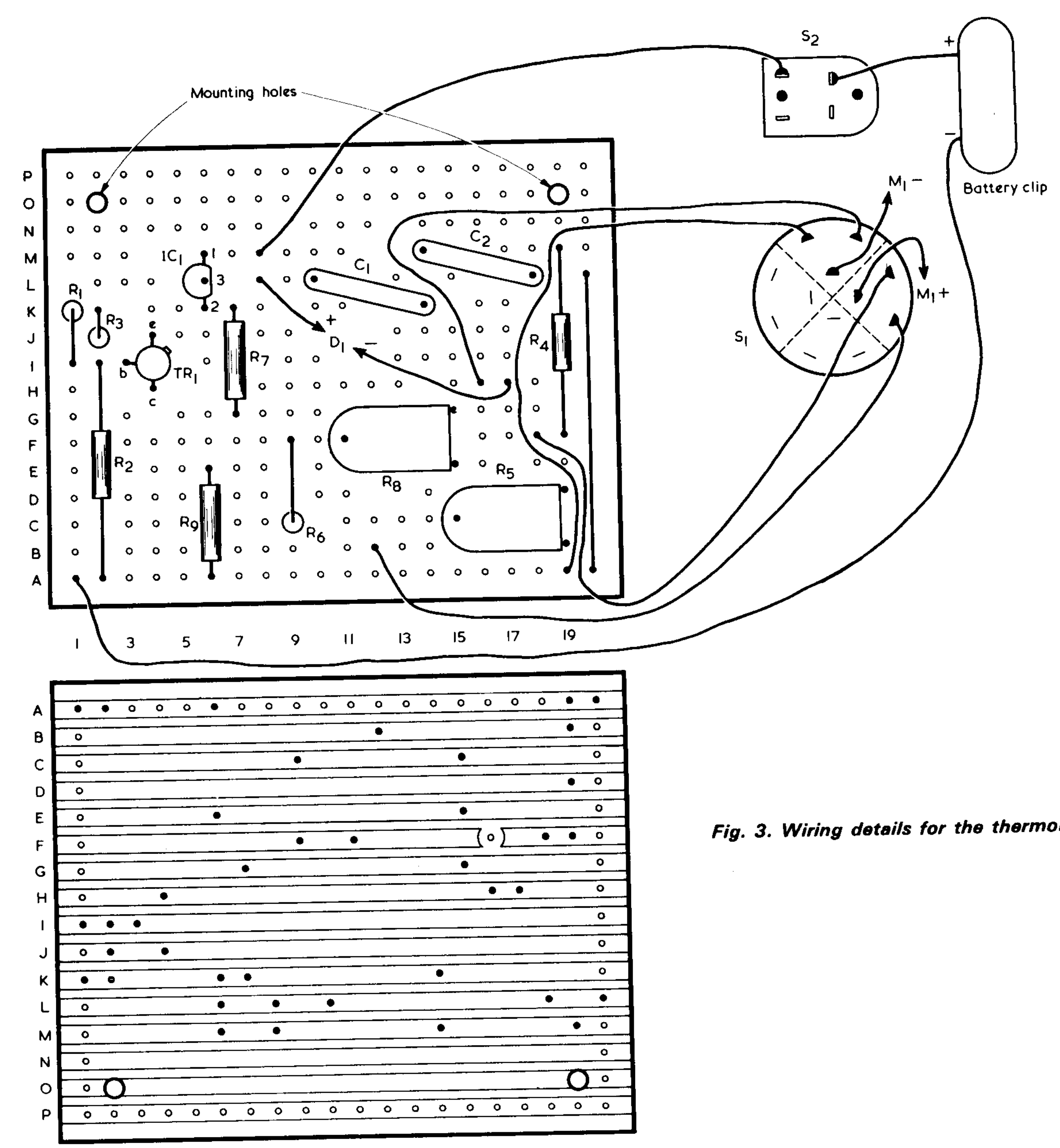
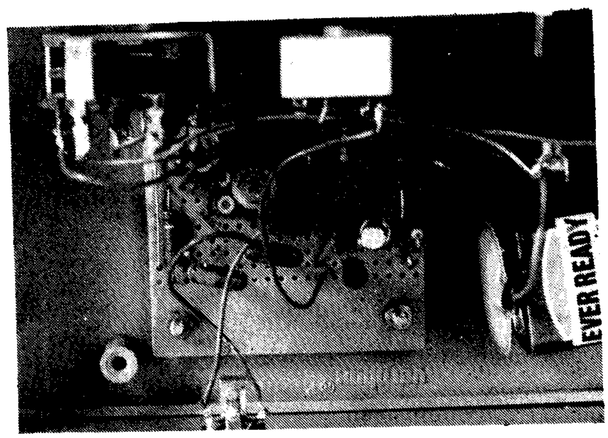


Fig. 3. Wiring details for the thermometer

SETTING-UP

At the outset the slider of R8 should be at the centre of its track and R5 should be adjusted to insert maximum resistance into circuit, i.e. adjusted fully clockwise.

The easiest way to set up the unit is to first add some ice cubes to a glass of cold water and then stir this mixture until no more ice can be dissolved. The water will then be at zero degrees Centigrade. The probe is placed in the water and allowed to cool to the same temperature, which should take no more than about 15 seconds. The unit is switched on and R8 is immediately adjusted to zero the meter. The probe should then be placed in some fairly hot water of known temperature, and it is necessary to have a calibrated standard thermometer of some kind available so that the water



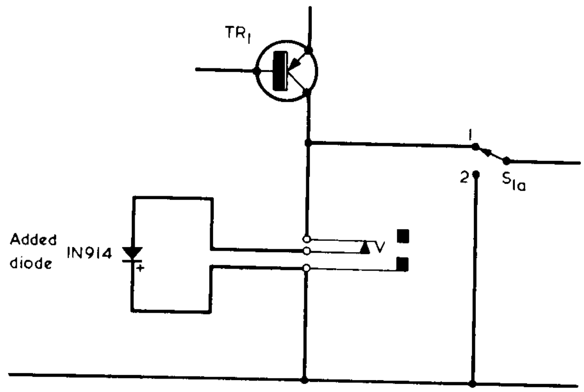
Detailed illustration of the Veroboard layout temperature can be measured. It is not too important what the actual temperature is provided it is of the order of 50 degrees Centigrade and is accurately known. After the sensor has heated up to the temperature of the water R5 is adjusted for the appropriate meter reading.

It is possible to set up the unit with any two known temperatures within its range which are reasonably well spaced apart, but with the lower temperature not being zero degrees Centigrade. However, the process is much slower. It is necessary to adjust R8 for the correct reading with the probe at the lower temperature and then adjust R5 for the appropriate reading at the higher temperature. This procedure has to be repeated until no further adjustment is needed to produce the correct readings.

The thermometer will work satisfactorily with a battery voltage as low as 6 volts, but when the battery check facility indicates that the battery voltage is down to about 7.5 it is advisable to fit a new one. There is otherwise a risk of the battery, even when it is of the steel-clad type, leaking and damaging the unit.

Finally, never switch on the unit without the diode sensor connected to it as this could cause excessive current to flow through the meter with a consequent risk of damage. If desired, the modified input circuit of Fig. 4 may be employed, in which an internal added silicon diode maintains the collector of TR1 at about 0.65 volt positive of the negative rail when the jack plug is out of the socket. Even with this modification, however, the unit should always be switched off when the jack plug is being fitted or removed. The added diode is wired across the tags of the jack socket. ■

Fig. 4. A modification which maintains the collector of TR1 at a low potential when no plug is inserted in the jack socket. The added diode is wired direct to the socket tags



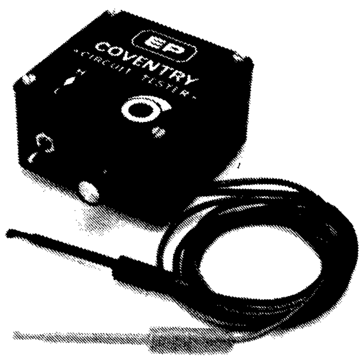
TRADE NOTE

CIRCUIT TESTER

The neat little item of test equipment you can see in the first photograph is the Model CT.6 Circuit Tester, which is manufactured by Electronic Products Coventry, Godiva House, 47-49 Allesley Old Road, Coventry, CV5 8BU.

This is one of a range of six models, each of which is housed in a rigid p.v.c. case measuring 75 by 75 by 40mm. containing a relaxation transistor oscillator and miniature loudspeaker. The speaker emits an audible tone when a circuit is completed via the test probes. There is a clear difference in tone when a low resistance is presented in the circuit being checked, and the unit is powered by a PP3 9-volt battery.

Rudimentary checks of wiring harnesses, printed circuit tracks, fuses, lamps, inductors, capacitors, coaxial cable terminations and switches can be quickly made using this range of testers. All models are supplied with extra-flexible test leads 1 metre long, the probes having spring loaded hook grips and gold plated surfaces.



Circuit tester type CT.6, manufactured by Electronic Products, Coventry. This contains a miniature speaker which emits an audible tone when the test probes couple to a circuit path of less than a specified maximum resistance

In the range the Model CT.1 is a low resistance tester, the maximum path resistance for audible signal being approximately 200Ω. The voltage on the probes is 8 volts and the current through them is 35mA. The Model CT.2 is a high resistance tester checking up to approximately 1MΩ. Probe voltage here is 4 volts and probe current 40uA. Next comes the Model CT.3, which is the same as the CT.1 but with a volume control added. Also, at minimum volume the probe current reduces to 7mA. The CT.2 with an added volume control appears as Model CT.4. The CT.5 combines the Models CT.1 and CT.2, and is fitted with a switch to select low or high path resistance. And, finally, the Model CT.6 combines the CT.3, CT.4 and CT.5 in one package; it has a switch for low or high resistance path selection as well as a volume control.

EASY TV PROGRAMME RECORDING AT HOME

The British consumer's choice of video recorders for taping TV programmes has been extended significantly with the arrival in the shops here of National Panasonic's VHS (video home system) TV programme recorder.

Priced at £750 including VAT, the National Panasonic VHS, model number NV8600, arrives in Britain with the track record of being the most widely sold TV programme recorder in America.

You can record a TV programme when everyone's out of the house, a programme on one channel when you're watching another channel, and a TV programme as it's screened, for enjoyment again later. You can also record your own home-made programmes with a handy TV camera.

The NV8600 gives up to three hours uninterrupted recording and playback time.

A three-hour tape costs £13.50; a two-hour tape £10.50; and a one-hour tape £8.00. The tapes can be re-used again and again — so that over their life span, their cost per minute of playing time is fractions of a penny.

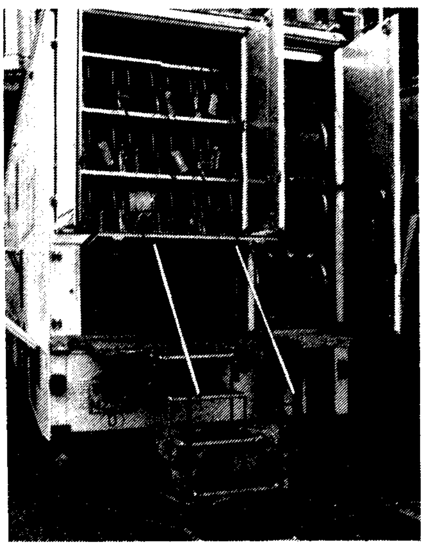
A key component in the VHS recorder is a unique 'direct drive' video head cylinder motor that guarantees the rock-steady running speed needed to ensure a stable, sharp picture.

With the National Panasonic VHS, the amateur cameraman can record his own programmes in the home, and play them back instantly — no processing delay, no processing costs. All it takes is the WV460 black-and-white TV camera, an optional extra to the VHS. It will cost approx £250 including VAT, and incorporates a built-in microphone for simultaneous sound recording.

National Panasonic's VHS (video home system) recorder, model NV8600, is pictured above. Equipment also in the photo is: on left, the new National panasonic 22-inch colour TV, model TC-2203; and a stand to show off the TV and the recorder

Information on local stockists may be obtained from: National Panasonic, Whitby Road, Slough, Berks.

SOPHISTICATED OUTSIDE BROADCAST UNITS



The cable reel compartment of the new £1.5m ZDF, Germany, outside broadcast unit which was manufactured by Dell Technical Vehicles Limited of Southampton. All major cable drums are power operated and the termination panels are also located in this area.

Two of the world's most sophisticated outside broadcast units, worth over £2m, and produced by Dell Technical Vehicles Limited of Southampton, have been supplied to the Mainz based German broadcast network, ZDF. They were recently used in London for video and sound recording of a James Last TV spectacular at the Royal Albert Hall.

The two vehicles, a 5 camera/sound unit and a complex sound recording van, were produced for ZDF by specialist vehicle builders, Dell, and recently commissioned in Germany. They feature a unique air-conditioning system.

The ZDF camera/sound unit was constructed by Dell on a 1624 Mercedes chassis modified with a third axle to give an uplift in weight carrying capability from 16 to 22 tons.

The Production Control compartment is manned by the director, mix operator and technical controller. It contains four colour and four black and white monitors and ten small black and white monitors. The video mix desk controls the 20 channel input and 10 channel mixer. There are two special mixers for feeding and selection of 22 special effects; five chroma key systems are available.

The sound recording vehicle contains a 36 channel Telefunken sound system, which makes the vehicle probably one of the most sophisticated mobile sound studios in the world. Recording facilities include a 16 track recorder capable of 15 tracks with synchronisation pulse and three two channel tape recorders. Air conditioning gives an ambient noise level of only 38 Db(A).

. . . COMMENT

O LEVEL EXPERIMENT FOR ELECTRONICS

We were interested in a report, under the above heading, which recently appeared in *The Sunday Times* written by their Education Correspondent.

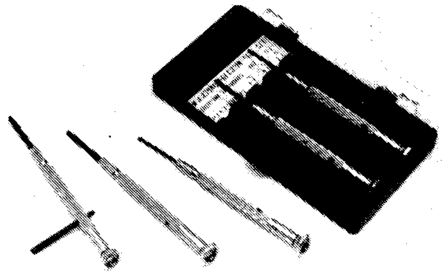
If the appropriate examining board approves, there is to be a new O level course in electronics tried out in schools this year. The writer said "The experiment reflects growing concern that schools are failing to prepare children for a world in which electronics will be a dominant part of their lives".

It appears that of the 40,000 children in London who took CSEs only 461 took a paper in electronics!

One lecturer said that in his opinion children should be given plenty of electronics projects to build as an aid to their learning. In this magazine we have always borne the needs of the beginner in mind and some of our constructional projects are therefore quite simple to build. It was with the learner in mind that, just over three years ago, we started publishing the popular feature *Electronics Data — For The Beginner.* Incidentally, in case you have not noticed, the feature now appears on the inside front cover.

We are always interested to hear from readers as to their wishes as to editorial content, and, if you are a beginner, do not be shy let us know what you think would be helpful to you and we will, if possible, try and oblige.

NEW MINIATURE TOOL SET



A new miniature precision tool set from Light Soldering Developments comprises two cross point (Phillips) screwdrivers, three hexagonal key wrenches (allen keys), 1.5, 2 and 2.5 mm A.F. and a tommy bar in a pocket sized rigid plastic case. The screwdrivers and wrenches are all hardened and tempered and are fitted into easy hold chromium plated handles.

This new tool set (Ref. 37305) is added to the existing range of precision tool sets available from LITESOLD including screwdrivers, box spanners and open ended spanners to metric sizes.

Full details are available from Light Soldering Developments Ltd., 97/99 Gloucester Road, Croydon, Surrey CR0 2DN.

"SATELLITES FOR BROADCASTING

A further volume — "Satellites for Broadcasting" — has been published by the Independent Broadcasting Authority as the eleventh in the series of occasional engineering texts initiated in 1972 under the general title of "IBA Technical Review".

This 72-page book with 73 illustrations, mostly two-colour, provides an introduction to the practices, possibilities and problems of using artificial earth satellites for television broadcsating and for national and international distribution of programmes.

These are examined in relation to the 1977 Region 1 Plan and World Agreement of the International Telecommunications Union and to current experimental projects including the Orbital Test Satellite of the European Space Agency.

Written by IBA and ITN engineers, the book includes a detailed description of the compact satellite receiving terminal built at the IBA's Engineering Centre at Crawley Court, Winchester, for 12 GHz propagation research.

Contents include: Development of Communication and Broadcasting Satellites; The ITU Plan for Space Broadcasting; Fundamentals of Satellite Broadcasting; Low-cost Satellite Receiving Techniques; IBA Earth Station at Crawley Court; Satellite Relays and Distribution; and Digital Modulation for Satellite Systems.

The book is intended for engineers and students directly involved in the field of broadcasting and is available to technical libraries and educational centres, in the UK and overseas.

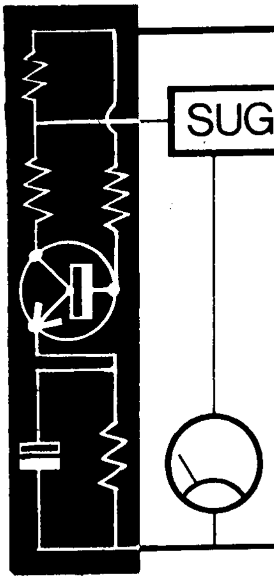
Enquiries to IBA Engineering Information Service, Crawley Court, Winchester, Hants.

THE WORLD OF WIRELESS

A catalogue with a difference has now been introduced by Ambit International, 2 Gresham Road, Brentwood, Essex. Priced at 45p, it infuses an informal magazine-style approach into its descriptions and specifications of the extended range of products available from this firm.

Containing 67 large pages 11¾ x 8¼in., the publication gives full details of Ambit stock, including an exceptionally wide and diverse list of coils, chokes, filters, r.f. transformers and other wound components. Also to be found are integrated circuits, ceramic filters, tuner modules and all the other components and assemblies which are associated with — to quote the catalogue title — "The World of Wireless". There are, again, many items, such as function generator i.c.'s, etc., which do not necessarily fall into the "wireless" category.

The catalogue is packed with circuit diagrams and engineering drawings, all accompanied by helpful and often humorous information on use and application. Not all the catalogue is concerned with products. One page, for instance, is devoted to the subject of impedances and the matching of tuned circuits. With its attractive presentation, the Ambit International catalogue/magazine should hold the interest of anyone concerned with radio and general electronics.



SUGGESTED CIRCUIT

PINGING BELL CIRCUITS

By G. A. French

Yes, the word in the title is "pinging" and not "ringing"! The author has noticed the provision of pinging bell devices in some microwave ovens to give warnings that the the cooking period has been completed, and was struck with the pleasant nature of the sound as compared with the more usual continual ringing of an electric bell. Although the pinging sound is repeated at intervals of several seconds it is still very noticeable and capable of attracting attention.

This article describes a number of circuits which enable a standard electric bell to give single pings, and these all rely on the action given when a charged electrolytic capacitor disharges into the coil of the bell.

THE BELL

The bell employed in the circuits is a Friedland "Underdome" type 792, which is widely available in shops retailing electrical goods. The bell design is particularly suited for the provision of single pings since the armature is attracted into the coil in the manner of a solenoid and has therefore a wide travel before striking the gong. The inertia of the armature enables it to continue towards the gong after a short pulse of current has been passed through the coil. The author has not checked operation with any other model of bell and cannot guarantee that alternative types will function in the circuits.

The Friedland bell has to be modified for the circuits by short-circuiting its interruptor contacts. This is necessary only because there is a tendency when the interruptor contacts are in circuit for the bell to give a double ping when the electrolytic capacitor which discharges into its coil has an exceptionally high charge. The modification is very easy to carry out. The thin base plate and the gong of the bell are removed, whereupon the interruptor contacts can be readily identified. The fixed contact is secured with a screw, and one end of a piece of thin insulated wire is carefully soldered to this contact close to the screw. The moving contact, actuated by the armature, connects to one of the two terminal screws on the upper side of the bell. The thin wire from the fixed contact is passed through the hole through which the bell supply wires pass and its end is secured under the terminal screw in company with one of the supply wires. The second supply wire connects in normal fashion to the remaining screw terminal on the upper side of the bell, after which the gong and the base plate are refitted. The link wire can be easily removed without damage to the bell if it is required to use the latter for normal operation at a later date.

Before continuing to the circuits themselves it should be mentioned that the coil of the Friedland bell has a low resistance, which is of the order of 3Ω only. If the bell, in its modified state, were connected directly across a battery or other supply, a correspondingly high current would be drawn.

SIMPLE CIRCUIT

A simple but nevertheless very effective bell pinging circuit for operation from a 9 volt battery is shown in Fig. 1. In this diagram C1 charges via R1 until the potential across its plates is close to or equals the supply voltage. If push-button S1 is then closed, the capacitor discharges into the coil of the modified bell, giving a single ping. When the push-button is released C1 charges up once more via R1 and is then ready to operate the bell when the push-button is pressed again. The push-button can be positioned remotely, away from the remainder of the components.

