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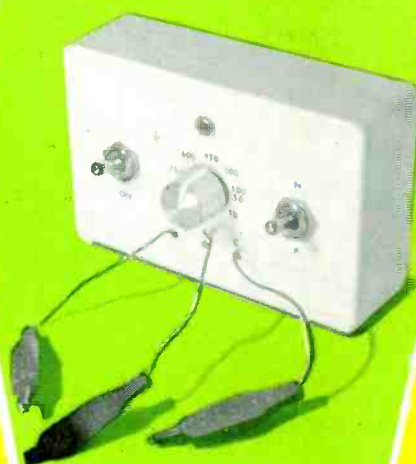

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RADIO & ELECTRONICS CONSTRUCTOR

OCTOBER 1976
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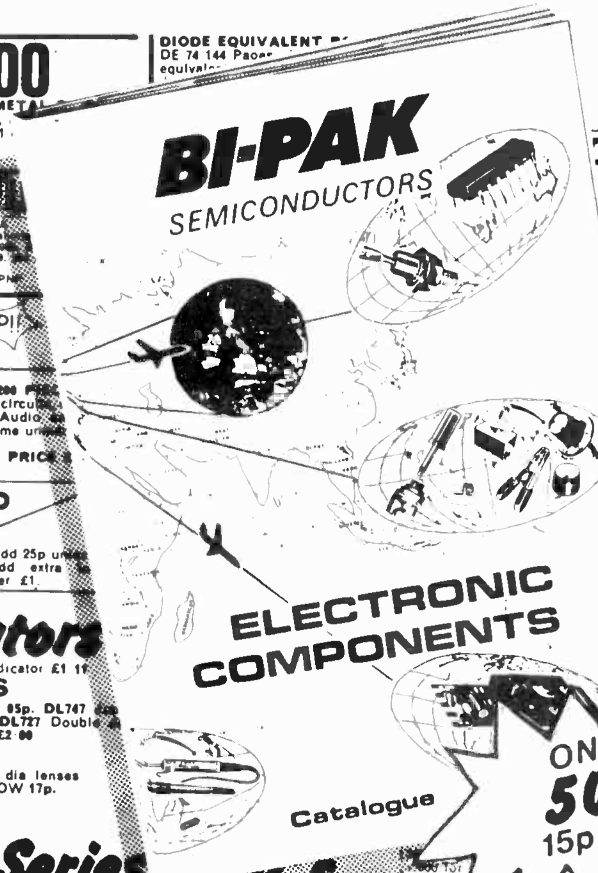

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[illegible]	*0·2[illegible]	OC42	*0·25	ZTX109	0·07
[illegible]	[illegible]	OC44	*0·16	ZTX300	0·07
[illegible]	[illegible]2	OC45	*0·13	ZTX500	0·09
[illegible]	[illegible]22	OC70	*0·10	2N696	*0·10
[illegible]	[illegible]13	OC71	*0·10	2N697	*0·11
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7410	0·09	0·09	0·08	7475	0·48	0·46	0·44	74157	0·95	0·93	0·91
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0.6	110	EC433	15p
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IN4005/6	1	6/800	5p
BY103	1	1,500	18½p
SR100	1.5	100	7p
SR400	1.5	400	8p
REC53A	1.5	1,250	14p
LT102	2	30	10p
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BYX38-900	2.5	900	60p
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BYX49-600	2.5	600	55p
BYX49-300R	2.5	300	26p
BYX49-900	2.5	900	40p
BYX49-1200	2.5	1,200	52p
BYX48-300R	6	300	40p
BYX48-600	6	600	50p
BYX48-900	6	900	60p
BYX48-1200R	6	1,200	80p
BYX72-150R	10	150	35p
BYX72-300R	10	300	45p
BYX72-500R	10	500	55p
BYX42-300	10	300	30p
BYX42-600	10	600	65p
BYX42-900	10	900	80p
BYX42-1200	10	1,200	95p
BYX46-300*	15	300	£1.00
BYX46-400*	15	400	£1.50
BYX46-500*	15	500	£1.75
BYX46-600*	15	600	£2.00
BYX20-200	25	200	60p
BYX52-300	40	300	£1.75
BYX52-1200	40	1,200	£2.50