When R1 has a value of 470Ω it is necessary to wait several seconds after releasing the push-button before C1 acquires sufficient charge to operate the bell once more. With R1 at 100Ω the capacitor becomes adequately charged almost immediately after the push-button has been released. Intermediate values in R1 give corresponding waiting times. The current drawn from the 9 volt battery is approximately 18mA when the push-button is pressed with a 470Ω resistor, rising to 90mA when R1 is 100Ω. These are also the initial charging currents in C1 which appear momentarily after the push-button is released. Although relatively high, the currents are much lower than those which flow in a standard electric bell circuit and are well within the capabilities of the type of battery which is intended for bell use. As soon as C1 has become fully charg-

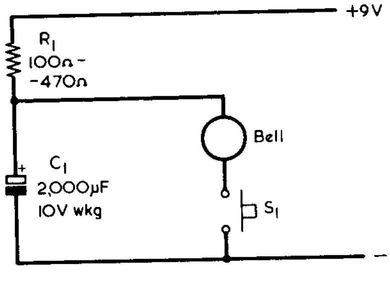


Fig. 1. A simple battery operated circuit. The bell gives a single ping when the push-button is pressed

ed after operation of the bell the only current which flows is leakage current in this capacitor. With modern electrolytic capacitors this should be of the order of a few microamps only, or even less. The circuit functions with supply voltages down to some 6.5 volts, but the waiting time, as C1 charges after release of the push-button, becomes significantly longer at these low voltages.

R1 should be rated at 1 watt for resistance values between 100 Ω and 300 Ω , and at ½ watt for values between 300 Ω and 470Ω .

Fig. 2 illustrates the circuit with a mains bell transformer instead of a 9 volt battery. The 8 volts from the bell transformer secondary is rectified by D1 and applied to the electrolytic capacitor via R1. The circuit functions in the same manner as does that of Fig. 1, except that the capacitor is now, of course, charged by the rectified transformer secondary voltage. The circuit is ready for use again almost imediately after the push-button is released and the running costs are negligibly low. The rectified voltage applied to the electrolytic capacitor can rise slightly above 10 volts, and so its working voltage rating is increased to 16 volts.

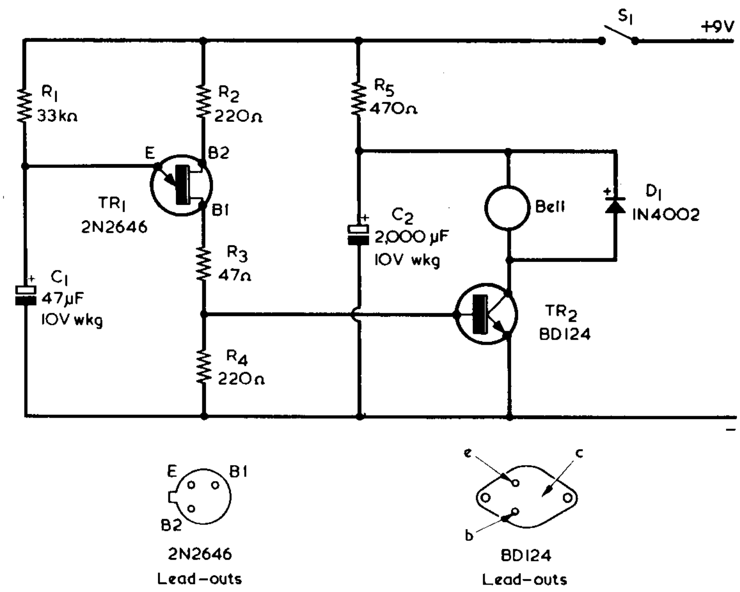


Fig. 3. A circuit which causes a series of pings to be sounded at approximately 3 second intervals

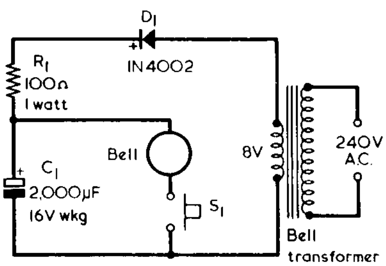


Fig. 2. Running costs are reduced to a negligible level if the single ping circuit is powered by a bell transformer.

CONTINUAL PINGS

A battery operated circuit which gives a series of continual pings is shown in Fig. 3. Here, the capacitor which discharges into the modified bell coil is C2, and it charges up via R5. Instead of a push-button switch the coil of the bell is coupled across the capacitor by turning on transistor TR2. Diode D1 is now added across the bell to suppress any high back-e.m.f. voltages which may appear across it.

The remaining transistor, TR1, functions as a standard unijunction oscillator. When S1 is closed, capacitor C1 commences to charge via R1. As soon as the voltage across C1 reaches the unijunction triggering level the capacitor discharges through the emitter-base 1 junction of the transistor and through R3 into the base of TR2. This pulse of current turns TR2 on and the bell gives a ping. C1 then commences to recharge via R1 and C2 to recharge via R5.

The circuit produces a series of pings from the bell at approximately 3 second intervals, the sound being very noticeable but not irritatingly so. Although both the electrolytic capacitors pass quite high discharge currents neither of these currents is derived directly from the supply. The average current drawn from the 9 volt battery is about 10mA only.

Transistor TR2 is maintained fully turned off, between pulses from TR1, by the resistor R4 between its base and the negative supply rail. Since the current TR2 passes when it does conduct can be in excess of several amps, a small power transistor is employed here. It does not need to be mounted on a heatsink, as its dissipation is quite low.

The circuit of Fig. 3 could be used as an audible alarm to warn of the end of a timing period, or for similar applications. It has to be remembered that it is necessary to wait for some 4 seconds following the application of the supply for the first ping to be sounded, after which the circuit continues with its regular pings spaced at 3 second intervals. The frequency may be decreased, if desired, by increasing the value of R1.

All the resistors in the circuit can be ¼ watt types. This includes R5, which required a ½ watt rating in the circuit of Fig. 1. It can be ¼ watt in Fig. 3 because it does not now have to pass the continual current which flowed in Fig. 1 when the push-button was pressed.

DOOR BELL

The circuit of Fig. 3 can be adapted as a unique door bell for a small house or flat by adding two push-buttons and several other components, as in Fig. 4. In this diagram S2 is the bell-push, and is situated remotely at the door. C3 is normally discharged, whereupon the base of TR3 is at the same potential as the negative rail and no supply voltage is available for R1 and R2 in the unijunction oscillator circuit.

When S2 is pressed, capacitor C3 becomes charged to the full supply voltage, taking with it the base of transistor TR1. This functions as an emitter follower, providing a positive voltage at its emitter for R1 and R2, whereupon the unijunction circuit commences to oscillate. A series of pings spaced at 3 second intervals is produced by the bell, and these continue for about a minute and a half as C3 discharges slowly into the base of TR3. At the end of this period the voltage at the upper ends of R1 and R2 is too low to allow the unijunction circuit to pass pulses of adequate amplitude to the base of TR2 and the pings stop (although the bell armature may operate weakly for some time at the

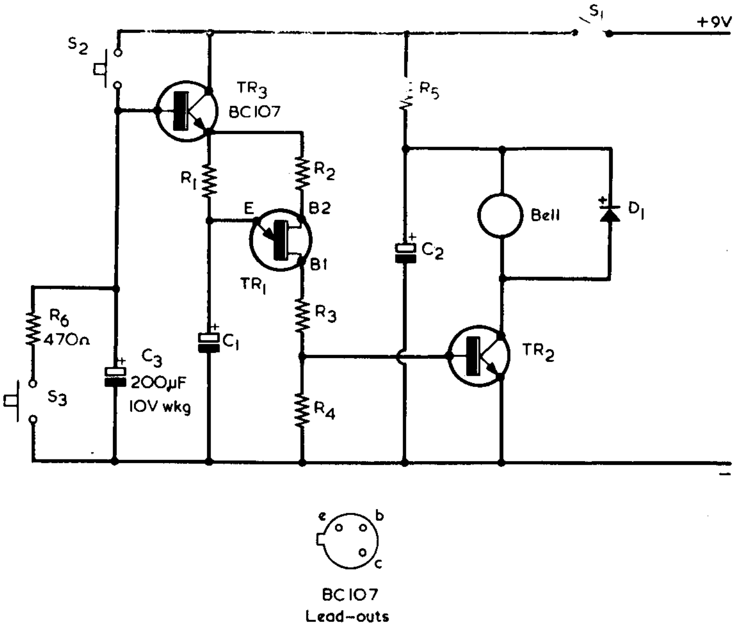


Fig. 4. The circuit of Fig. 3 adapted as a door bell. The pings continue to sound for about 1½ minutes after S2 is pressed

3 second intervals without striking the gong). A new 1½ minute period can be initiated by pressing S2 once more. As with Fig. 3, it is necessary to wait some 4 seconds for the first ping to be heard.

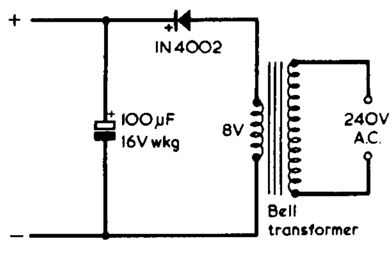
If the occupant of the house or flat wishes to silence the bell he presses push-button S3, which causes C3 to be discharged. Resistor R6 prevents a short-circuit across the supply if both the push-buttons should hapen to be pressed at the same time. It requires a wattage rating of ¼ watt.

The unit may be battery operated and the supply current in the quiescent state is leakage current in C2 and the transistors. With the prototype circuit this measured at 4µA. Operation continues for supply voltages down to some 7.5 volts, but the length of the period during which the pings continue after S2 is released is obviously then shortened.

Both the circuits of Figs. 3 and 4 may be powered from the mains, all that is required being the simple half-wave rectrifier supply shown in Fig. 5. Since this produces a voltage a little higher than 10 volts both C2 of Figs. 3 and 4, and C3 of Fig. 4, require working voltages of 16 volts instead of 10 volts.

In all the circuits, the 2,000µF capacitor which discharges into the bell coil may alternatively be 2,200µF or 2,500µF if these values are easier to obtain. Alternative values for the 200µF capacitor of Fig. 4 are, similarly, 220µF and 250µF. ■

Fig. 5. A mains supply unit for the circuits of Figs. 3 and 4



RECENT PUBLICATIONS

RADIO CIRCUITS USING IC's. By J. B. Dance, M.Sc. 128 pages, 180 x 105mm. (7 x 4in.) Published by Bernard Babani (publishing) Ltd. Price £1.35.

J. Brian Dance is a prolific writer on electronic and constructional matters, and has contributed to many magazines, including ***Radio & Electronics Constructor.*** In this book he turns his attention to integrated circuits, including in particular those encountered in radio applications. An introductory chapter discusses general factors concerning i.c.'s, including constructional hints on wiring i.c.'s into working circuits and the difference between linear and digital types.

The second chapter carries on to a.m. radio receivers and gives information on several ZN414 receivers, a superhet tuner incorporating the μA720, a car radio superhet using the μA720 and a μA706 audio i.c., another superhet employing the LM1820N and the LM386N, and a varactor tuned circuit in which the intergrated circuit is a TCA440.

In the third chapter, on f.m. receivers, circuits are given for use with the double-f.e.t. SD6000. There is also a 10.7MHz μA753 i.f. amplifier, a CA3089E f.m. limiter and demodulator circuit and a similar circuit application taking in the CA3189E. The chapter ends with a 40kHz ultrasonic generator and detector.

The fourth chapter continues the theme by giving circuits for stereo and quadraphonic decoders, and is followed by a final chapter concerned with voltage regulator i.c.'s. As can be seen, the book ranges widely within its chosen subject-matter.

MOBILE DISCOTHEQUE HANDBOOK. By Colin Carson. 128 pages, 180 x 105mm. (7 x 4in.) Published by Bernard Babani (publishing) Ltd. Price £1.35.

Setting up and running a mobile disco is not simply a matter of lugging around an amplifier, a couple of speakers and a turntable, and of then hooking these together at the chosen site. There is considerably more to the operation than this: a second back-up amplifier is virtually essential, as also are monitor headphones, mixers, cueing devices, presentation fronts and many other items. The person running the disco has to be capable of providing optimum conditions for the particular temporary venue in which each performance is to be held and of coping with any faults which may suddenly arise. Finagle's Law states that if, in a system, anything can go wrong it inevitably will, and the Law is liable to make itself particularly felt in the rough and tumble world of the mobile discotheque.

"Mobile Discotheque Handbook" starts with a short section on basic electricity then proceeds to disco equipment and operation in considerable depth. Much common-sense advice is given, this taking into account practical factors as well as the cost of equipment. The approach is informal and lively, and any budding disco operator should find the book excellent value at its modest price.

JOHN LOGIE BAIRD AND TELEVISION. By Michael Hallett. 95 pages, 235 x 195mm. (9 x 7½in.) Published by Priory Press, Ltd. Price £3.95.

This book, which appears in the "Pioneers of Science and Discovery" series published by Priory Press, deals in a simple manner with the life and achievements of John Logie Baird. Covering the subject mainly in chronological order, the book starts with Baird's early days, during which he was continually dogged by ill fortune and poor health. Even the triumphant period in 1936 when his high definition television signals were being broadcast from Alexandra Palace proved to be short-lived; his intermediate film system was run in tandem with the all-electronic Marconi-EMI 405 line system and the latter was ultimately chosen as that to be permanently adopted.

Of great attraction in the present book is the selection of large clear photographs and illustrations, these highlighting some of the historic moments in Baird's enterprising and courageous career and depicting patent drawings and the like from the early days of the inception of television.

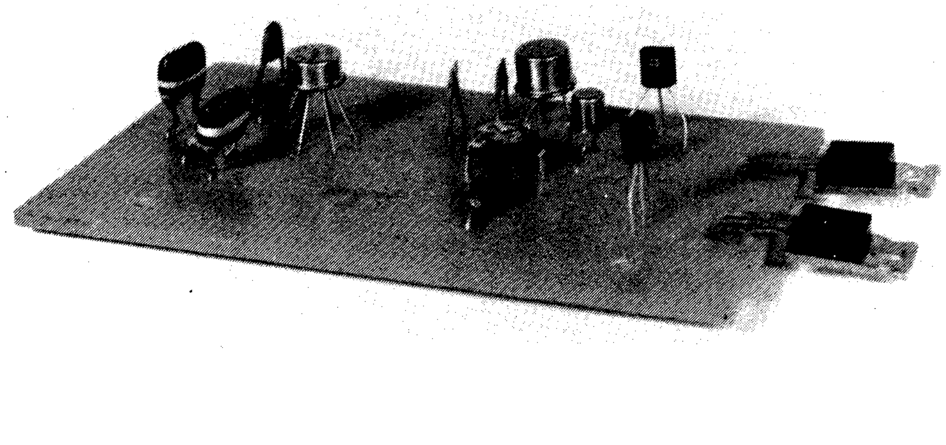
HIGH POWER Amplifier Modules

by
A. P. Roberts

**LOW DISTORTION A.F. OUTPUTS
UP TO 14 WATTS INTO 8 OHMS
D.C. AND A.C. COUPLED VERSIONS**

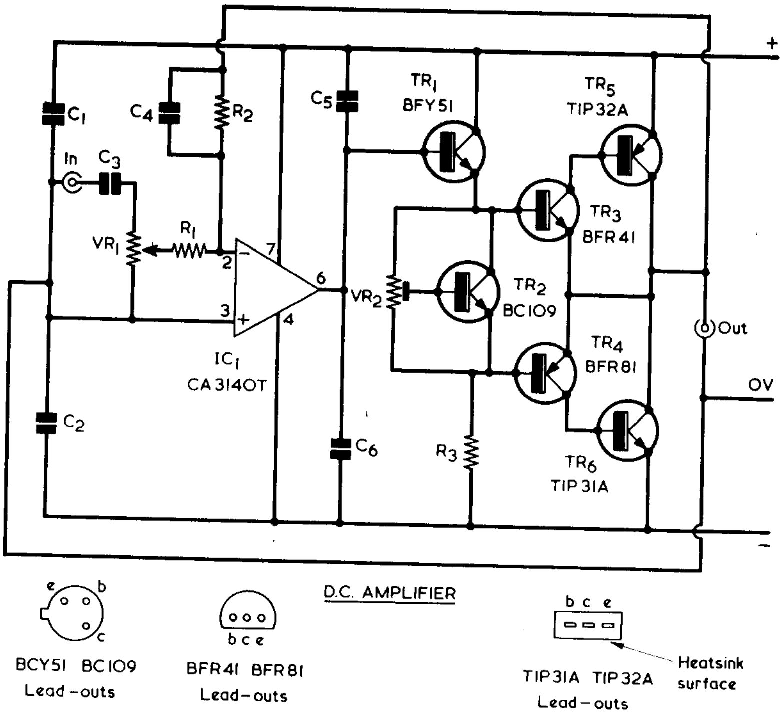
This article describes a high quality audio power amplifier module which should be of interest to anyone who is contemplating the construction of a hi-fi amplifier, or who requires a high quality power amplifier for any other purpose, such as a transmitter modulator or a public address system. The circuit is provided in two forms: a d.c. coupled version and a conventional a.c. coupled unit. Both versions have a high and virtually identical level of performance, which is understandable as they are basically the same. However, the d.c. coupled circuit does have certain advantages over the a.c. coupled one, and it has possible uses outside the field of audio (in servo systems, dual balanced power supplies, etc.).

When powered from a dual 15 volt supply (d.c. amplifier) or 30 volt supply (a.c. amplifier) the circuits will supply a maximum unclipped output power of approximately 14 watts into an 8Ω speaker. The level of t.h.d. produced is very low at power levels below 14 watts, being only about 0.1% or less, and is too low for the author to measure accurately using the equipment available to him. The unweighted signal-to-noise ratio of the circuit is excellent, at slightly better than -80dB.



The d.c. coupled amplifier module. The two output transistors appear at the extreme right

Fig. 1. The circuit of the d.c. version of the amplifier. This requires positive and negative supply rails and a central zero voltage earth rail



D.C. AMPLIFIER

The circuit diagram of the d.c. version of the amplifier appears in Fig. 1. To anyone who is unfamiliar with d.c. coupled circuits based on operational amplifiers this probably looks a little unusual, although this type of power amplifier design is quite frequently used these days. It would perhaps be helpful to examine a basic operational amplifier circuit before looking more closely at the practical circuit of Fig. 1.

Fig. 2 shows how an op-amp is used in the inverting mode, which is the configuration employed in the circuit of Fig. 1. Circuits of this type are powered from a dual balanced power supply with the central junction being used as the earth rail. The non-inverting input of the op-amp is connected to this earth rail.

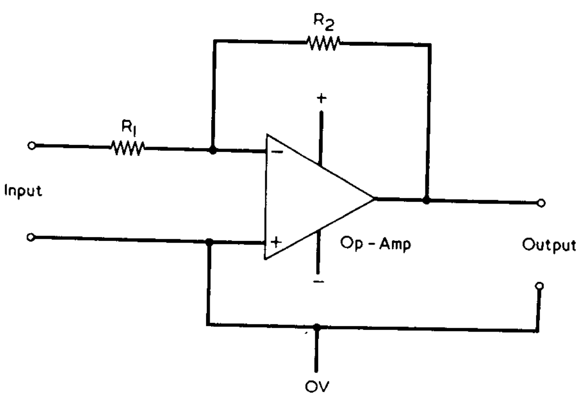


Fig. 2. The basic d.c. coupled inverting input operational amplifier configuration

COMPONENTS

D.C. AMPLIFIER

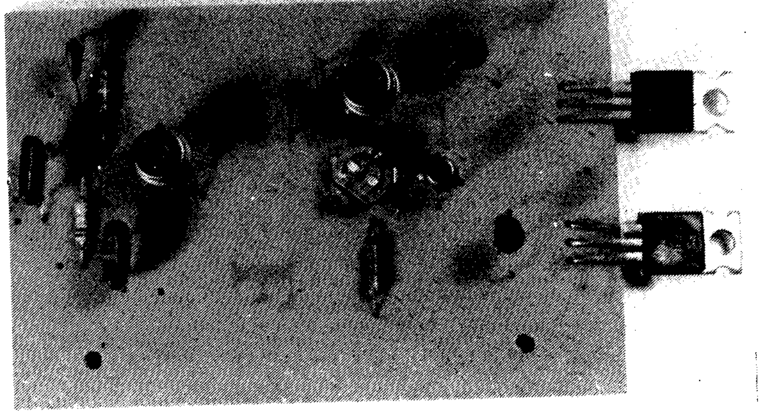
Resistors
(All fixed values ½ watt 10%)
R1 15kΩ
R2 330kΩ
R3 1kΩ
VR1 25kΩ potentiometer, log
VR2 4.7kΩ pre-set potentiometer, 0.1 watt horizontal

Capacitors
C1 0.1μF type C280 (Mullard)
C2 0.1μF type C280 (Mullard)
C3 1μF (see text)
C4 10pF ceramic
C5 1,500pF ceramic plate
C6 1,500pF ceramic plate

Semiconductors
TR1 BFY51
TR2 BC109
TR3 BFR41
TR4 BFR81
TR5 TIP32A
TR6 TIP31A
IC1 CA3140T

Miscellaneous
Control knob
Materials for printed circuit board
Heatsink for output transistors
Insulating sets for output transistors
Wire, solder, etc.

Top view of the d.c. version of the amplifier



Op-amps are basically differential amplifiers and they amplify the voltage present across the two inputs or, in other words, the *difference* between the input potentials. Theoretically, an operational amplifier has infinite voltage gain so that any difference in voltage across the inputs will result in the output of the amplifier going either fully positive or fully negative. The output goes positive if the non-inverting input is at the higher potential, or negative if the non-inverting input is at the lower potential. Practical operational amplifiers have finite voltage gain, of course, but the gain of most practical amplifiers is typically of the order of 200,000 times. Thus, only an extremely small differential input voltage will be sufficient to send the output of the amplifier fully positive or negative.

R1 and R2 in Fig. 2 form a negative feedback loop, and it is the values of these resistors which determines the voltage gain of the circuit. R1 also sets the input impedance of the amplifier whilst R2 provides biasing, causing the output to be at earth potential when there is no input signal voltage. If the output should tend to drift away from earth potential, say slightly positive for example, this would take the inverting input slightly positive of the earthed non-inverting input. The inputs would then be unbalanced, which would cause a negative swing in the output voltage. The output would return to earth potential again and the input balance would be restored.

The voltage gain of the circuit is equal to R2 divided by R1. This is termed the closed loop voltage gain. The voltage gain of the op-amp itself without any feedback is called the open loop voltage gain. The way in which R1 and R2 control the voltage gain is probably best explained with the aid of a simple mathematical example.

Assume that R1 has a value of 1kΩ and that the value of R2 is 10kΩ. If a negative input potential of 1 volt were to be applied to the circuit at the left-hand end of R1, the inputs would obviously be unbalanced and the output would go positive. It would only swing positive by 10 volts, however, as the current flow through R2 would then be equal to that through R1, and the two would balance each other, bringing the inverting input back to earth potential. The gain of the circuit will obviously be 10 times (10kΩ divided by 1kΩ) since an input of 1 volt produces an output of 10 volts.

It will be apparent that the feedback circuit has the effect of maintaining the inverting input at the same potential as the non-inverting input, which is at earth potential. Therefore the inverting input is also held at earth potential, and what is termed a virtual earth is formed here. As the input signal is connected to this via R1, the input impedance of the circuit must obviously be virtually equal to R1. (In practice, stray capacitances and other circuit imperfections may have some slight effect on the input impedance.)

PRACTICAL CIRCUIT

Operational amplifier i.c.'s are not designed to handle high powers, and so in order to use them as power amplifiers it is necessary to add a high power buffer stage at the output. By bringing the buffer stage within the feedback network, the basic configuration of Fig. 2 can still be retained. Furthermore, as the feedback is applied to the circuit as a whole it will counteract distortion in the entire circuit, and not just distortion contributed by the op-amp.

Returning to the circuit of Fig. 1, R1 and R2 set the input impedance of the circuit at 15kΩ and the voltage gain at approximately 22 times. This gives the circuit an input sensitivity of about 480mV r.m.s. for full output. The gain and input impedance can be altered to suit individual requirements if necessary, but it is advisable not to increase the gain of the circuit much above its present level as this will result in increased noise and distortion levels. Stability could also suffer. Similarly, raising the input impedance greatly could also result in instability and a significant reduction in the signal-to-noise ratio.

The buffer stage which is used at the output of the i.c. is a fairly conventional complementary circuit driven by an emitter follower stage. The emitter follower is not required for the gain it provides, but is needed in order to permit the usual quiescent bias voltage to be applied to the output stage. This bias is provided by VR2 and TR2, with TR2 functioning as an amplified diode. VR2 is adjusted so that a voltage of about 1.1 volts is developed across the collector and emitter of TR2. The voltage is not quite sufficient to turn on the transistors in the output stage, and at first it might be thought that quite a high level of cross-over distortion would be present as a result. In fact, the level of distortion on low level signals is slightly higher than that produced at medium and high output levels, but it is still of a very low order and is not of significance. This is due to the very high level of negative feedback used in the circuit which largely eliminates what cross-over distortion exists. This method of counteracting cross-over distortion has been covered in a previous article in this magazine ("CMOS Audio Amplifier", R. A. Penfold, in the issue for April 1977).

The main advantage of the system is that, with only a fairly low bias on the output stage, there is very little chance of thermal runaway occurring here, especially when it is considered that TR2 provides a degree of thermal stabilization in the conventional manner anyway. VR2 could be adjusted to permit a quiescent bias current through the output stage, but the circuit would then be more vulnerable to overloading, and good heat-sinking of the output stage would become more important.

A well-known arrangement is used in the output stage, with all four transistors being connected in the common emitter mode. Although common emitter stages normally provide a high level of voltage gain this is not the case here as each pair of transistors (TR3 — TR5 and TR4 — TR6) are connected with 100% negative feedback, and therefore provide unity gain. There is in fact unity voltage gain all the way from the output of IC1 to the amplifier output, but the current gain between these two points is extremely high. This gives the circuit a very low output impedance which is a matter of a few milliohms rather than ohms. The combination of the very low output impedance and the fact that the CA3140T i.c. used in the IC1 position is capable of an output voltage swing virtually equal to the supply rail potential means that the peak-to-peak output voltage swing which can be fed to the speaker is also nearly equal to the supply rail voltage. In consequence the circuit can provide optimum output power from a given combination of supply voltage and speaker impedance.

There is no need for a d.c. blocking capacitor to be used at the output as the quiescent output voltage is extremely small. The no-signal output current is probably no more than that which flows in a conventional amplifier due to slight leakage through the output capacitor.

Similarly, there is no need to use a d.c. blocking capacitor between R1 and the slider of the volume control, but it is essential that such a capacitor be included in series with the volume control. Otherwise any d.c. potential which is coupled to the

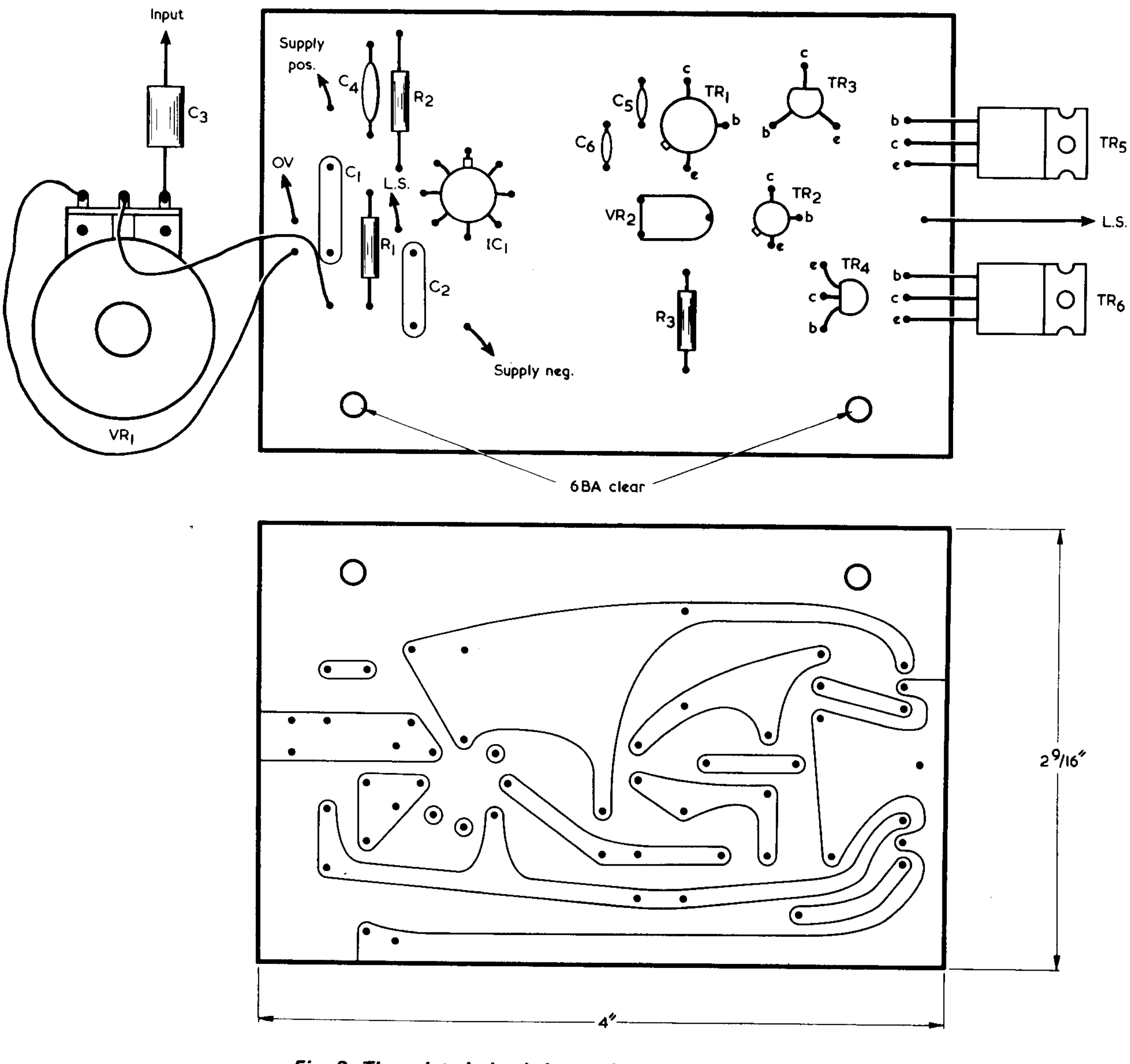


Fig. 3. The printed circuit layout for the d.c. coupled amplifier

input will be amplified 22 times and fed to the speaker. This could easily damage both the speaker and the amplifier. If the input of the amplifier is to be connected to a source which contains a d.c. element of known polarity, then C3 can be an electrolytic type suitably connected. If not, then a non-electrolytic type such as a Mullard C280 component must be employed.

The circuit has an extremely wide bandwidth unless steps to reduce it are taken. A wide bandwidth which extends well beyond the upper audio frequency limit is undesirable as it is likely to result in pick-up of radio frequency, and can also result in various forms of instability. C4, C5 and C6 are therefore included to roll off the high frequency response of the circuit. C1 and C2 provide supply decoupling.

CONSTRUCTION AND SETTING UP

A suitable printed circuit board layout for the amplifier is shown actual size in Fig. 3. This is constructed in the usual manner. TR5 and TR6 must be mounted on a substantial heatsink, and in many instances it will be possible to use the metal case or chassis of the equipment as the heatsink. In instances where this is not practical a large size commercially produced heatsink can be employed. The output transistors must also be insulated from the heatsink, using mica washers and plastic insulating bushes. Use a continuity tester to ensure that this insulation is completely effective.

The holes in the board for VR2 are positioned to take a component having 0.2in. spacing between track tags and 0.4in. spacing between track and slider tags.

Before applying power to the circuit ensure that VR2 is adjusted in a fully anticlockwise direction so that its slider is at the track end connecting to TR2 collector. Connect a multimeter set to read about 50mA in series with one supply rail, and then switch on the power. A current of about 20mA should be drawn by the circuit, and if VR2 is slowly adjusted in a clockwise direction a setting should be reached where any further advancement results in a large increase in current consumption. VR2 slider should be slightly backed off from this setting. As explained earlier VR2 can, if preferred, be adjusted for a small quiescent current through the output stage, and this could consist of an increase in current of, say, 5mA. However, this quiescent current will certainly not improve performance noticeably.

It is worth noting that if the circuit is operated with one supply rail absent there will still be only a small quiescent output current, and the amplifier will not be damaged.

COMPONENTS

A.C. AMPLIFIER

Resistors
(all fixed values ½ watt 10%)
R1 15kΩ
R2 8.2kΩ
R3 8.2kΩ
R4 1kΩ
R5 330kΩ
VR1 25kΩ potentiometer, log
VR2 4.7kΩ pre-set potentiometer, 0.1 watt horizontal.

Capacitors
C1 1μF electrolytic, 25 V. Wkg.
C2 10μF electrolytic, 25 V. Wkg.
C3 1,500pF ceramic plate
C4 1,500pF ceramic plate
C5 2,200μF electrolytic, 25 V. Wkg.
C6 100μF electrolytic, 40 V. Wkg.
C7 10pF ceramic

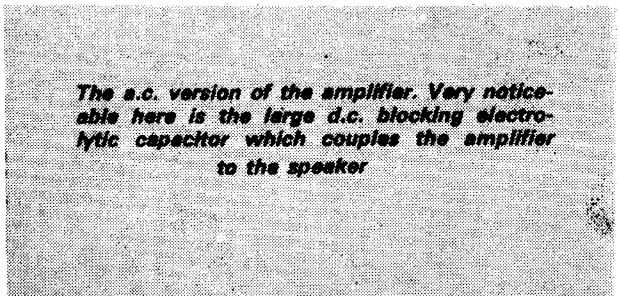
Semiconductors
As for d.c. amplifier

Miscellaneous
As for d.c. amplifier

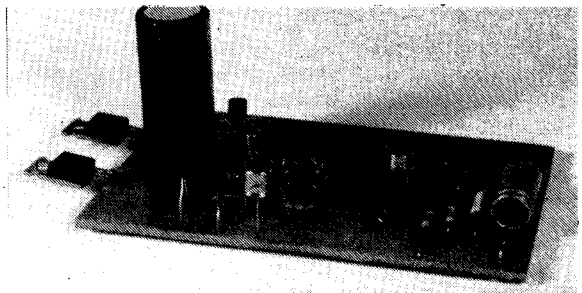
A.C. VERSION

The circuit of Fig. 4 is provided for constructors who prefer an a.c. coupled amplifier. This is much the same as the circuit of Fig. 1, except that d.c. blocking capacitors have been added at the input and output. R2 and R3 bias the non-inverting input of the i.c. to half the supply rail potential, and C2 smooths out noise which could otherwise be coupled to this input from the supply lines via R2. The supply line ripple rejection of this circuit is quite good, and it is not necessary to use an electronically smoothed power supply. However, this circuit is not as good in this respect as the d.c. version, and circuits of the type shown in Fig. 1 and Fig. 2 have inherently high supply ripple rejection.

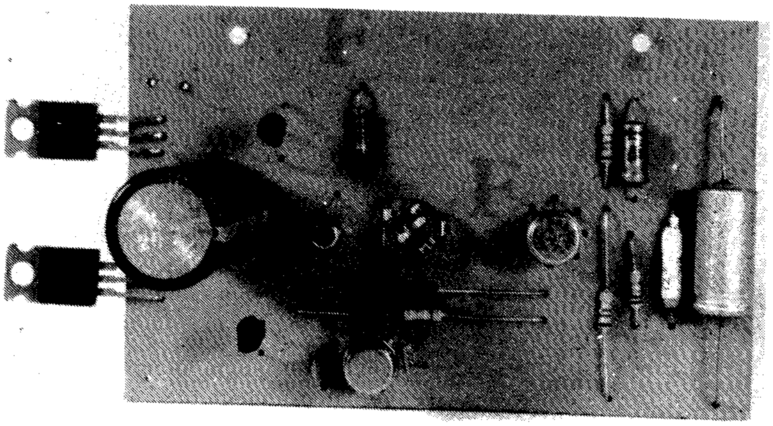
Another disadvantage of the circuit of Fig. 4 is that it is slightly more expensive since a large electrolytic capacitor must be used at the output. The capacitor also reduces the low frequency power bandwidth of the circuit, although in practice this may not be of any consequence.



The a.c. version of the amplifier. Very noticeable here is the large d.c. blocking electrolytic capacitor which couples the amplifier to the speaker



Illustrating how the a.c. amplifier components are laid out on their printed circuit board

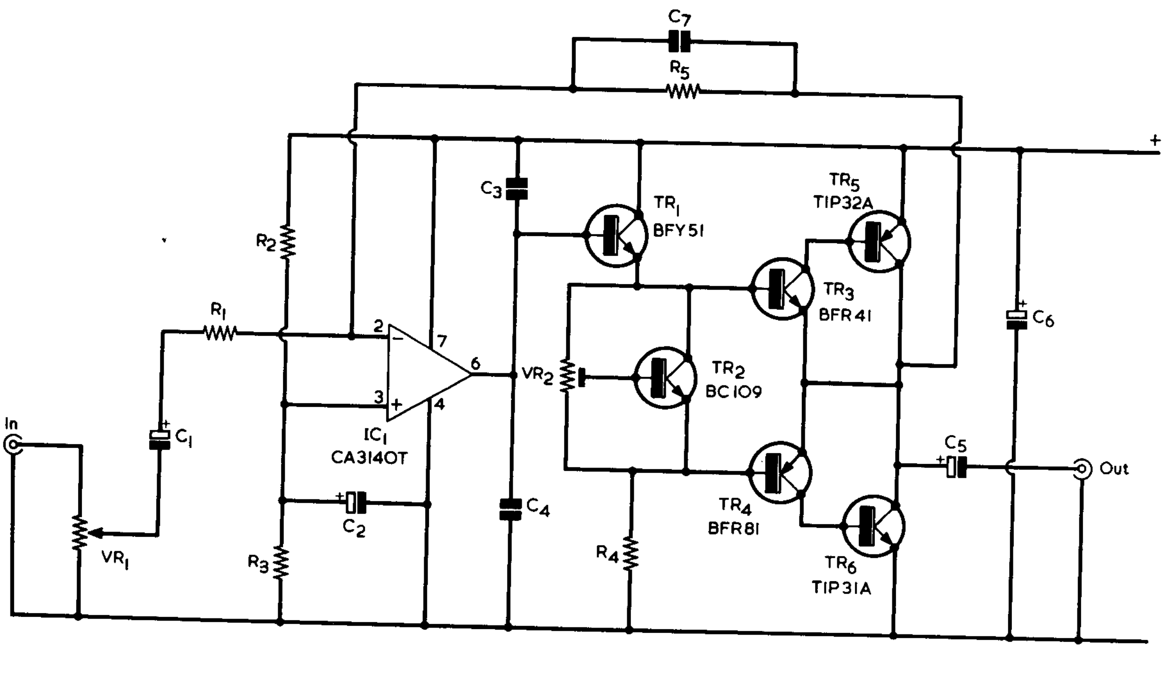


A suitable printed circuit board design for the a.c. version of the amplifier is reproduced actual size in Fig. 5. The construction and setting up of the circuit is the same as for the d.c. amplifier except that, due to the different layout, VR2 should be initially set fully clockwise if its slider is to be at the end of the track connecting to TR2 collector. It is then adjusted in an anticlockwise direction.

POWER SUPPLY

The amplifiers should not be powered from a supply of significantly more than 15 volts positive and negative for the d.c. version or 30 volts single rail for the a.c. version. Using the power supply circuit shown in Fig. 6 these voltages correspond to a maximum mains transformer secondary voltage of 10-0-10 volts. With a practical transformer, this power supply will normally provide just slightly more than 15-0-15 or 30 volts under quiescent conditions. Transformers with 10-0-10 volt secondaries are not listed by the larger component mail-order houses, but these secondary voltages may be obtained from transformers having secondaries tapped at 0-5-20-30-40-60 volts. Connection is made to the 20, 30 and 40 volt taps. At a slight loss in supply voltage and audio power, the more common transformers with 9-0-9 volt secondaries may be employed.

In order to supply a single amplifier the power supply transformer secondary should be rated at 1 amp. For a stereo amplifier the current rating should be increased to 2 amps, and the rating of the two fuses should be similarly altered. Also, the 1N4001 rectifiers should be replaced by higher current types, such as the 1N5400.