*Avalanche type

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25	900	BTX94-900	£4.00
25	1200	BTX94-1200	£6.00

12-0-12 50M/A Min. Txfmr. 90p

RS 2mm Terminals Blue & Black 5 for 40p

Chrome Car Radio facia 15p

Rubber Car Radio gasket 5p

DLI Pal Delayline 50p

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BPX40	65p
BPX42	£1.00
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BPY68, BPY69, BPY77 Diodes £1.00

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BPX29	£1.00
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ASZ20	8p
ASZ21	30p
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BCY30-34	10p
BCY70/1/2	8p
BF115	10p
BY127	9p
HG1005	10p
HG5009	3p
HG5079	3p
L78/9	3p
M3	10p
OA81	3p
OA47	3p
OA200-2	3p
OC23	20p
OC71/2	5p
OC200-5	20p
TIC44	24p
2G240	2-50
2G302	15p
2G401	15p
2N711	25p
2N2926	7p
2N598/9	6p
2N1091	8p
2N1302	8p
2N1907	2-50
Germ. diode	1p
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2S3230	30p

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1	400	BTX18-300	50p
1	240	BTX30-200	40p
15	500	BT107	£1.60
6.5	500	BT101-500R	90p
6.5	500	BT109-500R	£1.00
20	600	BTW92-600RM	£3.00
15	800	BTX95-800R Pulse Modulated	£8.00
30	1000	28T10 (Less Nut)	£3.00

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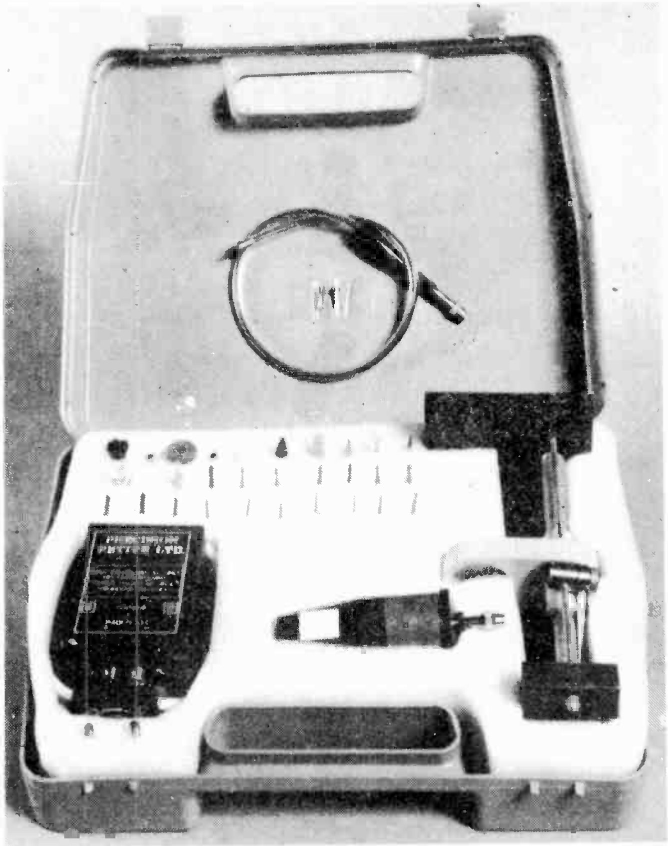