A.C. AMPLIFIER

Fig. 4. The a.c. version of the amplifier requires only a single supply rail. There are d.c. blocking capacitors at the input to the integrated circuit and at the output to the speaker

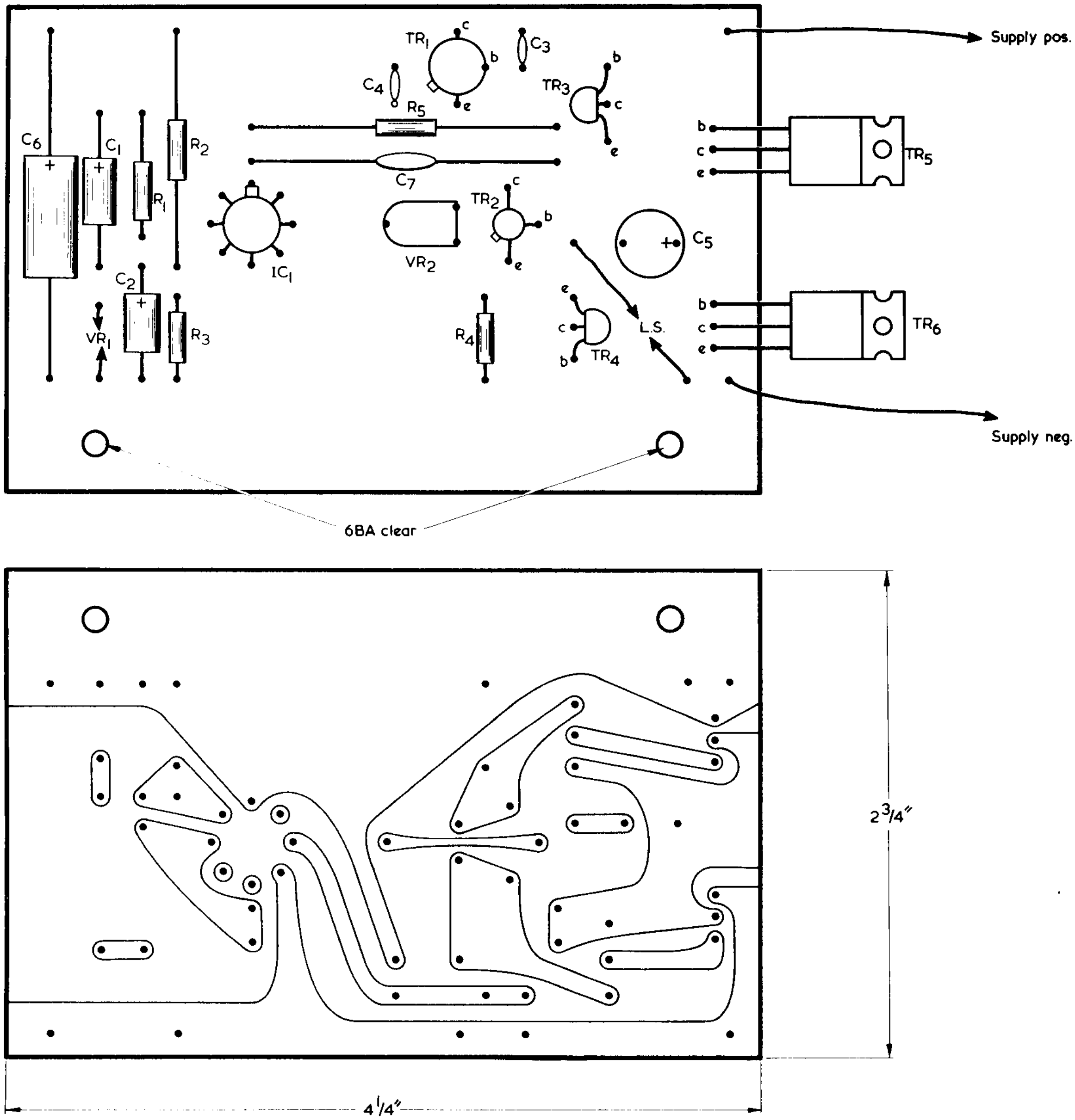
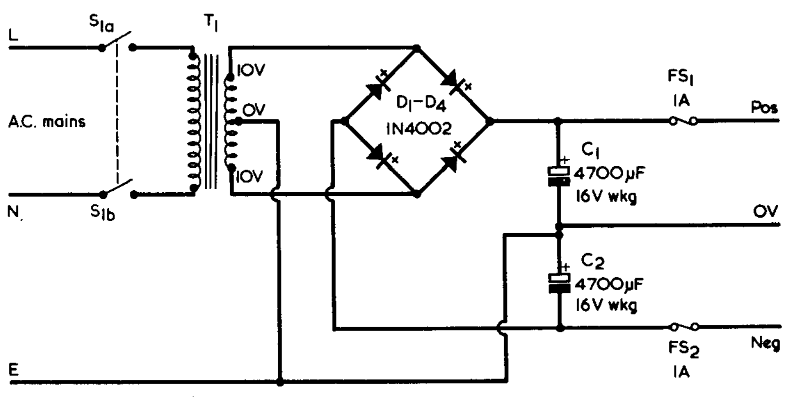


Fig. 5. The a.c. coupled amplifier is assembled on its printed board as shown here. Like Fig. 3, this is reproduced full size

Fig. 6. A suitable power supply for the d.c. coupled amplifier. Transformer ratings are discussed in the text. With slight modification the power supply may also be used with the a.c. coupled amplifier



As shown, the power supply of Fig. 6 offers the positive and negative rails for the d.c. version of the [illegible] output is ignored. Also, the mains earth can be transferred from the centre rail to the negative output rail and fuse FS2 omitted. ■

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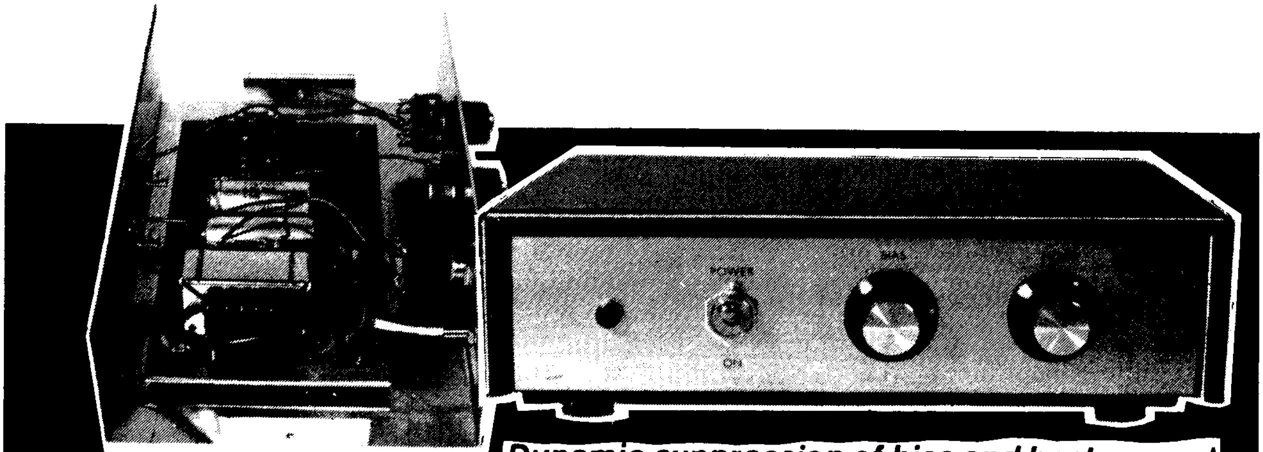


Dynamic suppression of hiss and background

NOISE REDUCTION AMPLIFIER

By
P. R. Arthur

Dynamic unit improves and boosts the performance of portable cassette recorders.

Probably many readers of this magazine own a portable cassette recorder or cassette/radio unit, and have wondered if it is possible to improve the reproduction quality provided by such units. While it is likely that this can be achieved by modifying the recorder, a more practical solution is to feed the output of the unit to a separate noise reduction circuit, amplifier and speaker.

The amplifier which forms the subject of this article is intended for use in such an application, and it incorporates noise reduction circuitry of the dynamic noise limiter (d.n.l.) type. The circuit is very simple and uses just two active devices. It is mains powered and provides an output power of about 2.5 watts r.m.s. into an external 8 Ω speaker. The total harmonic distortion is typically only about 0.2% at all output power levels, and the unweighted signal-to-noise ratio is about –72dB. Thus the unit does not significantly detract from the signal it processes. In fact, provided a reasonably good speaker is used, the combination of the increased output power the unit offers plus the effect of the d.n.l. circuitry results in a remarkable improvement in audio quality.

D.N.L. PRINCIPLE

The d.n.l. system relies on the fact that the most noticeable noise on the output from a cassette recorder is the familiar high frequency tape hiss. This hiss is only significant at low recording levels though, as it is masked by high level signals. It is more readily masked by high frequency signals than by middle or low frequency ones.

Basically the d.n.l. system consists of a low pass (or treble cut) filter which attenuates the tape hiss in the presence of low recording levels. At higher recording levels the treble cut is progressively reduced, and it is completely removed at very high recording levels.

A slight flaw exists in this system, in that there is some loss of treble response except at very high volume levels. However, the reduction in the tape hiss level tends to be much more noticeable than the loss of high frequency response, and a dynamic noise limiter can produce a large subjective improvement in the quality of a signal.

Also, many pre-recorded cassettes as well as home produced ones are recorded using some form of noise reduction encoding, such as the popular Dolby B system. Most of these systems are somewhat similar to the d.n.l. one so far as the decoding is concerned, but during the recording process the cassette is encoded in the form of treble boost on low level signals. This enables both noise reduction and a flat frequency response to be obtained.

It must be emphasised that the unit described here is *not* a Dolby decoder, nor will it properly decode any other form of noise reduction encoding. As one would expect, though, results are better when using this type of cassette as the low level treble boost which is applied during the recording process tends to compensate to some extent for the treble cut which is applied to low level signals during playback.

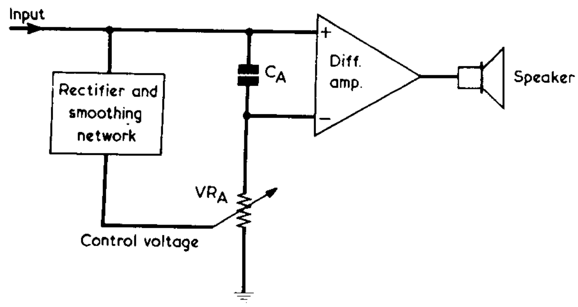


Fig. 1. The basic manner in which the noise reduction amplifier functions. The resistance of VRA reduces with increasing input signal voltage, causing less high frequency content to be present at the inverting input of the amplifier

BASIC OPERATION

Fig. 1 illustrates the basic arrangement of the noise reduction amplifier. The amplifier itself is a differential type which has the usual non-inverting (+) and inverting (–) inputs. It is not a high gain type such as the 741 and similar types, but has a voltage gain of only about 2 times. The input signal is fed to the non-inverting input of the amplifier, and the boosted signal which appears at the output is fed to a loudspeaker. The input signal is also fed to the inverting input via low value capacitor CA which, together with VRA, forms a high pass filter. Positive-going signals at the non-inverting input result in positive-going excursions at the output of the amplifier, and negative-going inputs produce negative output excursions. As the name implies, the inverting input produces an output signal of opposite polarity to that applied to the input. The high frequency signals passed to the inverting input via CA therefore cancel out to some degree the same signals at the non-inverting input, and so the required treble cut is achieved.

VRA is not an ordinary resistor, but is a device whose resistance can be controlled by an applied voltage. The control voltage is derived from the input signal by means of a rectifier and smoothing network, and is proportional to the input signal level.

The circuit is arranged so that the larger the control voltage, the lower the resistance of VRA. CA and VRA form a high pass filter by a form of potential divider action. The impedance of CA falls with rising frequency, and so higher frequency signals are coupled to the inverting input with less attentuation and are thus cancelled out to a greater degree. The resistance of VRA reduces in the presence of high level signals, and this raises the frequency at which a significant amount of roll-off is produced. With very high input levels there is only a significant amount of roll-off at frequencies above the upper limit of the audio range, and so the treble signals receive full amplification. Therefore, in effect, the higher the amplitude of the input signal the lower the degree of treble cut which is applied to it.

THE CIRCUIT

Fig. 2 shows the complete circuit diagram of the unit, including the mains power supply section. The very versatile LM380 i.c. audio amplifier forms the basis of the unit, and this device has both non-inverting and inverting inputs with a pre-set voltage gain of typically 50 times. Such a gain is rather higher than is required in the present application, and so an attenuator is used at each input, that at the non-inverting input consisting of R2 and R4, and that at the inverting input consisting of R3 and R5. The LM380 operates perfectly well without the necessity of using d.c. blocking capacitors between the attenuators and its inputs.

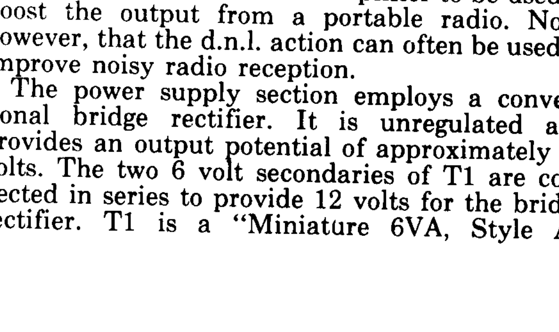
The input signal is coupled to the non-inverting input of the amplifier via C4, and it is also coupled by way of C3 to a rectifier and smoothing network. C3 has been given a fairly low value so that this part of the circuit responds more readily to high frequencies than it does to middle and bass ones.

The electronic variable resistor is actually a p-channel JUGFET, TR1, and its source — drain terminals provide the variable resistance path. The negative control voltage which is formed by the rectifier and smoothing network is fed to the gate of TR1. VR1 superimpose a positive bias voltage onto the control voltage. This biases TR1 to a point where it exhibits quite a high source — drain resistance, but where only a fairly small negative change of gate voltage is needed to reduce this resistance to about 100 . Thus the rectified negative control voltage produced the desired result.

High frequency coupling between the two inputs of the amplifier is provided via either C5 or C6, depending upon which of these is selected by S2. C6 is used when processing ordinary tapes, and C5 (which provides increased treble cut) is used on tapes which have a high treble output. These include Dolby encoded and chromium dioxide types.

The coupling is removed in position 1 of S2, and the unit then operates as a straightforward amplifier. This enables the amplifier to be used to boost the output from a portable radio. Note, however, that the d.n.l. action can often be used to improve noisy radio reception.

The power supply section employs a conventional bridge rectifier. It is unregulated and provides an output potential of approximately 18 volts. The two 6 volt secondaries of T1 are connected in series to provide 12 volts for the bridge rectifier. T1 is a "Miniature 6VA, Style A"



The rear panel. The input socket is to the left, with the output socket appearing between this and the mains lead

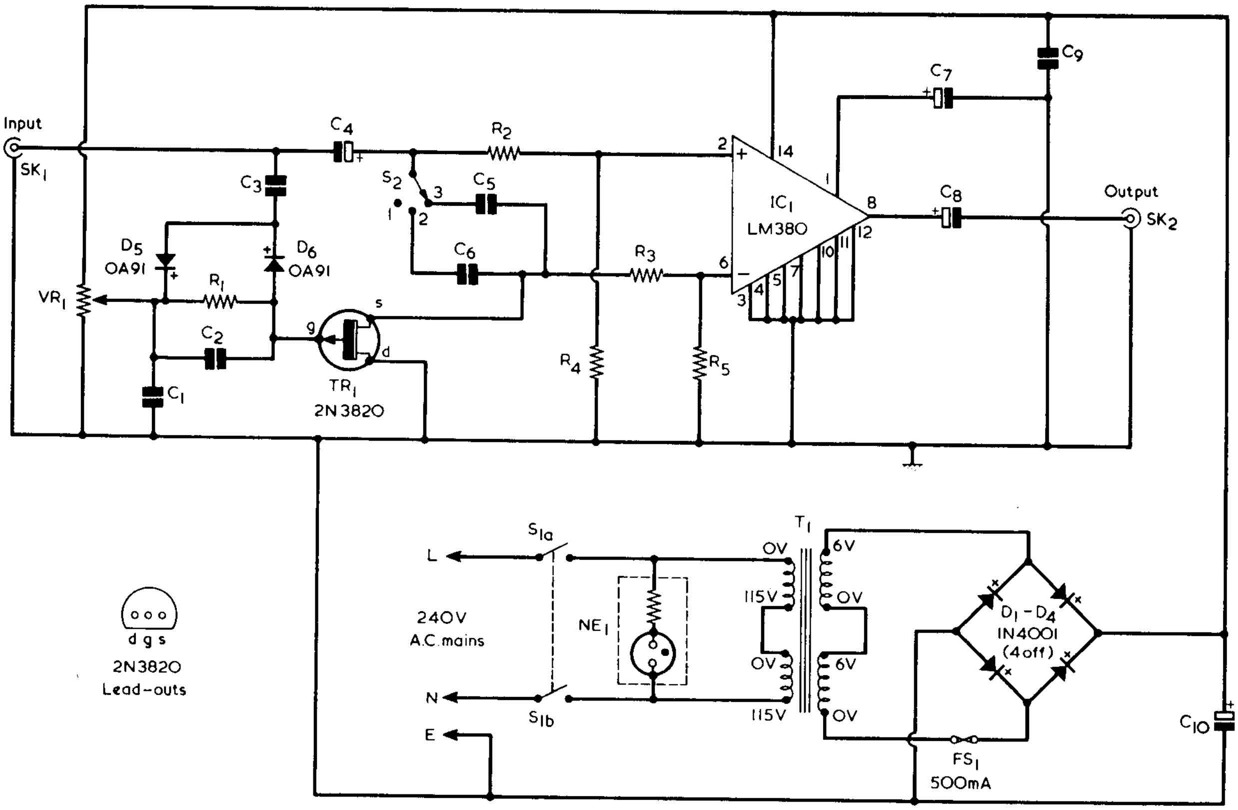


Fig. 2. The complete circuit of the noise reduction amplifier. The use of an integrated circuit audio amplifier considerably reduces complexity

COMPONENTS

Resistors
(All fixed values ¼ watt 5%)
R1 120k Ω
R2 5.6k Ω
R3 5.6k Ω
R4 220 Ω
R5 220 Ω
VR1 100k Ω potentiometer, linear

Capacitors
C1 0.22μF type C280 (Mullard)
C2 0.1μF type C280 (Mullard)
C3 0.047μF type C280 (Mullard)
C4 10μF electrolytic, 10 V. Wkg.
C5 0.015μF type C280 (Mullard)
C6 0.01μF type C280 (Mullard)
C7 10μF electrolytic, 25 V. Wkg.
C8 1,000μF electrolytic, 16 V. Wkg.
C9 0.1μF type C280 (Mullard)
C10 1,000μF electrolytic, 25 V. Wkg.

Semiconductors
IC1 LM380
TR1 2N3820
D1-D4 1N4001
D5 0A91
D6 0A91

Transformer
T1 mains transformer, secondaries 0-6V, 0-6V at 0.5A (see text)

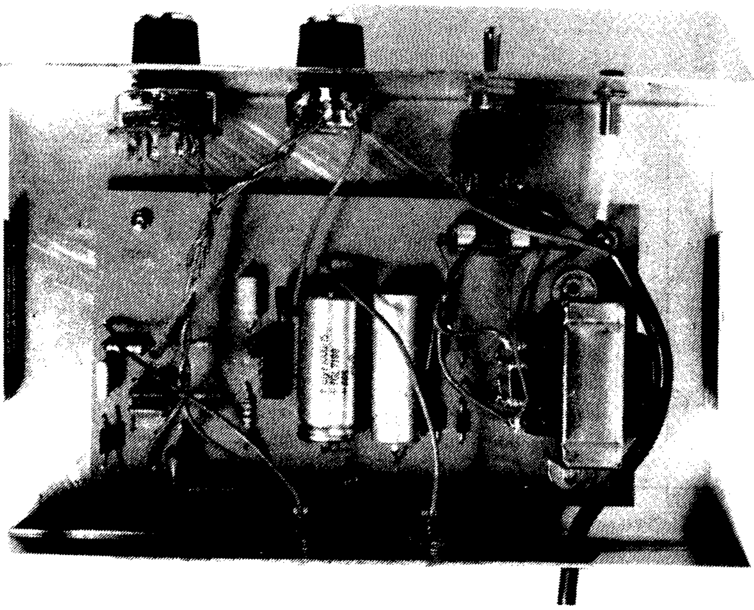
Switches
S1(a)(b) d.p.s.t. toggle
S2 4-pole 3-way rotary (see text)

Indicator
NE1 neon indicator (see text)

Sockets
SK1 3.5mm. jack socket (see text)
SK2 3.5mm. jack socket (see text)

Fuse
FS1 500mA fuse, 20mm.

Miscellaneous
Instrument case, 8 x 5¼ x 2in (see text)
20mm. fuseholder (see text)
2 control knobs
Materials for printed circuit board
3-core mains lead
Grommet
Nuts, bolts, wire, etc.



Looking inside the amplifier case. Wires from the printed board to the front panel components may, for neatness, be lightly twisted together as shown here

transformer, and is available from Doram Electronics Ltd. It has the unusual feature of having two primary windings, and these are series connected for use with the normal U.K. mains voltage.

Fuse FS1 is a 20mm. 500mA type and it fits in a 20mm. chassis mounting fuseholder, the latter also being available from Doram Electronics Ltd. The unit is assembled in an instrument case measuring 8 by 5¼ by 2in. This is a case Type BV1, which is retailed by Bi-Pak Semiconductors.

S2 is a 4-pole 3-way rotary switch, with connections made to one of the poles only. NE1 is a panel mounting neon indicator with integral series resistor suitable for connection to 240 volts a.c. mains.

CONSTRUCTION

Apart from the controls, neon indicator and input and output sockets, all the components are mounted on a printed circuit board which is illustrated full size in Fig. 3. It is not recommended that any other form of construction be used as the printed board has a large area of copper laminate which acts as a heatsink for the LM380. Inadequate heatsinking would not result in the i.c. being damaged, since the LM380 incorporates thermal and output short-circuit protection circuitry, but it would reduce the maximum available output power.

The 20mm. fuseholder is mounted by a single 6BA bolt and nut. It is advised that the 6BA clear hole for this be drilled first, following Fig. 3, after which the precise position of the adjacent locating hole is marked off with the aid of the fuseholder itself.

The prototype is constructed in the metal instrument case which has just been referred to. The general layout of the unit can be seen in the accompanying photographs, and is not particularly critical. Working from left to right, the components on the front panel are the neon indicator, S1, VR1 and S2. On the rear panel, the mains lead passes through a hole behind the mains transformer. This hole is fitted with a grommet and the mains lead should be secured inside the case with a plastic or plastic-faced clamp. Next to the mains lead hole is the output jack socket, followed by the input jack socket.