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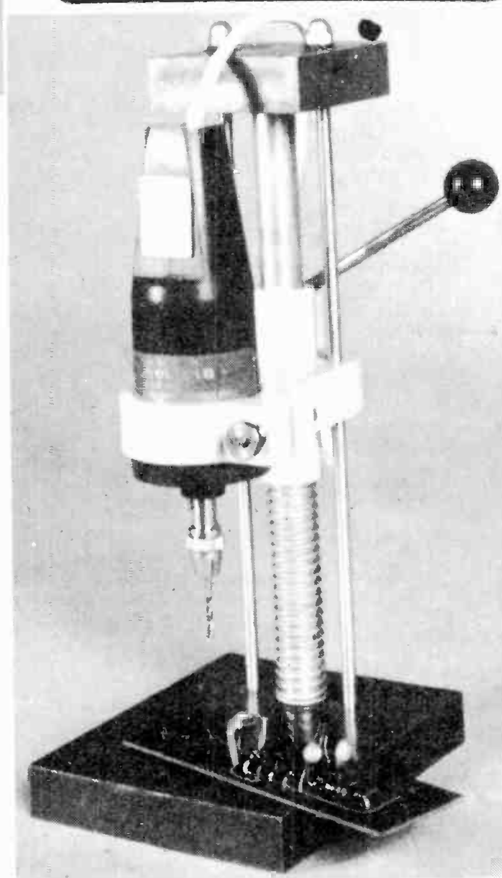

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NOVEL TRANSISTOR

Intended mainly for checking small signal transistors, this simple unit employs an electronic comparator to indicate collector current instead of the more conventional meter.

Since transistors feature in virtually every electronic design for the home-constructor as well as in most pieces of commercially produced domestic electronic equipment, some form of transistor tester is a virtual necessity for the amateur electronics enthusiast. Many articles describing transistor testers have been published in the past, and a few of these have described quite complex instruments capable of measuring a number of transistor parameters with a high degree of accuracy. However, all that most people require is a simple tester that will offer a clear indication of whether or not a transistor is usable by giving an approximate measurement of gain. Also, considering the present very low cost of most popular transistors it is preferable for the tester to have a similarly low constructional cost if it is to be an economically viable proposition.

The simple tester which forms the subject of this article has been designed with these points in mind.

BASIC ARRANGEMENT

Fig. 1. shows the basic arrangement used in most transistor testers. The potentiometer supplies a base current to the test transistor and the meter registers the resultant level of collector current. Since the supply voltage can be assumed to be constant the potentiometer setting may be directly related to base current. It is thus possible to measure the current gain of the test transistor (which is, of course, its collector current divided by its base current) using only a single meter.

If the potentiometer is always adjusted to produce the same level of collector current, base current and test transistor current gain become directly related, and the potentiometer can be calibrated directly in terms of current gain.

There is no reason why a meter should be used to indicate the required level of collector current. Indeed, considering the relatively high cost of moving-coil meters, there is a large incentive to seek an alternative. A recent design ("Novel Transistor Gain Meter" by G. A. French, *Radio & Electronics Constructor*, April, 1976) used a relay as the collector current sensor. Taking this one step further, the author has employed a purely electronic current sensor in the present design. The result is a very inexpensive but useful transistor tester.

CURRENT SENSOR

The basic configuration of the current sensor is shown in Fig. 2. This circuit employs a single high

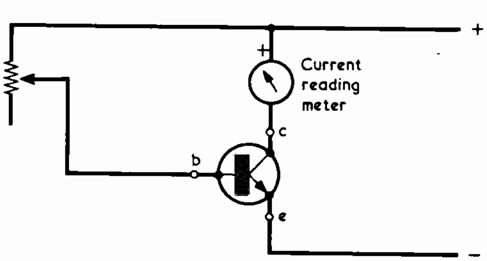


Fig. 1. Basic circuit for a transistor gain indicator. An n.p.n. transistor is assumed

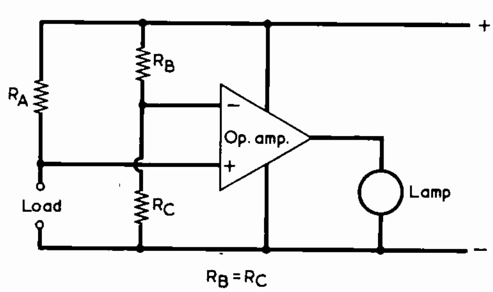
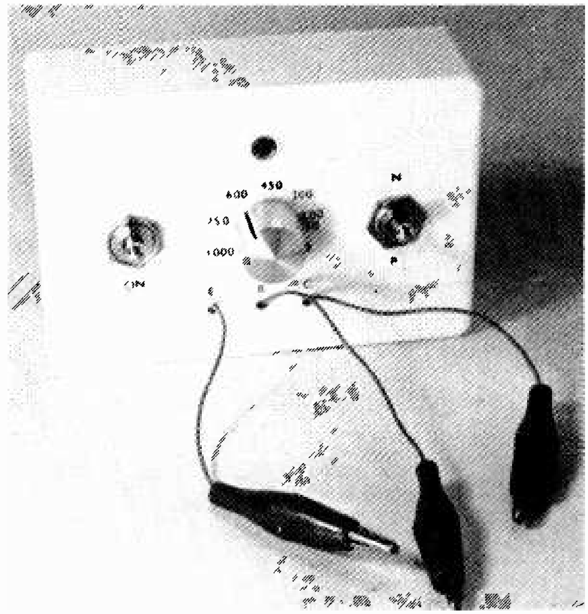