The printed board is secured to the bottom of the case with three 6BA bolts and nuts, metal spacing washers being employed to space the board under-

A view from the rear of the amplifier case

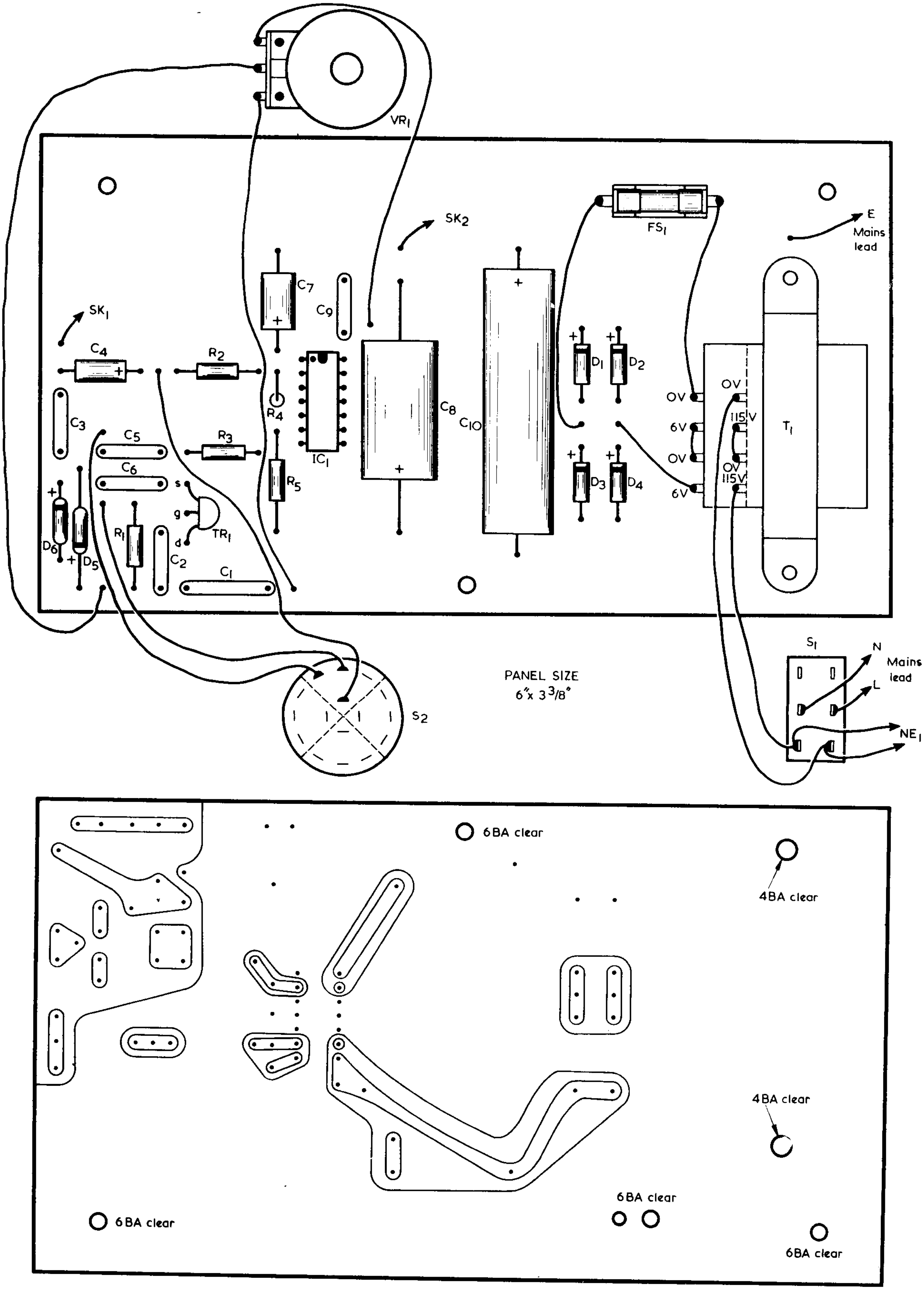


Fig. 3. Details of the printed circuit board, which is reproduced full size. The large copper area at chassis potential provides heatsinking for IC1

side clear of the inside metal surface of the case and thereby prevent short-circuits. The case takes up its earth connection from the printed board via these spacing washers. Single unscreened wires connect to the tip contacts of the input and output jack sockets. These should be of the non-insulated type, and they take up their earthy connections via their mounting bushes and nuts.

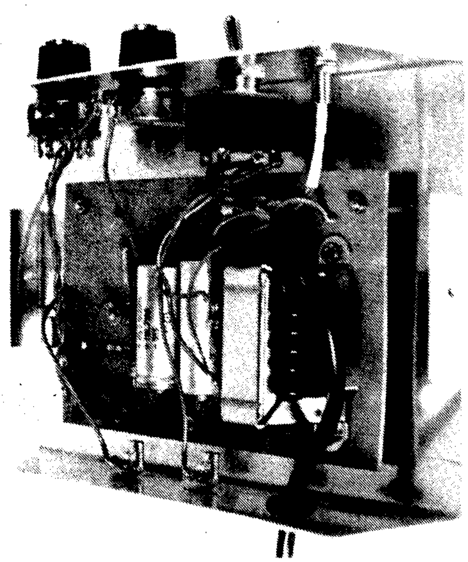
USING THE UNIT

The input socket of the amplifier is fed from the earphone socket of the cassette recorder. At the impedance and signal voltage levels involved there should be no need to use screened cable, but the interconnection should be such that the chassis of both units are at the same potential. Although the earphone output of the recorder is intended to feed into a low impedance load, there seems to be no need to add a dummy load resistor at the input of the amplifier. The effect of a dummy load resistor was tried in practice, but it merely resulted in increased distortion both with transformerless recorder outputs and with the older types having an output transformer.

The output of the amplifier connects to an 8 Ω speaker which should be mounted in a cabinet and be capable of handling at least 3 watts r.m.s.

The volume level is adjusted by means of the volume control on the recorder. Cassette recorders are often fitted with a simple top cut tone control and, if this should be the case, the control is adjusted for maximum treble.

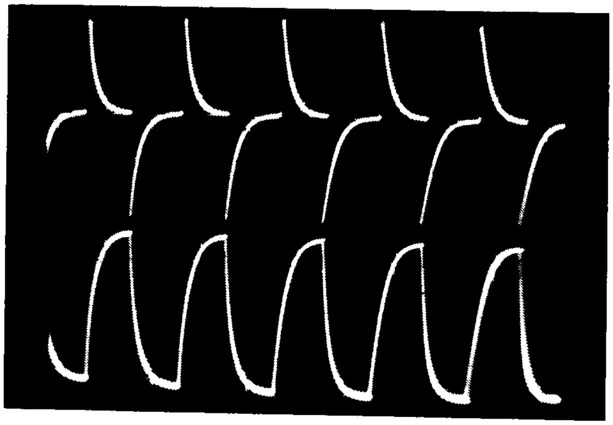
To obtain good results it is essential that bias control VR1 be correctly adjusted. With the volume adjusted to a low level it should be possible to locate a small range of settings over which VR1 operates as a sort of top cut tone control. The potentiometer should be set at the maximum cut end of this range of settings. It may be found that this results in the treble cut being reduced on fairly low level signals, with a rise in the background noise level being very apparent on such signals. In this case it will be necessary to back VR1 off slightly from the point at which it begins to lift the treble cut.



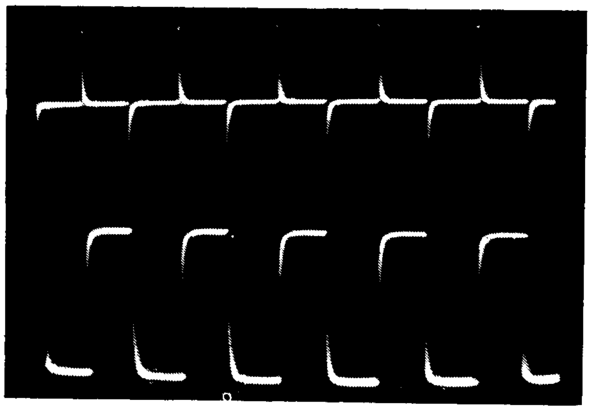
The printed board is spaced away from the bottom of the case to prevent short-circuits to its underside

In theory it is necessary to readjust VR1 each time the volume control setting is altered. This was not found to be the case in practice, and once the correct setting for VR1 has been located it does not seem to be necessary to readjust it unless the volume control setting is *greatly* changed. The higher the volume control setting, the further VR1 will need to be backed off.

Two of the photographs illustrate oscillograms obtained with 1kHz square wave input, the upper waveform in each being the signal at the inverting input of the LM380 and the lower waveform that at the output. The first photograph shows the result given with a low level signal. The square wave harmonics are largely fed to the inverting input and the slowing up of the output waveform due to the cancelling effect can be clearly seen.



Waveforms at the inverting input (upper) and the output (lower) given with a low level 1kHz square wave input



Waveforms with a high level 1kHz square wave input. Only supersonic harmonics are fed to the inverting input and the output shows little evidence of high frequency attenuation

The second photograph illustrates conditions with a high signal input level. This time only very high frequency harmonics outside the audio range are passed to the inverting input and in consequence there is little slowing up of the output waveform. ■

SHORT WAVE NEWS
FOR DX LISTENERS

By Frank A. Baldwin

Times = GMT *Frequencies = kHz*

AFRICA

Stations on the African continent can be of great interest to the Dxer and short wave listener alike, some of the programmes are colourful to sav the least, African music and rhythms are well worth taping for those that are so equipped. The early evenings and mornings are the best times for logging these transmissions — why not try an African safari tonight?

● ZAMBIA
Lusaka can be found on **4911** where they were logged at 1950 when radiating a programme of African music complete with drums and chants in the Home Service.

● TANZANIA
Dar-es-Salaam on **5050** at 1903, OM with a newscast in Swahili until 1910 then into a programme of local music and songs in the Commercial Service scheduled from 1300 to 2015. The National Service in Swahili is also radiated on this channel but from 0300 to 0500. The power is 10kW.

● CONGO
RTV Congolaise, Brazzaville, on **4765** at 1940, drums, YL's with shrill cries, OM announcer in vernacular. This is probably the easiest of African stations to receive here in the U.K. — if you are a beginner then this is where to make a start with them. The power is 50kW and a sign-off weekdays is at 2400. A newscast in English can be heard at 2130.

Pointe Noire on a measured **4843** at 2010, OM's discussion in French. This one is not so easy to receive but is well worth a try. It often relays Brazzaville but does have some local programmes. The evening schedule is from 1700 to 2100.

● BENIN
Cotonou on **4870** at 2000, YL and OM alternate with a newscast in English. The schedule here is around the clock and is the Home Service in French and vernaculars. The power is 30kW.

● GHANA
Accra on **4915** at 2249, OM with a talk on local affairs in English. The schedule is from 0530 to 0805 (Sundays through to 2300) and from 1200 to 2300, the power being 10kW.

● CAMEROON
Garoua on **5010** at any time throughout the evening (it closes at 2200). I tend to use this one as an indicator for African reception conditions. If its good then so are the other Africans on the 60 metre band.

If a tougher task appeals to you then try migrating to the 90 metre band. The secret here is to watch the band over a period of time, sooner or later (mostly later) conditions will favour the reception of African stations.

● TOGO
Radio Lama Kara on a measured **3222** at 1912, OM in vernacular, light music in the Palm Court style! The schedule is from 0530 to 0830 and from 1630 to 2230, the power being 10kW.

● SWAZILAND
TWR Mpangela on **3240** at 1916, OM with a talk in English about the Bible. This one operates from 0315 to 0414 and from 1800 to 1905 according to the schedule — and in Afrikaans and vernaculars only! The power is 30kW.

● RWANDA
Radio Rwanda, Kigali, on **3330** at 1925, drums, OM in vernacular, African music in the Home Service, scheduled here from 0300 to 0600 (weekends to 0700) from 0900 to 1200 (weekends to 2100) and from 1330 to 2100, the power being 5kW.

● LIBERIA
ELWA Monrovia on a measured **3227** at 2135, YL's with chants, drums, African music. This is the Home Service in vernaculars which operates from 0610 to 0800 and from 1805 to 2220. The power is 10kW.

With that we leave the African continent and pay brief visits to some other far away places with strange sounding names.

● CZECHOSLOVAKIA
Prague on **7345** at 1916, OM with the English programme directed to the U.K., Eire and Middle East, scheduled here from 1900 to 1930.

● FINLAND
Helsinki on **11755** at 1915, OM with a newscast of local affairs in the English programme for Europe, scheduled from 1900 to 1925. Also in parallel on **9550.** This programme is also intended for the Middle East and West Africa.

● INDIA
All India Radio, Delhi, on **11620** at 1930, featuring a programme of Indian music in the English transmission for East Africa, the U.K. and Western Europe, scheduled from 1745 to 1945 and in parallel on **7225, 9525, 9730** and on **15125.**
For those interested, other English programmes from Delhi during the evening period are as follows — from 1945 to 2045 to North & West Africa, the U.K. and West Europe on **7225, 9525, 9755, 9912, 11620** and on **11880;** from 2045 to 2230 to the U.K., West Europe and Australasia on **7145, 7225, 9525, 9912, 11620** and on **11740.**

● EGYPT
Cairo on **17745** at 1230, YL with Arabic songs in the 'Voice of the Arabs' programme, scheduled here from 0800 to 1400 and from 1500 to 1825.

● ALBANIA
Tirana on **11985** at 1535, OM with the English programme for Africa, scheduled here from 1530 to 1600 and also in parallel on **9480.**

● NETHERLANDS
Hilversum on **21640** at 1545, OM with a programme in Arabic beamed to the Middle East and Gulf States, scheduled on this channel from 1530 to 1620.

● TIBET
Lhasa on **9490** at 1610, OM with programme in Hindi to South Asia, heard under a USSR transmitter on the same channel. The Hindi programme is scheduled from 1600 to 1700.

● COLOMBIA
Radio Bucaramanga on **4845** at 0155, commercials and announcements in Spanish, local pops on records. The schedule is from 1000 to 0400 and the power is 1kW.
Ecos del Atrato, Quibdo, on **5020** at 0314. YL with love song, OM with announcements in Spanish. The schedule is from 1100 to 0400 and the power is 1kW.

● ECUADOR
Radio Popular, Cuenca, on **4800** at 0404, OM in Spanish, local pops on records. This station has a 24-hour schedule, the power being 2kW. Sometimes identifying as 'Amiga Popular de Cuenca' this one can be heard after Radio Lara, Barquisimeto, closes at 0400.
La Voz de los Caras, Bahia de Caraquez, on **4795** at 0349, a programme of local music with OM announcer. The schedule is from 1300 to 0400 (Sundays to 0520) and the power is 3kW.

● DOMINICAN REPUBLIC
Radio Mil, Santo Domingo, on **4930** at 0307, local pops on records, OM in Spanish. The schedule is from 0900 to 0400 and the power is 1kW.

● PERU
La Voz de la Selva, Iquitos, on **4825** at 0410, OM with commercials in Spanish, local pops, station schedule is from 1000 to 0500 and the power is 1kW.
Radio Quillabamba on **5025** at 0318, OM with commercials in Spanish, light music background with 'noticias'. Schedule is from 1100 to 0500 and the power is 5kW.
Radio Atlantida, Iquitos, on **4790** at 0150, OM with songs in Spanish, guitar music, commercials. The schedule is from 0900 to 0600 and the power is 1kW.

● BRAZIL
Radio Brasil Central, Goiania, on **4985** at 0216, OM with song in Portuguese, LA music. The schedule is around the clock and the power is 5kW.
Radio Relogio, Rio de Janeiro, on **4905** at 0159, OM in Portuguese, time pips, identification. This station features time pips throughout the transmissions as a background addition, it is on the air daily from 0800 to 0300 except from Tuesday to Friday from 2200 to 2330. The power is 5kW.
Radio Aparecida on **5035** at 0220, local songs and music of the pop variety. The schedule is from 0900 to 0300 and the power is 1kW.
Radio Sociedad, Feira de Santana, on **4865** at 0300, OM with identification, announcements and local pops on records. The schedule is from 0730 to 0400 and the power is 2kW.
Radio Emisora Rural, Santarem, on **4765** at 0322, OM with announcements in Portuguese with added echo-effect, local pops on records. The schedule is from 0830 to 0400 and the power is 10kW.

● AUSTRALIA
ABC Brisbane on **4920** at 2006, pops on records after a newscast in English. The schedule is from 1900 (Sundays from 1930) to 1402 and the power is 10kW.

● CHINA
Radio Peking on **6225** at 1430, YL with songs in the Domestic Service 1 programme, scheduled here from 1100 to 1735 and from 2000 to 0100.
Radio Peking on **9920** at 1430, Chinese songs and music in the Kazakh Domestic Service for Minority Groups.
Radio Peking on **11695** at 1415, YL with the programme for Cambodia, scheduled from 1400 to 1500 on this channel.
Radio Peking on **11650** at 1418, YL with an English programme beamed to South Asia from 1400 to 1500.
Radio Peking on **12420** at 1440, programme of Chinese music in the domestic Service 1, scheduled here from 0750 to 1735 and from 2203 to 0300.

● CLANDESTINE
Voice of the People of Thailand on a measured **9423** at 1510, OM with songs followed by military music in the Laotion programme, scheduled from 1430 to 1520.

● NOW HEAR THIS
Radio Libertad, Junin, Peru, on a measured **5041** at 0417, OM in Spanish, typical plaintive Andean song by YL, mournful flute music. This one has a 24-hour schedule and can vary in fre-

ULTRA-SENSITIVE OP-AMP METER

By J. B. Dance

This low cost CA3140 circuit allows measurement of currents below 0.001μA, voltages below 10mV and resistances up to 100,000MΩ

This article shows how the economical CA3140 operational amplifier can be used in a very simple meter circuit which will provide a full scale deflection with an input current of only 1 nanoamp (one-thousandth of a microamp). Other current ranges such as 0.01μA, 0.1μA, 1μA, 10μA, etc., can easily be added. The circuit can also measure small input voltages and provides a full-scale deflection with inputs of 10mV, 100mV or 1V at an input resistance of 10MΩ. In addition, the circuit can be used for measuring resistance values up to some 100,000MΩ.

The meter driven by the operational amplifier requires a full-scale deflection of 1V, and can consist of a 0-100μA or 0-1mA meter movement in series with a suitable resistor. The circuit has not been designed to give the highest possible accuracy, but the accuracy should be well within plus or minus 5% and probably within plus or minus 3%; this is adequate for almost all purposes.

METER AMPLIFIERS

The normal moving-coil meter can be made quite sensitive, but if one wishes to measure currents in the nanoamp range one must employ an amplifier with such a meter. Numerous circuits have been published which incorporate the 741 op-amp as an amplifier to produce full-scale deflection on a 0-1mA meter with an input current of about 1μA. This is about the smallest current a 741 device can measure with reasonable accuracy, since the typical input current required by a 741 is 0.2μA, whilst the maximum input current required by any 741 device is 0.5μA.

High performance hybrid operational amplifier devices which contain two junction field effect input transistors and an operational amplifier in a single package can be used to measure much smaller currents, although some of these devices are fairly expensive. However, the RCA device type CA3140 is very suitable for measurements in the nanoampere range and is also very cheap being only about three times the price of a 741 device.

THE CA3140

The CA3140 device employs p-channel MOS field effect transistors in the input stage so that input impedances of about 1.5TΩ (1.5 million megohms) are obtained. The input currents required are typically 10 picoamps with a maximum value of 50 picoamps for any one device.

The CA3140 is very much like the well-known 741 operational amplifier except that it has a far greater input impedance. As in the case of the 741, the CA3140 has an internal frequency compensating capacitor and is provided with offset nulling facilities.

The connections of the CA3140 are shown in Fig. 1. This device is obtainable as the CA3140E in an 8 pin dual-in-line package with similar connections to those of the 741. The CA3140 can also be obtained as the CA3140T in a circular metal can with 8 straight leads and as the CA3140S in a similar metal package with the leads bent into the 8 pin dual-in-line configuration. More expensive types are available as the CA3140A and the CA3140B, but generally any of the other three types is ideal for the present application.

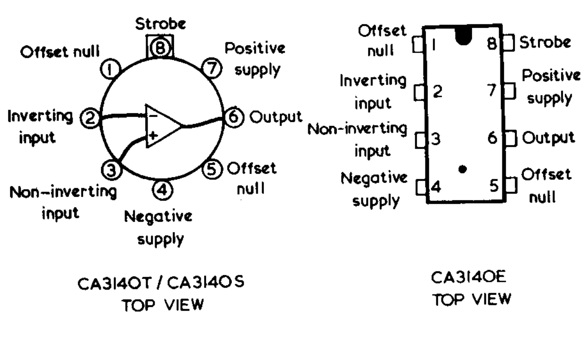


Fig. 1. Pin connections for three versions of the CA3140

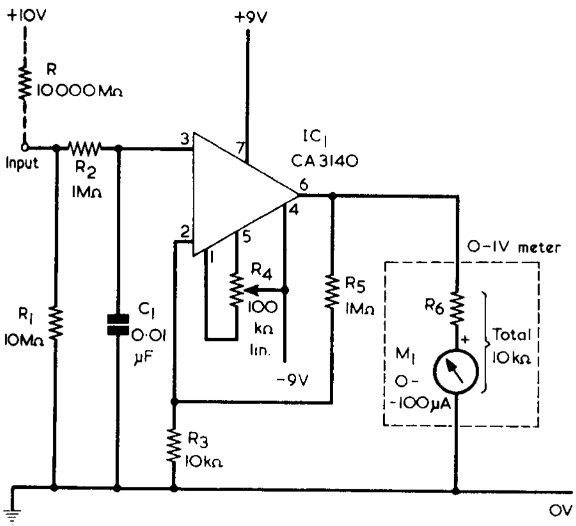


Fig. 2. Simple operational amplifier circuit capable of low current and voltage measurements

BASIC CIRCUIT

The basic meter circuit, used by the writer in his initial experiments, is shown in Fig. 2. It was not found necessary to employ decoupling capacitors from the two power supply rails to ground with any of the CA3140 devices used, but if any unwanted oscillations should occur (giving peculiar meter readings) 0.1μF capacitors from pin 7 and from pin 4 to ground should remove this trouble.

The positive and negative 9V power supplies shown may be conveniently obtained from batteries, but a positive and negative 15V supply is equally satisfactory. The minimum supply voltage is 2V positive and negative, but the maximum output swing is then limited to rather less than these values. It is essential that the OV line be connected to the OV of the power supply. The power supply current is normally 3 to 4mA, but it can be appreciably greater when the circuit is settling down to a final meter reading.

The potentiometer R4 should first be adjusted so that the meter indicates OV when the input point of the circuit is connected to the OV line. The setting of this potentiometer is fairly critical and some drift of the zero occurs as the temperature of the CA3140 silicon chip changes; R4 should therefore be adjusted again after the circuit has been operating for a few minutes.

Any meter with a full-scale deflection of 1V and a resistance of 1,000Ω or more may be used across the output. With 15V supplies a meter with a full-scale deflection of 10V may be employed if a 10 times decrease in the sensitivity is acceptable. A meter with an f.s.d. of 1V is given by a 0-100μA meter movement and a series resistance which causes the total resistance to be 10kΩ as is shown in Fig. 2.