Fig. 2. Employing an operational amplifier as a current sensor

TESTER

By
A. P. Roberts



gain operational amplifier as a voltage comparator. A potential divider given by the equal value resistors RB and RC biases the inverting input of the device to half the supply potential. With no load connected, the non-inverting input will be taken to virtually the full positive supply rail potential by way of RA. Under these conditions the output of the operational amplifier will be fully positive and the indicator lamp will light.

If a variable resistor having a track value greater than RA is connected to the load terminals, and is adjusted to insert its full resistance, the non-inverting input will still be positive of the inverting input and the operational amplifier output will still be fully positive. The variable resistor is then adjusted to insert a continually decreasing resistance, whereupon the non-inverting input becomes less and less positive. When the variable resistor value is fractionally greater than RA, the non-inverting input will be positive of the inverting input by a small amount and the operational amplifier output will continue to be fully positive, with the lamp alight. If the variable resistor value is next made fractionally smaller than RA, the non-inverting input will be slightly negative of the inverting input, and the amplifier output will go fully negative, extinguishing the lamp. The range of resistance in the variable resistor between these two states is extremely small because of the exceptionally high voltage gain of the operational amplifier. With the 741 op-amp, for instance, voltage gain is typically 200,000 times.

The changeover point at which the lamp becomes extinguished occurs when half the supply voltage is applied to the non-inverting input. Since the supply voltage is known, RA can be given a value which allows the changeover to take place at any desired current, within reason, flowing through it. The circuit thereby functions as a current sensor. The current drawn by the non-inverting input of the operational amplifier is very low, and can be completely ignored

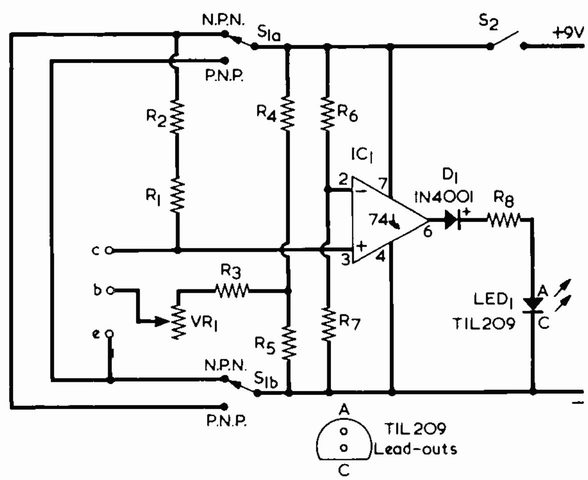


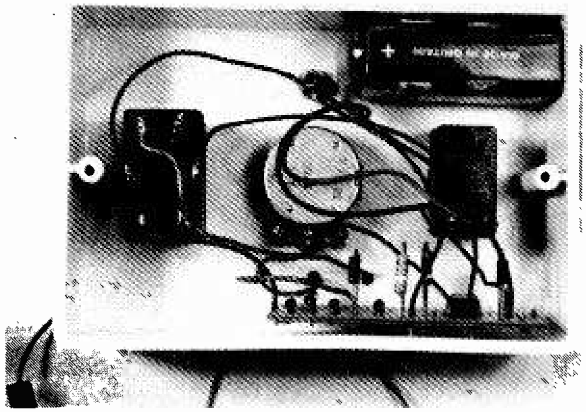
Fig. 3. The circuit of the transistor tester

when, as in the practical transistor tester, the current in RA is of the order of milliamps.