Let us now consider what happens if we feed a current of 0.001μA to the input of the circuit of Fig. 2. This may be done by connecting the resistor R (shown dotted) to the input and applying 10V positive to its other end. The current of 0.001μA flows through R1 and produces a voltage drop of 10mV across it. The components R2 and C1 attenuate any high frequency signals picked up by the input circuit and also reduce the effect of stray capacitance in the input circuit.

The input voltage at pin 3 is multiplied by the gain of the circuit. This gain is 1 + R5/R3, or about 100 times with the values shown in Fig. 2. Thus the 10mV positive at the input is amplified to 1V positive at the output. This circuit can therefore be used as a voltmeter with a full-scale deflection of 10mV and an input resistance of 10MΩ (that is 1,000MΩ per volt).

If the value of R5 is changed to 90kΩ the voltage gain will be reduced to 10 times; the ranges for full-scale deflection will then be 0.01μA and 100mV with the same 10MΩ input impedance. Similarly the value of R5 can be reduced further to zero, in which case the gain of the amplifier is unity and full-scale deflection is obtained with a current of 0.1μA and a voltage of 1V.

CURRENT MEASUREMENTS

It was found that the value of R1 could be increased to 100MΩ in order to obtain a full-scale deflection with an input current of 100 picoamps, but errors occur if one tries to measure such extremely low currents with this simple circuit. The typical CA3140 input current is then 10% of the current being measured and zero drift can be troublesome. A value of 10MΩ was therefore selected for R1.

Current ranges in the microamp region can easily be obtained by reducing the value of R1. For example, if R1 is 100kΩ the currents for full-scale deflection are 0.1μA, 1μA and 10μA when the amplifier gain is respectively 100, 10 and 1.

VARIOUS RANGES

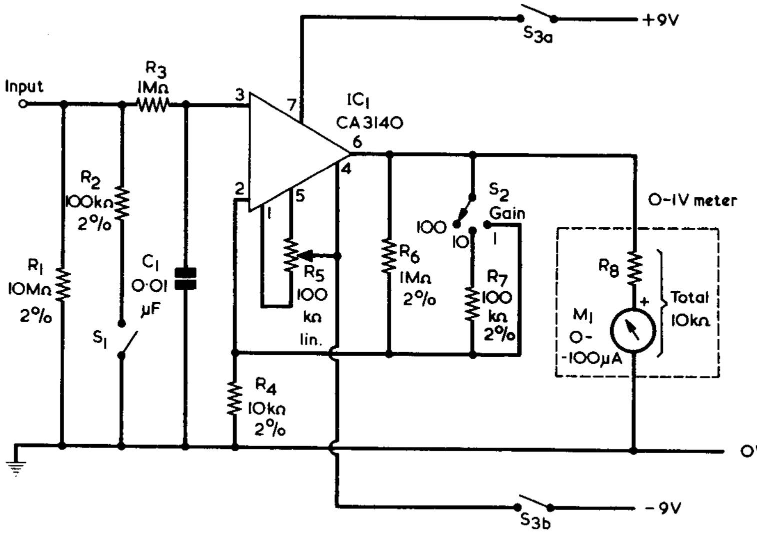
A complete working circuit for a multi-range measuring instrument using the principles discussed is shown in Fig. 3. The voltage gain of the CA3140 amplifier can be selected by S2 to have a nominal value of 100, 10 or 1. R6 is always in circuit in order to avoid excessive switching transients. With S1 in the "100" position the value of 1 + R6/R4 is actually 101, but this is adequately near the desired value to provide the accuracy for which we are aiming. When R7 is switched into circuit by S2 it is connected in parallel with R6 in order to obtain a gain of about 10 times with sufficient accuracy.

Closing switch S1 causes the input resistance to be reduced by a factor of 100 so that larger currents can be measured. The voltage and current ranges which can be obtained with the circuit of Fig. 3 are shown in the table.

Further options are available with the circuit. If, for instance, one wishes to measure larger currents one may switch an even smaller resistor in parallel with R1; a 1kΩ resistor will provide full-scale deflections of 10μA, 100μA and 1mA, whilst a 10Ω resistor will provide ranges of 1mA, 10mA and 100mA.

Another variation is to switch in a 20kΩ resistor in series with R8 so that the total meter and series resistance becomes 30kΩ Full-scale deflection on whatever range is selected will then be increased by a factor of 3. Yet a further modification could

Fig. 3. The complete meter circuit. This offers the current and voltage ranges listed in the Table



consist of employing a centre-zero 100-0-100μA meter movement; the circuit could then measure input voltages and currents of either polarity.

It is important to appreciate that the two inputs of the CA3140 are sensitive to stray pick-up of signals when the gain is set to 100 times. The components R4 and R6 should in consequence be positioned as near to pin 2 of the device as possible, whilst R3 and C1 should be positioned close to pin 3. The sensitivity of the circuit can be shown by touching the input with a finger; this will usually produce full-scale deflection if the circuit is switched to one of its more sensitive current ranges.

Readers having access to home constructor suppliers only may have difficulty in obtaining the close tolerance 10MΩ resistor required for R1. If a suitable resistor cannot be selected from a batch of wider tolerance components, a 5% resistor may be employed with the corresponding possible small loss of accuracy accepted. Switch S3(a) (b) in Fig. 3 is, of course, the on-off switch, and is required when the circuit is powered by two 9 volt batteries.

Apart from the sensitivity of the current ranges, one of the features of the circuit is the high input impedance of 10MΩ on all the voltage ranges. Thus, the circuit imposes a very small load on the circuit to which the input is connected.

Voltage Gain (Set by S2)	Input Voltage For F.S.D.	Input Current For F.S.D. (S1 open)	Input Current For F.S.D. (S1 closed)
1	IV	0.1μA	10μA
10	0.1V	0.01μA	1μA
100	0.01V	0.001μA	0.1μA

RESISTANCE MEASUREMENT

The circuit of Fig. 3 can also be used to measure high value resistors. S1 should be open for such measurements and the unknown resistor is connected between the input and a 10 volt supply in the manner which was shown in Fig. 2. If, with S2 set to "100", the unknown resistor has a value of 10,000MΩ there will be 0.01 volt across R1 and the meter will read full-scale deflection. 100,000MΩ will cause an output reading of 0.1 volt.

A simple circuit of this nature forms an ideal first exercise in the use of an operational amplifier. It should be remembered that the CA3140 is a CMOS device and that the usual precautions against applying high static voltages to it should be observed. Soldering should be carried out with an iron whose bit is reliably earthed. ■

Mail Order Protection Scheme

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3 BAND SHORT WAVE SUPERHET Part 2

By R. A. Penfold

Building the i.f. and a.f. amplifiers.

In last month's issue we introduced this comprehensive short wave superhet design and described the construction of its case and the circuitry of its r.f., oscillator and i.f. stages. We proceed next to the r.f. coilpack.

COILPACK CONSTRUCTION

All the mixer and oscillator circuitry is contained in a coilpack assembly. This consists of a metal bracket on which are mounted the coils and the wavechange switch and a perforated s.r.b.p. board carrying TR1, TR2 and the associated components. The board is secured to the metal bracket by way of two solder tags soldered to the s.r.b.p. board wiring. This method of construction is employed because it is necessary for the r.f. and oscillator wiring to be kept short in the interests of efficiency and stability. Details of the coilpack are given in Fig. 4. In this diagram, coils 1, 2 and 3 are the os-

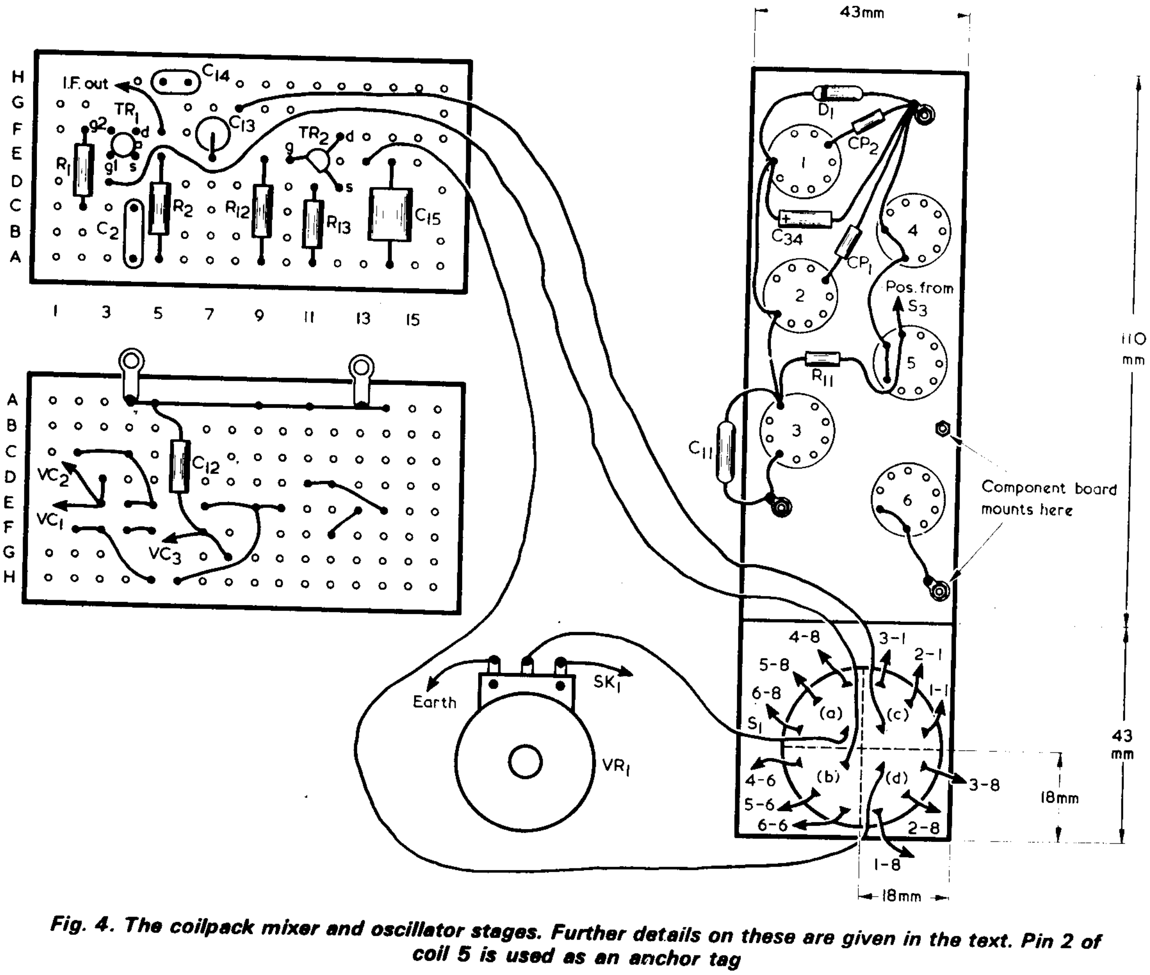


Fig. 4. The coilpack mixer and oscillator stages. Further details on these are given in the text. Pin 2 of coil 5 is used as an anchor tag

cillator coils (L2) whilst the aerial coils (L1) are shown as 4, 5 and 6. The Range 5 coils are at the front, nearest the switch, the Range 4 coils are in the middle and the Range 3 coils are at the rear.

The component panel is a plain perforated board of 0.15in. matrix having 16 by 8 holes, and it is helpful if this is made first as its two solder tags define the positions of the corresponding mounting holes on the metal bracket. The components are fitted in the positions shown in Fig. 4. with their lead-outs bent flat against the underside of the board. They are then wired together as shown in the diagram, after which C12 is wired in on the board underside. The two solder tags are next soldered in place. TR2 is wired into circuit with the lead-out layout shown in Fig. 3. (In some data references the drain and source lead-outs of this transistor are shown transposed).

The metal bracket is then cut out and drilled. Cut out a piece of 18 s.w.g. aluminium sheet 153 by 43mm. and drill this to take the coils, the switch and the bolts which secure the various solder tags. The precise positioning of the coils is not too critical, but they should be kept as far apart from each other as is reasonably possible and they must not be mounted too far forwards where they would foul S1 when the right angle bend in the bracket is made. The coils require 6.5mm. diameter holes and are mounted by the plastic nuts with which they are supplied. The holes for the solder tag bolts are drilled 6BA or M3 clearance.

The two sets of coils are separated by a vertical screen which has been omitted from Fig. 4 for the sake of clarity. This is made from a piece of 18 s.w.g. alumium sheet measuring 90 by 40mm. A 90 degree bend is made 10mm. in from one of the 90mm. long sides of the aluminium sheet, and this provides a small flange which enables the screen to be mounted to the coilpack bracket. It is secured by a single 6BA or M3 bolt and nut situated in a central position on the 10mm. flange. The screen is mounted so that its rear edge is flush with the rear edge of the coilpack bracket. It is advisable to place a strip of p.v.c. insulating tape across the top edge of the screen so that there is no risk of wiring short-circuiting to it.

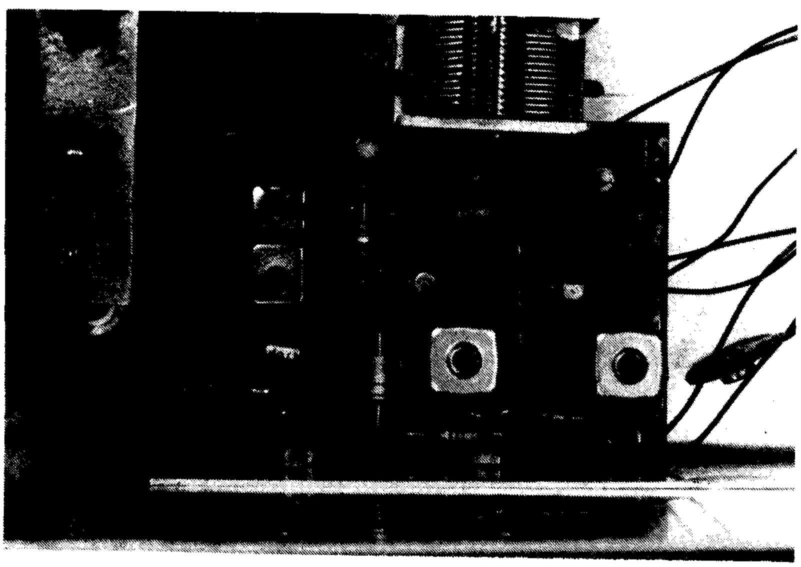
The component panel has its two tags mounted to the metal bracket at the points indicated, the two solder tags being on the bracket underside as this is illustrated (i.e. on the same side as the coil core adjusting screws). It should be mounted well forward on the bracket, and its body is alongside the coils with its component side towards the coils. When it has been fitted the remaining wiring can be carried out. It will probably be found easiest to start by wiring in D1, R11 and the other connections to the coil pins. The four central tags of the switch may then be wired up, followed by the outer tags. It is essential that all this wiring be kept as short and direct as possible. Also, before connecting up to S1 ascertain with a continuity tester the three outer tags corresponding to each inner tag. Their relative positioning may differ with some switches, from that shown in the diagram. (The same comment applies to the other rotary switch in the receiver, S2).

Soldered connections are made direct to the coil pins. The soldering iron must be applied very quickly to these pins as the plastic material in which they are mounted melts readily with heat.

The completed coilpack is then mounted in the case with the coil core adjusting screws pointing upwards. The edge of the bracket should just clear the edge of the front flange of the chassis. The coilpack bracket is secured in place by way of the mounting bush and nut of the wavechange switch. Short connections are next made to the fixed vanes of VC1, VC2 and VC3. The rear section of the 2-gang capacitor is VC2 and the front section is VC3. The variable capacitors obtain the chassis connection to their moving vanes via the metal case.

I.F. AMPLIFIER

The i.f. amplifier stages are constructed on a plain perforated s.r.b.p. panel of 0.15in. matrix having 25 by 16 holes. This is a standard 3.75 by 2.5in. panel and does not have to be cut down from a larger size. Details of this panel are given in Fig. 5. The three mounting holes are 6BA or M3 clearance and are drilled out with a bit of appropriate size. It is also necessary to slightly enlarge the holes through which pass the i.f. transformer and filter tags and mounting lugs. The mechanical filter consists of two parts, the larger being the actual filter and the smaller a matching i.f. transformer.



The i.f. amplifier board. This includes the mechanical filter with its matching transformer

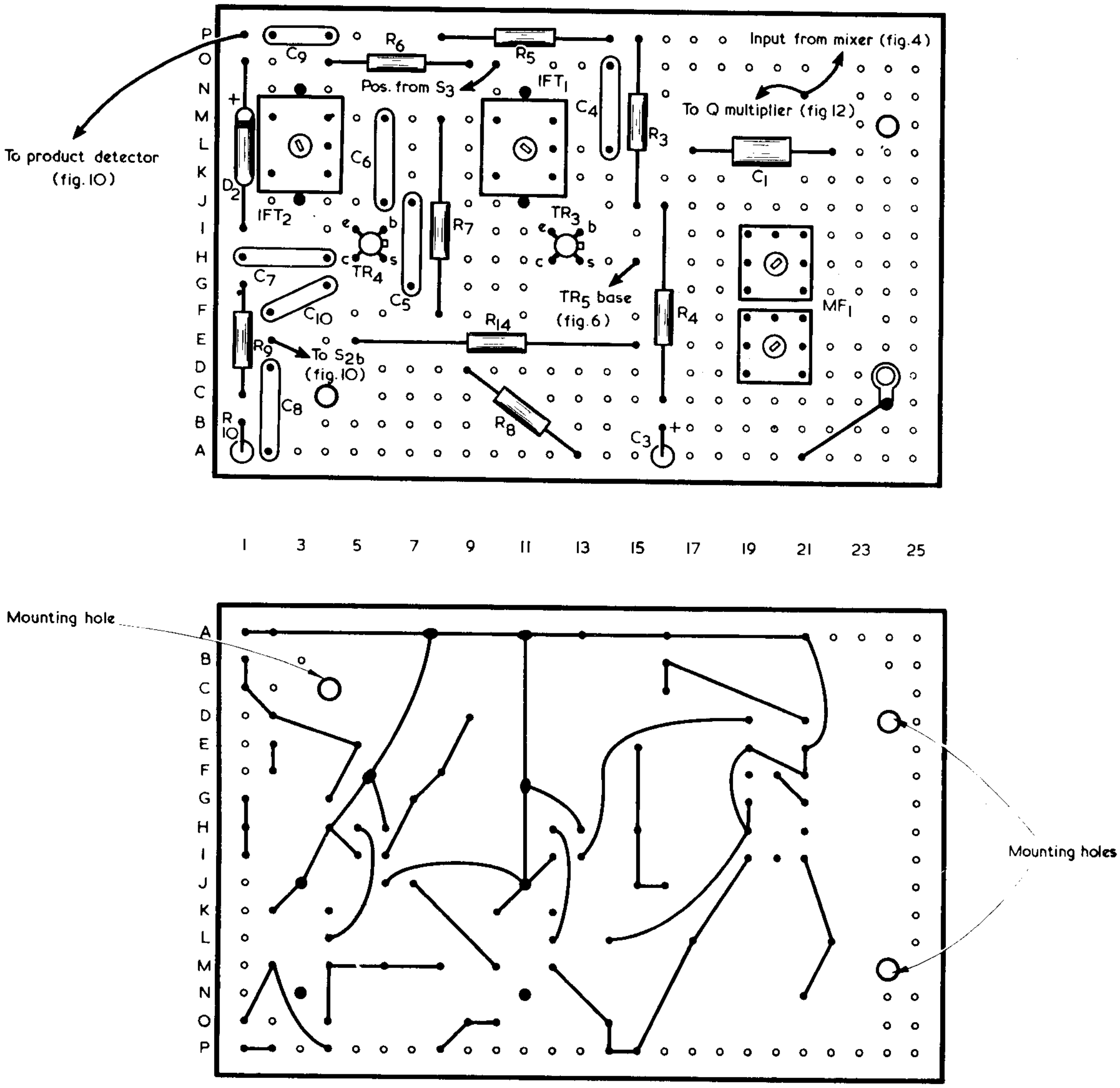


Fig. 5. The component and wiring sides of the i.f. amplifier

After drilling has been completed the components are mounted and the underside wiring is carried out. It is important to keep this wiring short and direct and, also, flat up against the panel underside. The chassis connection is made by way of a solder tag secured under one of the mounting nuts for the board. Veropins of the 0.15in. type are fitted at the points where external connections are made to the board.

The completed board is mounted at the extreme right hand side of the chassis and as far towards the rear as is possible. The end with the filter is towards the right. Spacers about 6mm. long are used over the mounting bolts to keep the panel underside clear of the chassis.

As the i.f. transformers and mechanical filter are supplied pre-aligned their cores must not be touched at this stage. They will be aligned when the receiver has been completed.

"S" METER WIRING

There are very few components in the "S" meter circuit and so point-to-point wiring is used here. This is shown in Fig. 6. Readers who prefer a more rigid mounting for the transistor may fit a small 2-way tagstrip at an appropriate point and solder the base and collector leads of TR5 to its tags. One connection is not shown in Fig. 6: this is a wire connecting the negative terminal of the meter to the solder tag at one of its mounting bolts.

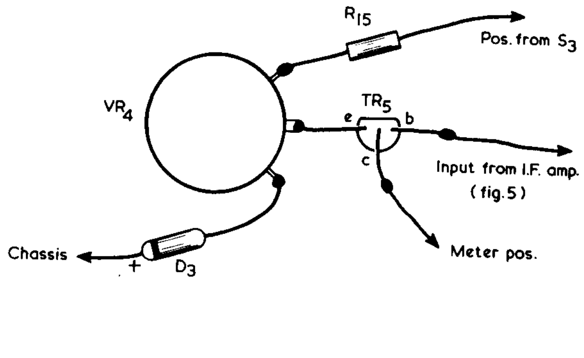


Fig. 6. Wiring details for the "S" meter circuit

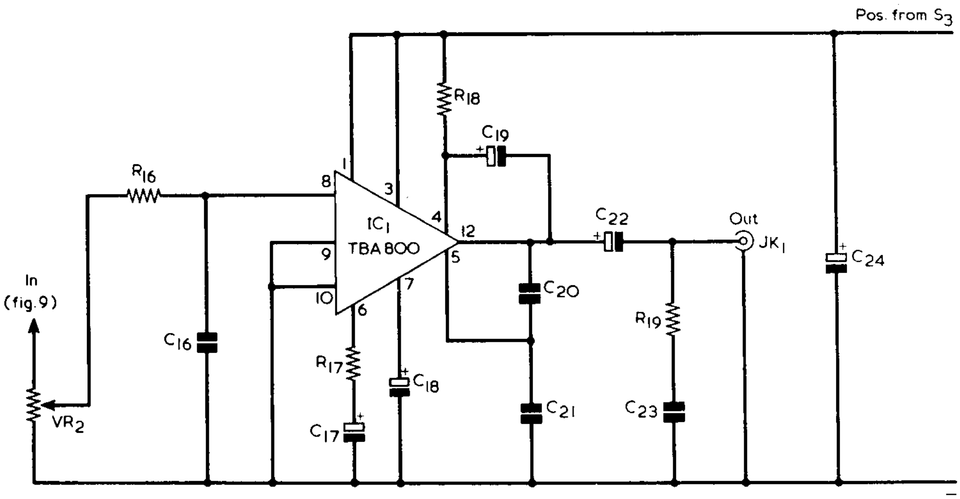
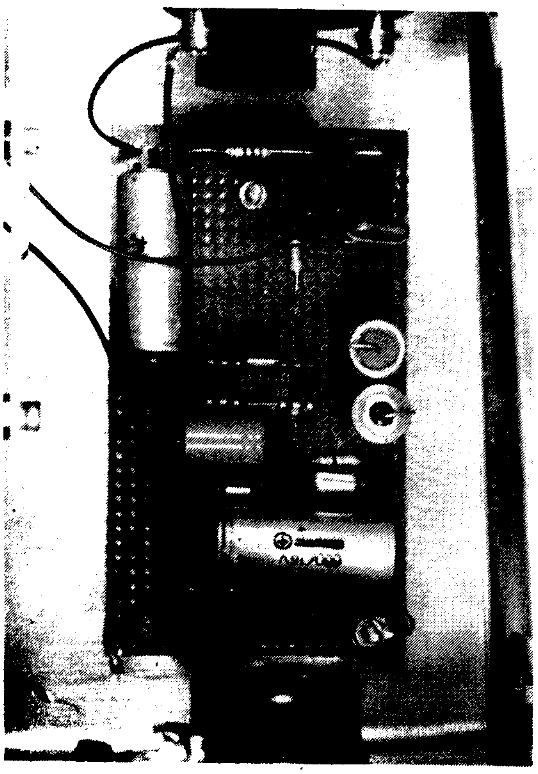


Fig. 7. The circuit of the a.f. amplifier section

A.F. PANEL

The circuit of the audio amplifier is shown in Fig. 7. This is based on the popular TBA800 i.c., which is the only semiconductor device used in this part of the receiver.



The a.f. amplifier. This is based on a TBA800 integrated circuit

VR2 is a conventional volume control, and R16 and C16 form an r.f. filter at the input to the i.c. The internal circuit of the TBA800 is such that no input d.c. blocking capacitor is required. The voltage gain of the circuit is controlled by the value given to R17, and this has a rather low value since a fairly high voltage gain is needed in the present application. C20, C21, R19 and C23 ensure that the circuit has good stability.

The audio amplifier is constructed on a plain perforated s.r.b.p. board of 0.1in. matrix having 36 by 20 holes. Details appear in Fig. 8.

The TBA800 is encapsulated in a 12-pin quad-in-line package. It has two heat sink tabs which serve no useful function in the present circuit as the i.c. is only called upon to provide a comparatively modest output. These tabs must be either cut off or bent up out of the way.

The panel is first cut to size and the three mounting holes, which may be either 6BA or M3 clearance, are then drilled out. The components are next mounted in place and their lead-out wires bent over at right angles on the underside of the panel. Wiring is carried out in the same way as for the i.f. panel, the various connections being shown in broken line in Fig. 8. Note that the chassis connection is picked up by a solder tag at one of the mounting nuts.

The panel is wired up to the rest of the receiver circuit before it is finally mounted on the chassis. It is positioned behind JK1 with C24 to the rear and its exact positioning is not critical. Spacers approximately 6mm. long on the mounting bolts keep the underside of the panel clear of the chassis. If jack socket JK1 is of open non-insulated construction it takes up its "sleeve" contact connection via its mounting bush and nut. Take care to connect the output from C22 to the correct tag of the socket.

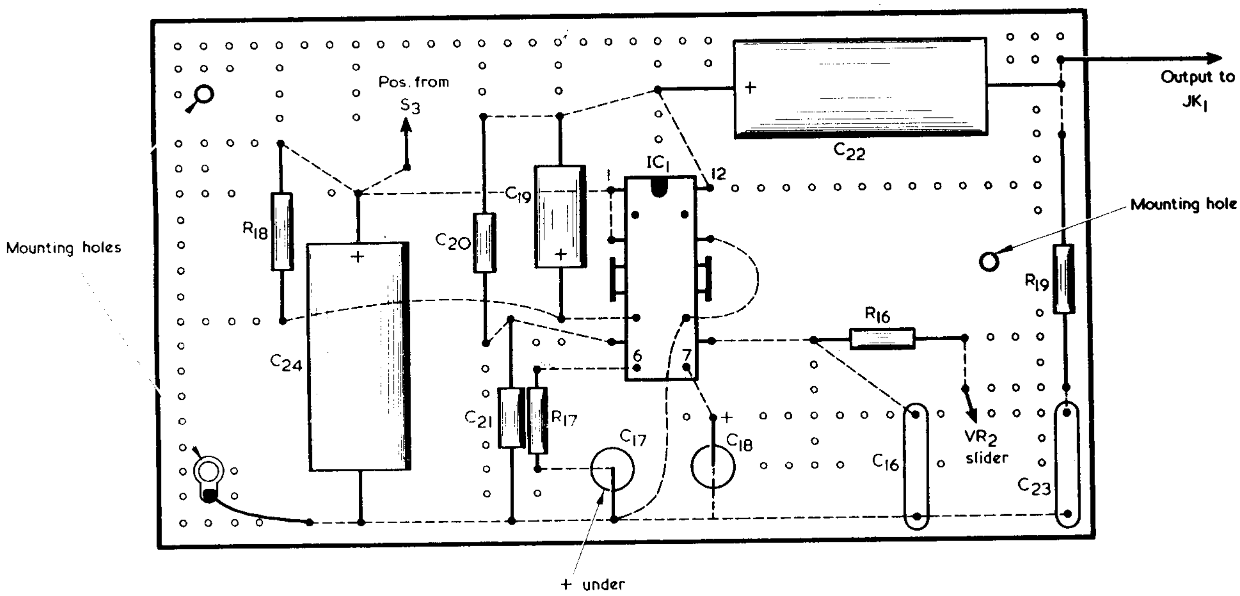


Fig. 8. The audio amplifier board is wired as shown here. Wiring under the board is reproduced in broken line

NEXT MONTH

We continue with constructional details in the next issue, carrying on to the product detector.

(To be continued)

BOOK REVIEW

LINEAR IC EQUIVALENTS & PIN CONNECTIONS. By Adrian Michaels. 319 pages, 180 x 125mm. (7 x 5in.) Published by Bernard Babani (publishing) Ltd. Price £2.75.

In the old days of valves we used to grumble about the unnecessary proliferation of similar types having different bases and envelope shapes. Had we realised, then, the teeming chaos which was to come with transistors we would have kept quiet! Now we have a host of integrated circuits of widely diverse types and applications but, surprisingly enough, little duplication of similar devices. Perhaps the almost universal acceptance of the dual-in-line package has caused designers to refrain from needless variations on basic types; many modern i.c.'s have direct replacements available from a wide list of manufactuers.

Nevertheless, there are still very many integrated circuits of differing function available at present, and for the linear types the book under review gives details of pinning and equivalents. The i.c.'s are listed in 137 pages of the book and, with about 25 devices per page, there are some 3,400 entries. Naturally, the number of actual types dealt with is lower than this because of cross-referencing.

The listings are under the general headings of type, pinout, function, land of origin, manufacturers, European equivalents and American equivalents, and the tables are followed by 176 pages of pin connection drawings. The book is a companion volume to "Digital IC Equivalents & Pin Connections", published in 1977 by Babani Press and priced at £2.50.

In your work-shop

CASSETTE RECORDER FAULT

The Case of the Missing Erasure

Dick took the small cassette recorder over to his bench and looked at it with interest, noticing that it had provision for a 240 volt a.c. input as well as a plastic battery cover. He removed the latter, to reveal four 1.5 volt cells nestling cosily between their contacts. Pulling his battered multimeter towards him, he selected a 0-10 volt range and applied the test prods to the end contacts of the series combination of cells. The meter needle indicated slightly in excess of 6 volts. He switched on the recorder and checked again. This time the reading was a little lower than 6 volts. Dick switched off.

It was quite evident that the recorder was set up for battery instead of mains operation and that the four 1.5 volt cells were giving very nearly their full nominal voltage.

He selected "Playback" and switched on again. The little motor whirred and he heard a faint rustling noise, for all the world as though someone were pushing their way through the undergrowth of a wood. Then, faintly, came the sound of a bird followed, more loudly, by several further birds. The recorder had patently been used by someone wishing to capture the sounds of Nature.

MULTIPLE RECORDING

Suddenly the wood seemed to come alive with the sound of what was manifestly a very boozy party indeed. A party, moreover, which did not have the dulcet tone of birdsong but was an unharmonious amalgam of many voices unsteadily ploughing their way through "I'll take you home again, Kathleen". Whilst the birds continued with commendable clarity to twitter in the background as the tape progressed past the heads of the cassette recorder the reproduction of the celebrating choristers carried a noticeable and unpleasant distortion.

Dick frowned in puzzlement.

"Hey, Smithy!"

"Hallo!"

"What do you make of the racket from this cassette recorder I've got here?"

Smithy the Serviceman stood up and wandered over towards his assistant.

"I should imagine," he remarked absently, "that the erase oscillator has stopped working."

Dick switched off the recorder and regarded Smithy, now at his side, with ill-concealed annoyance.

"Why," he asked irritably, "do you keep coming out with off-the-cuff statements like that? You haven't even *looked* at this darned recorder yet, but you're already telling me what's wrong with it."

"I was merely hazarding a guess," replied Smithy mildly. "Seeing that, as always, you have to have the volume of anything on your bench turned up full blast, I couldn't help but hear that recording right from the start. Those birds were reproduced quite clearly, so obviously the recorder was working all right when they were recorded. But the party was noticeably distorted and the sound of the birds hadn't been erased. I should imagine that the birds were recorded first, and that the erase oscillator had failed when, later, the party was being recorded. That explains why the sound of the birds was not wiped off the tape."

"Couldn't it have been the other way round? The party first and the birds second?"

"The party," repeated Smithy firmly, "was distorted. This would tie in with the erase oscillator being out of order because there would then be no bias for the record-playback head when the recording was being made. Anyway, you can easily check whether the erase circuit is working. Run a piece of tape through with the recorder switched to 'Record', and see if what is on the tape becomes wiped off or not."

Dick carried out Smithy's bidding. He ran a further length of the tape through with the machine switched to "Record", rewound it, selected "Playback" and ran it through again. The mixture of innocent birdsong and what seemed by now to be developing into an out-and-out orgy was resoundingly audible. Whatever serviceable functions the cassette recorder possessed, it was clear that successful erasure could not be numbered amongst them.

"Humph," grunted Dick. "I'm a bit baffled by all this. I'm more used to the old reel-to-reel recorders and I don't remember seeing many of *them* in here, come to think of it. How, exactly, does the erase oscillator work?"

"It applies a high level supersonic sine wave signal to the erase head," replied Smithy, "which is, of course, passed over by the tape before the record-playback head." (Fig. 1).

"What does the sine wave do?"

"To answer that," said Smithy, "it is first necessary to look at the recording tape itself. This has a magnetic coating which can be regarded as consisting of many very tiny particles of magnetic material, each of which can be magnetised to exhibit a north and south pole like a bar magnet. The more technical concept for these tiny magnetic areas is to call them 'domains'. The erase head has a relatively wide gap and, as the tape passes over this, the domains in its coating are taken up to saturation with continually reversing magnetic polarity by the high frequency erase signal. When the tape leaves the gap the erasing magnetic field reduces in strength and has gradually lessening effect on the domains, which tend to retain the last strong polarity which was imparted by the erase field. The overall result is that the tape coating then consists of domains which have magnetic polarities distributed in completely random manner, with the magnetic fields of individual domains being cancelled out by neighbouring domains. The overall magnetic field is virtually zero. Erasing the tape is rather the same as degaussing a colour television picture tube."

ERASE FREQUENCY

"Is the frequency of the erase signal important?"

"Well, it has to be higher than twice the highest audio frequency to be recorded or you'll get audible beating with the audio frequencies. Also, it must not beat with the 19kHz pilot tone on stereo v.h.f. radio transmissions, if you're recording from the radio. This applies nowadays of course to mono transmissions as well, since the BBC keeps the pilot tone on all the time. A very important point is that the erase signal must be a pure sine wave."

"Why's that?"

"Because," repiled Smithy, "a pure sine wave does not have any harmonics and is, therefore, fully symmetrical about its central zero line. This gives true random magnetisation of the tape domains which leave the erase head. It is even harmonics on the erase waveform which can give the most trouble here, because if present they would cause the composite erase waveform to have a d.c. component, with the result that a higher proportion of domains would be magnetised with one polarity and there wouldn't be a full cancelling-out erasure effect. The outcome would be a noisy tape. I hardly need to add that the erase oscillator is only switched on during recording."

"Perhaps we should have a look at the circuit of the erase oscillator in this cassette recorder," suggested Dick. "Shall I get the service sheet out?"

"That would be an excellent idea," agreed Smithy.

Dick walked over to the filing cabinet and started leafing through the sheets.

"Did you hear," he remarked over his shoulder, "about the chap who'd been out on the town one night and who woke up next morning to find his bedroom full of aircraft?"

Smithy groaned.

"Don't tell me you're starting off on those dreadful gags of yours again."

"D'you know what the chap said?"

"No," sighed Smithy. "I don't know what he said."

"He said, 'Darn it, I've left the landing light on again!' Ah, here we are."

Grinning, Dick pulled out the cassette recorder service sheet and returned with it to the shuddering Serviceman. Smithy took it from him, opened it out at its circuit diagram and pointed at the erase oscillator section. (Fig. 2).

"Here," he remarked, "is the erase oscillator for this particular cassette recorder. Erase oscillator circuits vary considerably between different makes and models of recorder, but they all have a tuned LC circuit which resonates at erase frequency. In the simple cassette circuit we have here the erase oscillator drives the erase head directly, but in more complicated recorders there may be an amplifier between the oscillator and the erase head. Also, for greatest purity of signal, the oscillator may be a push-pull type."

"What would the frequency of oscillation be?"

Smithy consulted the manual.

"With this recorder," he announced, "it's 50kHz. As you can see, the circuit is pretty easy to follow. The oscillator is turned on by applying the negative supply via a section of the record-playback switch. The primary of the oscillator transformer is tuned by a 0.022μF capacitor and one end connects to the collector of the transistor. The other end couples, via an

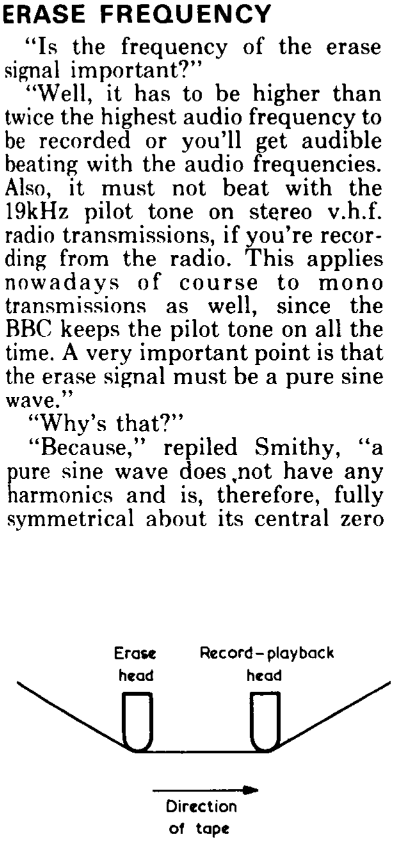


Fig. 1. The tape in the cassette recorder passes the erase head and then the record-playback head. During recording the erase head is actuated and erases any signal which is present on the tape before it reaches the record-playback head

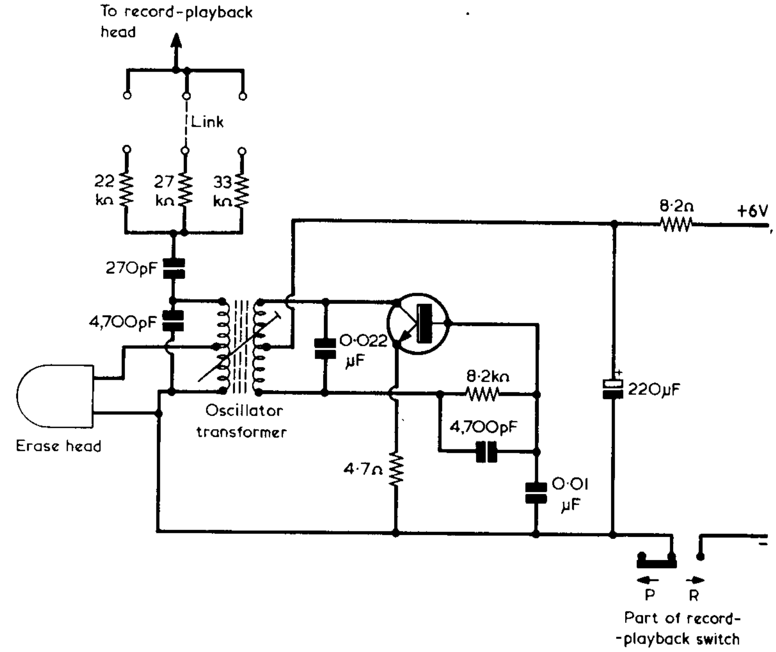


Fig. 2. The erase oscillator circuit in the cassette recorder serviced by Dick

8.2k Ω resistor and a 4,700pF capacitor to the transistor base, with a 0.01μF capacitor to the negative rail to keep the base input signal at just the right level. There is a 4,700pF capacitor across the secondary of the transformer, too, as well as a 4.7 Ω resistor in the emitter circuit to give negative feedback. All these various components ensure that the erase signal passed to the erase head is both pure in waveform and strong in amplitude. The field produced by the erase head has to be good and powerful if it is to do its job properly."

BIAS SIGNAL

"There's a 270pF capacitor from the top end of the transformer secondary," remarked Dick, "and it connects to three resistors with values of 22k Ω, 27k Ω and 33k Ω. What are they for?"

Smithy looked down at the capacitor and the resistors.

"They're for applying bias to the record-playback head when you're recording," he stated. "You use a link wire to connect which of the three resistors gives the best bias amplitude to the particular record-playback head which is fitted."

"I thought," moaned Dick, "that things were going too easy. What in heck is this bias business?"

"You need a bias signal at the record-playback head when you're recording," said Smithy, "in order to get the recorded a.f. signal onto the linear parts of the tape magnetising characteristic."

He pulled out a pencil, pulled Dick's note-pad towards him and sketched out the tape characteristic on the top sheet. (Fig. 3(a).)

"This curve," he went on, "shows you what happens when you try to magnetise a piece of recorder tape. The horizontal axis represents magnetising force, which during recording is provided by the record-playback head, and the vertical axis represents the magnetic field strength which is caused to appear in the tape magnetic coating. 'Field strength' is not really the proper term nowadays, though, and we should more properly call it 'magnetic flux'. As you can see, the slope of the characteristic is low close to the centre zero point and it also curves quite a bit. As the magnetising force increases, the slope gets steeper and you need less and less magnetising force to establish a corresponding flux in the tape. Also, the characteristic goes into two regions, on either side of the centre zero point, where it is quite straight and linear. If you take the magnetising force beyond the linear parts of the characteristic the tape coating begins to approach saturation and the characteristic becomes curved again."

"Well, I'm with you so far, Smithy. Keep at it!"

"Okay, I will! Let's say, to start off with, that we apply a signal to be recorded direct to the record-playback head without any precautions to prevent distortion. The magnetising force exerted by the record-playback head on the tape will follow the signal. We'll try it with a sine wave."

Smithy drew a cycle of a sine wave below the characteristic, based on the central vertical line.

"We'll next see what happens when that sine wave is converted into magnetic flux by way of the tape characteristic. Here we are."

The Serviceman sketched out the corresponding magnetic flux waveform. (Fig. 3(b).)