PRACTICAL CIRCUIT

The practical working circuit of the transistor tester is given in Fig. 3. The indicator lamp is the light-emitting diode LED1, and this is fed from the output of the operational amplifier via D1 and current limiting resistor R8. D1 is included because the output of the op-amp, when it is fully negative, is about 2 volts positive of the lower supply rail; without D1 this would be just sufficient to produce a visible glow in LED1. D1 provides a voltage delay of about 0.5 volt and therefore ensures that the l.e.d. is fully extinguished when the op-amp output is negative.

The potential divider, R6 and R7, applies half the supply voltage to the inverting input of the op-amp.



The parts of the tester fit neatly into its plastic case

R1 and R2 form the collector load for the transistor under test, and they have a total resistance of 2.25kΩ. The changeover point occurs when there is half the supply voltage (i.e. 4.5 volts) across these two resistors, and this corresponds to a current flow in them of 2mA. Thus, the circuit gives the changeover effect when the collector current of the test transistor is 2mA; many small signal transistors have their current gain quoted at around this figure in brief form data sources.

R4 and R5 provide a second potential divider, and half the supply potential appears at their junction. It is from this point that the base current is fed to the test transistor, the current flowing via VR1 and R3. R3 limits base current to a reasonably low level, and the control knob of VR1 is calibrated with a scale which indicates the current gain. Taking the base current from a potential divider in this manner means that half the supply voltage is available both for n.p.n. and p.n.p. transistors, with a consequent easing of polarity switching requirements.

When VR1 inserts minimum resistance, and assuming that the test transistors is a silicon device with a forward voltage drop of 0.65 volt across its base-emitter junction, the base current in the test transistor is approximately 210μA. This figure is given by 3.85 volts (4.5 minus 0.65) divided by 0.018MΩ. With VR1 set for maximum resistance the base current is approximately 1.7μA, again assuming a silicon transistor. The base currents will be a little higher if the test transistor is a germanium type, which will exhibit a forward voltage drop in its base-emitter junction of around 0.2 volt.

The range of base currents gives the unit a theoretical gain measuring range of around 9.5 to 1,200 at a collector-emitter voltage of 4.5 volts and a collector current of 2mA. All contemporary small signal transistors have current gain values that fall within this range. The author has also found it possible to check the majority of power transistors using this circuit, although the results obtained mainly indicate that the power transistor being tested is capable of current amplification and can therefore be considered serviceable.

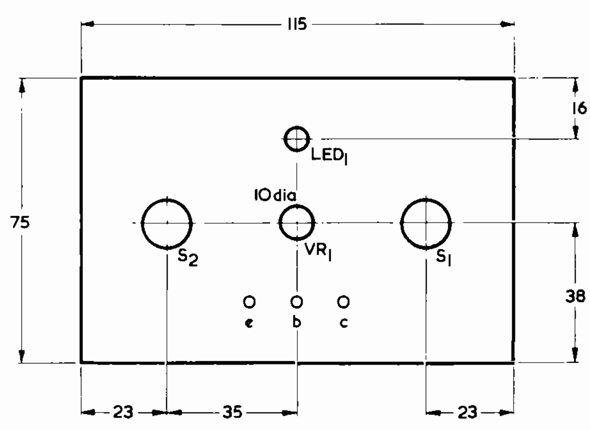
Note that the actual gain range given with units built up to the circuit may vary somewhat from the figures just quoted, this being due to component tolerances and variations in supply potential. The theoretical range has been made a little wider than is really necessary to allow for these factors.

S1 is the polarity switch and it reverses the supply to the test transistor emitter and collector load as required to accommodate n.p.n. and p.n.p. transistors. S2 is the on-off switch.

Power consumption is about 6mA with the indicator lamp extinguished, and is about 12mA when it is turned on. The current drops by approximately 2mA when a test transistor is not connected.