"Blimey," said Dick, "that second waveform's really distorted. The central bits are all squashed up."

"Which they're bound to be, after the input sine wave has been changed to a magnetic flux waveform by way of the tape characteristic. Let's see if I've got an indiarubber."

Smithy dug around in his pockets and produced a grubby rubber eraser. He rubbed out the two waveforms and added a new waveform. (Fig. 3(c).)

"Here's the bias waveform," he continued. "It's conveniently derived from the erase oscillator, and the tips of the waveform are just at the centre parts of the linear sections of the tape characteristic. Now, I'll rub out the bias waveform and redraw it mixed with the sine wave that we want to record on the tape. And I'll also show the final result you get so far as the magnetic flux waveform is concerned."

Smithy erased the bias waveform and sketched in the combined bias and input signal waveform. This time Dick had to wait patiently for several minutes as Smithy carried on to draw out the flux waveform. (Fif. 3(d).)

"There you are," pronounced Smithy at length, as he put down his pencil. "With bias, the input magnetising waveform has an envelope which takes the sine wave right onto the linear parts of the characteristic. Not much of the bias waveform will be present on the tape when it leaves the record-playback head because of its high frequency, and we can safely assume that all that's left are two sine waves corresponding, without distortion, to the magnetising force envelope applied to the linear parts of the tape characteristic. We can then take the further graphical step of combining these two sine waves together, whereupon we get a final resultant waveform, centred on the magnetic flux zero line, which is also a sine wave."

"Stap me," exclaimed Dick, "that takes a bit of absorbing."

"It isn't easy," conceded Smithy. "In fact, it's a matter of history that when tape recording first started it was found experimentally that the greatest fidelity of reproduction was achieved by adding a supersonic bias frequency to the audio signal to be recorded. There were quite a few attempts to rationalise theoretically the practical fact that the bias signal improved quality, and the explanation I've just given you is pretty well as close to actuality as you can get whilst keeping things reasonably simple."

"Well, it seems reasonable enough to me," commented Dick. "What I now find puzzling is that in this cassette recorder a high power erase signal is pumped directly into the erase head. And yet the bias signal extracted from the erase oscillator circuit is applied to the record-playback head via a dirty great resistor of around 27kΩ."

"That's not entirely the case," Smithy corrected him. "The erase signal voltage is stepped up by the secondary of the erase oscillator transformer before it is applied to the 27kΩ resistor, or to one of the resistors on either side of it. Even so, you've raised a point which is worth dealing with next, this being that, in terms of power, a surprisingly small signal level is required at the record head to successfully impress a recording on the tape as it passes over it. This is partly due to the fact that the record head gap is much narrower than the erase head gap, so that it produces a more concentrated magnetising force on the tape. To show you what I mean about record head sensitivity, let's take a look at the record amplifier output part of

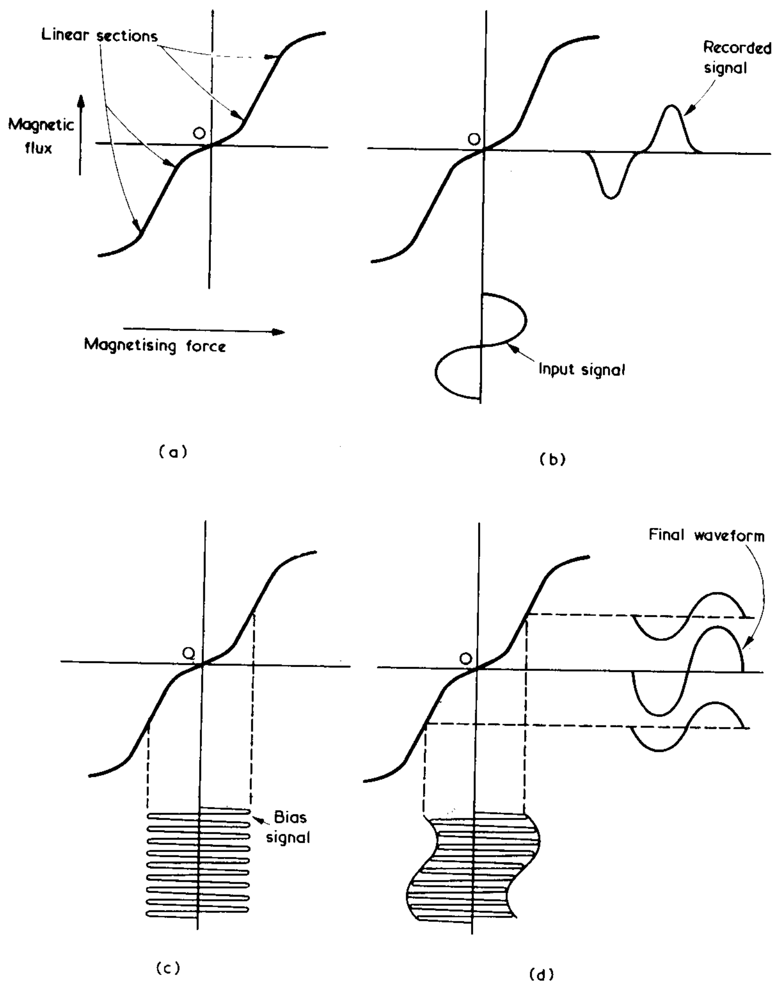


Fig. 3(a). Characteristic curve illustrating magnetising force, provided by the record head, and the consequent magnetic flux in the tape

(b). Applying a sine wave input signal to the characteristic results in a highly distorted recorded signal

(c). The peaks of the bias signal take the magnetising force to the centres of the linear sections of the characteristic

(d). Here the bias signal and the sine wave to be recorded are applied to the characteristic. Two recorded sine wave signals are produced, which may be combined in a final resultant

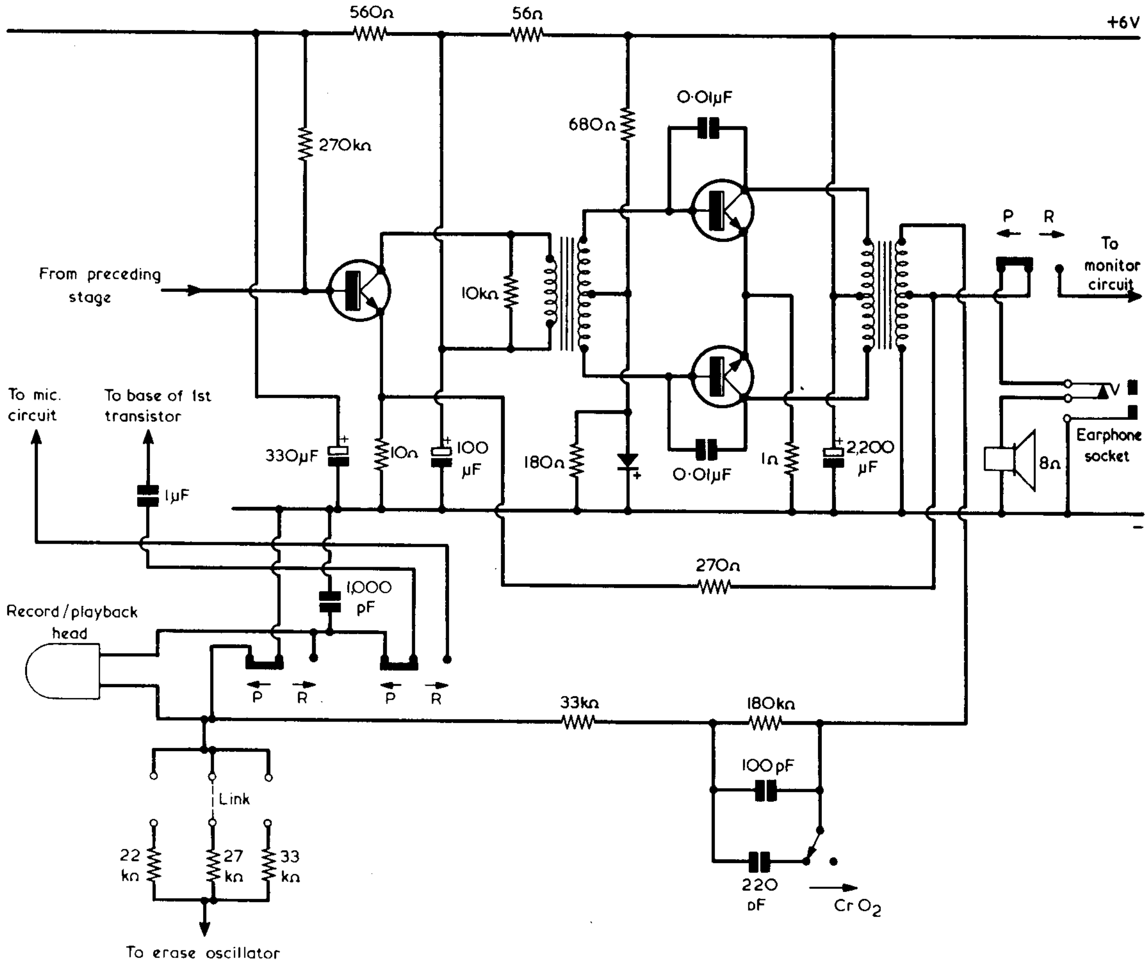


Fig. 4. The a.f. driver and output stages of the cassette recorder. The monitor circuit consists of a switch and several attenuating resistors which permit the earphone or speaker to monitor the output signal during recording. The three sections of the record-playback switch are shown in the "Playback" position. This, and Fig. 2, are slightly simplified versions of the corresponding sections in the Ferguson 3276 cassette recorder.

RECORD AMPLIFIER

Smithy indicated the appropriate amplifying section of the cassette recorder circuit. (Fig. 4).

"Gosh," said Dick, looking down at the circuit. "This amplifier output stage uses input and output transformers. That's a bit old-fashioned, isn't it?"

"There's a reason for those transformers," stated Smithy. "Just take a butcher's at the way in which the audio output signal is applied to the record-playback head when the record function is selected. Working back from the head you'll bump into another of your dirty great resistors. This time it's a 33k Ω one."

"What's that for?"

"It's common practice to insert, in series with a record head, a resistor whose value is much higher than the impedance of the head at any frequency in the audio range. The result is that signals of differing frequency but similar voltage level cause approximately the same current to flow in the coil of the head. Don't forget that it's the *current* in the head coil which does the magnetising of the tape. In this particular recorder we next find a high frequency boosting circuit consisting of a 180kΩ resistor shunted by a 100pF and a 220pF capacitor in parallel. This little lot gives a degree of high frequency lift to overcome losses in the head and the tape."

"There's only 100pF when the switch in that part of the circuit is opened."

"True," agreed Smithy, "and that caters for chromium dioxide tape. Chromium dioxide tape has a greater sensitivity to high frequencies at low tape speeds than has ferric oxide tape, and so it requires less high frequency boost in the feed to the record-playback head. And now we come to the output stage of the record amplifier. The recorder supply voltage is only 6 volts so that, if a standard modern transformerless output stage were used, there'd only be a maximum output voltage swing of about plus and minus 3 volts. When used for recording, the record-playback head is sensitive, but it's not so sensitivie as to be operated, via the series resistors in its feed, by a signal voltage as low as 3 volts peak. And so an a.f. output transformer is needed so that its secondary can step up the output voltage to a sufficiently high level. And that is why the amplifier employs an output transformer. For convenience the output transistors then need to be fed by an input transformer. You'll note, incidentally, that the record output stage doubles as a playback output stage when playback is selected. A tap lower down in the output transformer secondary then feeds an 8Ω speaker and an earphone socket."

"When playback is selected," said Dick, gazing thoughtfully at the circuit in the service sheet, "the record-playback head connects almost directly to the base of the first a.f. transistor in the recorder. No series resistors this time."

"There's no need for them," said Smithy. "During playback, we're interested in signal voltage as well as signal current from the head. You'll see that a 1,000pF capacitor connects across the head on playback. This capacitor, in company with other components in the amplifier later on, helps to produce the required playback frequency characteristic."

Smithy abruptly pushed the service manual towards his assistant.

"And that's it," he remarked firmly. "Enough nattering for now! I've got my own work to do, so I'll leave you to find what's gone wrong with that erase oscillator. I'm not so pessimistic as to think that you won't find the snag quite easily."

"Talking about being pessimistic," put in Dick quickly, before the Serviceman could leave him, "what's the definition of a pessimist?"

Smithy wavered.

"Here we go again," he snorted irately. "The annoying thing is that I know I won't have any peace of mind until you tell me. All right, what is the definition of a pessimist?"

Dick grinned broadly.

"A pessimist," he said cheerfully, "is someone who puts prunes on his All-Bran!"

FINAL DEFINITION

Wearily, Smithy weaved his way back to his side of the Workshop, whilst his chuckling assistant turned his attention to the cassette recorder and its unserviceable erase oscillator. It was not long before a few voltage and continuity checks led him to the emitter of the erase oscillator transistor, and he quickly applied his soldering iron and a little solder to the imperfect joint it had with the circuit print. The result was an erase oscillator which once more functioned correctly.

But Dick's curiosity was aroused to the level that he could not erase the recording, even distorted, of that party. He started to run the tape through but was stopped by an outraged Smithy, who forcibly pointed out the ethics which should be observed so far as customers' confidentiality was concerned.

"We shouldn't listen to peoples' private tapes," concluded Smithy sternly. "It's a question of correct moral behaviour."

"Fair enough," acquiesced Dick amicably. "Then, if we're talking of moral behaviour, let me ask you a question."

Inevitably, Smithy fell for it.

"All right," he said unwittingly, "what is it?"

"What," asked Dick, "is your definition of a sadist?"

"Ye gods," fumed Smithy, "you *never* miss a chance do you? All right, what *is* the definition of a sadist?"

"A sadist," replied Dick happily, "is someone who's terribly nice to a masochist!" ■

Radio Topics

By Recorder

Electronics has many sidelines, and one which has been present for very many years now is that of short wave listening. The short wave bands are jam-packed with transmissions, many of them using standard amplitude modulation which can be resolved without the necessity for product detectors and the like. There is a certain escapism in being able to retire into the world of short waves, to dig leisurely along the dial until something of interest is unearthed.

WHAT RECEIVER?

Naturally enough, the newcomer to short waves asks the first obvious question: what sort of receiver is required? There isn't a direct answer to this question, since everything depends upon the type of listening you want to undertake and the amount of money you're prepared to spend.

If you just want to listen to the more powerful broadcast transmissions, then you might get the performance you require from a mass produced receiver of the domestic entertainment type which happens to have several short wave bands in addition to the medium or medium and long wave ranges. Some of the sets in this category have a fairly reasonable performance whilst others are pretty terrible. In general, the performance improves with the price. Sets of this type have a telescopic short wave aerial and, perhaps, an actual aerial input terminal. Unfortunately, it is not an easy matter to judge the performance of a short wave receiver of this nature whilst buying it; radio shop salesmen are not normally short wave oriented and short wave signal pick-up in the shop itself may well be limited. The usual shortcomings with these types of sets are poor sensitivity, poor selectivity and vulnerability to second channel interference, the last showing up as whistles as the set tunes through the stations.

If you have a receiver of the entertainment type and you want to increase its short wave sensitivity, a useful approach is to couple a long wire aerial to it. The aerial may consist of 40ft. or more of wire strung up in a reasonably clear situation. If the set has an aerial terminal the long wire can connect to this but, in the absence of such a terminal the long wire aerial has to couple to the telescopic aerial of the set. In general, it is unwise to connect the long wire directly to the telescopic aerial. It is likely that a direct connection of this nature will both detune and damp the first tuned circuit in the receiver, with a considerable increase in second channel interference together with cross-modulation from powerful signals close to those you want. A much better solution is to have a very loose coupling between the long wire and the telescopic aerial. An insulated lead-in from the long wire can be coiled a turn or two, lengthwise, down the extended telescopic aerial, whereupon the capacitance between the two may be more than adequate for signal transfer. It may even be possible to obtain satisfactory signal transfer by having the long wire lead-in run several inches away from the extended telescopic aerial and parallel with it.

VALVE SETS

I am certain that older readers will agree with me when I say that the short wave performance of the old valve entertainment type sets was a lot better than is given by their modern transistor counterparts. This is not an example of maudlin nostalgia but simply a recognition of the fact that it is quite easy to design a low cost valve superhet having a reasonable short wave performance, much easier in fact than it is to do the same with a low cost semiconductor superhet.

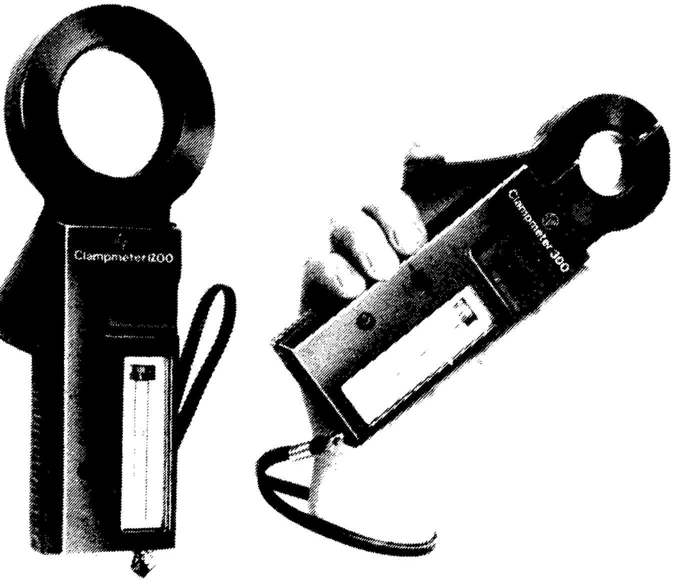
As designers of communications equipment themselves admit, valves have a linear signal voltage performance which almost completely defeats cross-modulation, as well as the ability to accept a wide range of signal amplitudes without overloading and the capability of being used in relatively low noise mixer circuits. They can also be employed in very simple automatic gain control circuits which have an almost unbeatable smoothness of operation. You'll find plenty of the more serious short wave listeners using valve receivers, incidentally. What is probably the only major design difficulty with valves is that they heat up and are liable to cause oscillator tuning drift unless suitable steps to prevent this are taken.

So far as serious short wave listening is concerned you may well decide to purchase a communications-type receiver which is specifically intended for the purpose. Again, you pays your money and you takes your choice. However, there is the advantage here that you will be buying the set from people who have a good idea of what short wave listening is all about, instead of from commish-hungry salesmen who, immediately after having sold you a short wave radio, will next be using their talents to flog a refrigerator.

Don't forget that you can build your own short wave radio if you wish. There have been quite a few designs in *Radio & Electronics Constructor* for short wave receivers, both simple and complex. If you don't want to spend too much money, you can get successfully started with an inexpensive t.r.f. design having reaction. The secret behind these simple sets is the reaction circuit itself; if the reaction control is gentle and smooth so that you can take it slowly up to the oscillation point you will be surprised at the wealth of signals you can pick up.

CLAMPMETER

Over recent years, instruments of the Clampmeter type have become increasingly popular for measurements on power systems because of the particular safety features they offer. The measurement of alternating current has always been a problem, both in terms of actually performing the measurement and of the safety of the instrument whilst in the circuit. With the Avo Clampmeters, alternating currents may be measured wherever a single conductor is available without the need to break the circuit, and the measurement can be taken in complete safety.



Two Avo instruments, the Clampmeter 1200 and the Clampmeter 300. The ends of the instruments are clamped over single conductors carrying high alternating currents to obtain current readings without the necessity of a direct connection

In addition, the Clampmeters have voltage and resistance ranges, forming the instrument into a complete multimeter for the electrician or engineer. The Avo range consists of the Clampmeter 300 for current measurements up to 300 amps on the highest scale, and the Clampmeter 1200 for current measurements up to 1,200 amps.

Further features include an ingenious and readily manipulated thumbwheel range switch which actually changes the scale as each range is selected. Another unusual facility is a pointer lock. If the instrument is used in an inaccessible position, the pointer can be locked and the instrument removed before being read in the open.

The Clampmeter is intended for one hand operation and can be used in either the left or the right hand. A wrist-band is attached as a precaution against accidental dropping. The instrument, complete with all its accessories, is supplied in a sturdy p.v.c. carrying case which can be carried either in the hand or strapped to a belt for greater portability.

Further details can be obtained from Avo Limited, Archcliffe Road, Dover, Kent, CT17 9EN.

REMOTE CONTROL

The hearing ability of cats and dogs extends quite a bit higher in terms of frequency than does that of humans. This fact makes me wonder sometimes what our pets make of the electronic sounds in the domestic scene which pass relatively unnoticed by their owners. The early 405-line TV sets used to have line output transformers which sang away quite loudly at the line frequency of 10,125Hz. 625-line sets have line output transformers running at 15,625Hz, which must have mildly irritated those of our pets who had become accustomed to the old lower frequency. (That line frequency of 15,625Hz is always nice and easy to remember, incidentally, because the last three digits are 625.) In general, though, cats and dogs seem to have what is almost an annoying indifference to the scenes and sounds which are projected by our domestic electronic equipment.

A friend, who is now the proud owner of a remotely controlled TV set, told me that his dog seemed a little agitated at first when he started using the control unit, which emits a beam of ultrasonic sound. However, the dog soon got used to the ultrasonic sound and, after a week or so, simply ignored it. Which set me to looking through some news items for the earlier part of this year, to find a report that in Denmark two Alsatians and a boxer dog went beserk after sitting near a remotely controlled TV. In the end they had to be put down.

An isolated instance? Presumably so, because there seem to have been no further accounts of remotely controlled TV affecting cats and dogs. I note, however, that there is no end to the reports on the effects TV programmes have on us human beings . . . ! ■