CONSTRUCTION

The tester can be assembled in a small plastic case large enough to house the battery and the Veroboard panel in the manner illustrated in the photograph of the interior. The case employed for the prototype measured approximately 115 by 75 by 35mm. (4.5 by 3 by 1.4in.) and cases of this size, or slightly larger, will be satisfactory. The case has a removable lid which is used as the rear. The opposite side then becomes the front panel of the tester and is drilled as shown in Fig. 4. This diagram assumes outside dimensions of 115 by 75mm., and the positions of the holes may be amended as required for larger front panels. The holes for the two switches and the l.e.d. have diameters to suit the particular components employed. The three small holes marked "E", "B"



All dimensions in mm.

Fig. 4 Drilling details for the front panel

COMPONENTS

Resistors

(All fixed values ¼ watt 5% unless otherwise stated)

R1 750Ω
R2 1.5kΩ
R3 18kΩ
R4 1kΩ 2%
R5 1kΩ 2%
R6 39kΩ 2%
R7 39kΩ 2%
R8 680Ω
VR1 2MΩ or 2.2MΩ potentiometer, linear

Semiconductors

IC1 741 in 8-pin d.i.l.
D1 1N4001
LED1 TIL209 or similar with panel holder

Switches

S1 d.p.d.t. toggle
S2 s.p.s.t. toggle

Miscellaneous

PP3 or PP3-P battery (see text)
Battery connector
Control knob
Plastic case (see text)
Veroboard, 0.1in. matrix, 24 holes by 10 strips
3 miniature crocodile clips
Wire, solder, etc.

and "C" allow the passage of flexible test leads terminated in crocodile clips. The clips connect to the lead-outs of the transistor being checked. When the test leads are fitted later they each have a knot on the inside to prevent strain on their internal connections.

All the small components are mounted on a 0.1in. matrix Veroboard panel having 24 holes by 10 strips. Details of this panel are shown in Fig. 5. There are six breaks in the copper strips, as shown in the underside view of the panel. Once these have been made, the various components and the two link wires are mounted and soldered in.

The panel is then wired to the battery clip and the components on the front panel, using ordinary stranded connecting wire. This wiring is also shown in Fig. 5. The panel is positioned in the bottom right hand side of the case as viewed from the rear, and is held in place by the wiring and the case lid. The panel is very light and no other means of fixing is necessary.

There is a space for the PP3 battery in the top right hand side of the case, also as viewed from the rear. This is held in position when the lid of the case is screwed on. If necessary, a small piece of foam rubber or plastic can be glued to the inside surface of the lid to ensure that the battery is held firmly.

USING THE TESTER

A scale calibrated in current gain can be marked around the control knob of VR1. This is not entirely essential because, after a little experiment with different transistors, one soon becomes accustomed to the correct approximate position of the control knob for various types. As may be seen in the photographs of the front panel of the author's unit, numbers corresponding to different gain levels were fitted at the appropriate points, and this is quite adequate in practice. The numbers were taken from "Panel Signs" Set No. 4, which is available from the publishers of this magazine.

Operation of VR1 is quite straightforward, and the potentiometer is simply adjusted to the point where the l.e.d. changes from one condition to the other. Due to the very high gain of the 741 i.c. the changeover point is extremely well defined, and it is very difficult to resolve a point in the potentiometer travel where the light is at an intensity between fully on and fully off. Note that with n.p.n. transistors the l.e.d. is alight at the left hand side of the scale and is off at the right hand side. The opposite is true when the unit is switched to test p.n.p. transistors.

Scale calibration points can be found by connecting a silicon transistor to the tester with a sensitive current meter in series with the base connection. VR1 is then adjusted to produce suitable base currents, whereupon the scale is marked accordingly at these points. As examples, base currents of 200μA and 20μA correspond to gains of 10 and 100 respectively. Alternatively, VR1 can be adjusted for appropriate resistance values between the base test lead and the junction of R4 and R5. A resistance value of 190kΩ corresponds with a gain of 100 and 1.9MΩ with a gain of 1,000. Fig. 6 gives a table showing both base current and resistance values for selected gain figures, as used in the prototype.

The scale produced by these methods will be applicable to silicon transistors, and germanium transistors will read about 11% high (because the appropriate base current is passed at a higher resistance

A rear view of the tester with the Veroboard panel partly removed

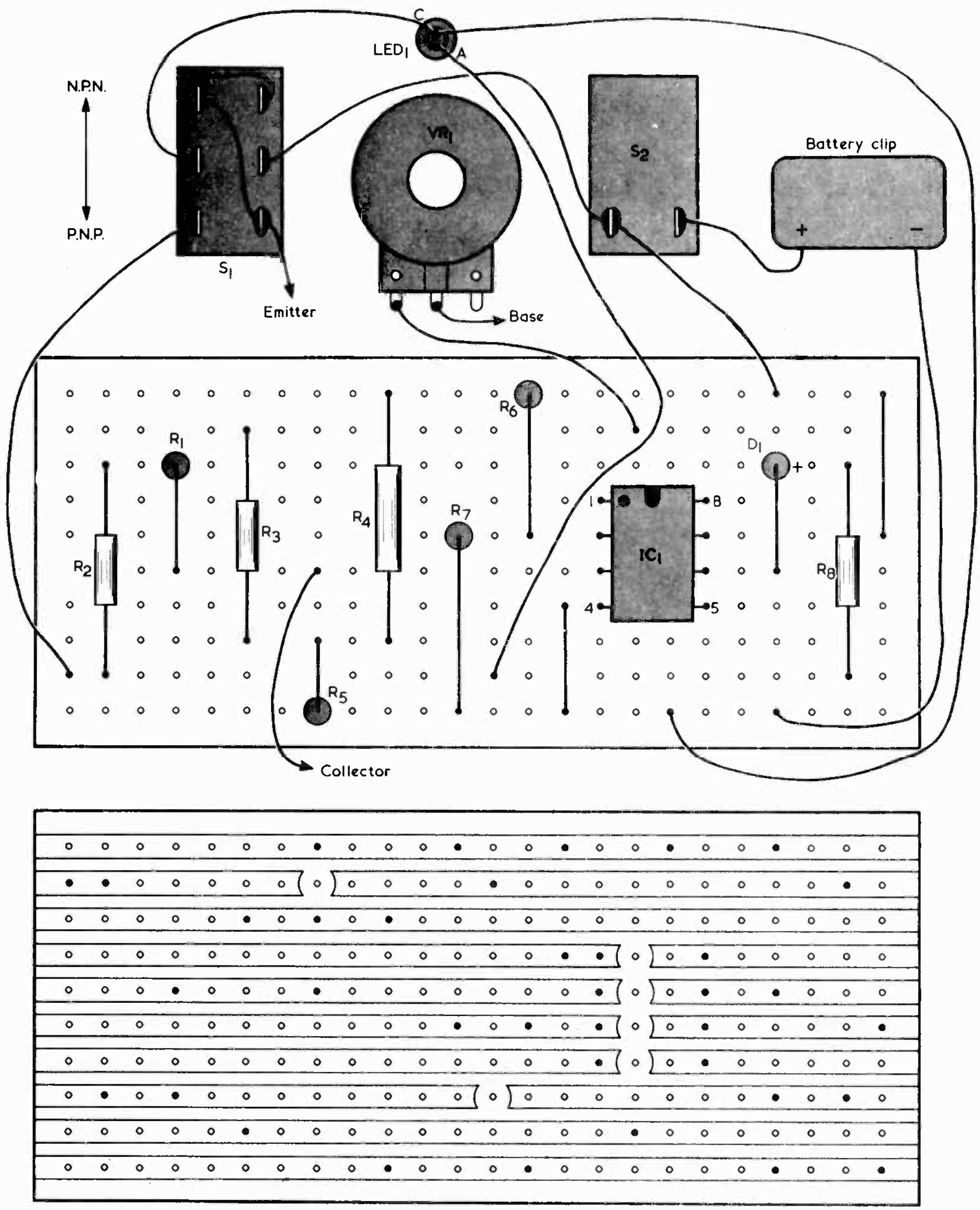


Fig. 5. Illustrating the wiring on and around the Veroboard panel

in VR1). Since germanium transistors are a comparative rarity these days, it is considered that a single scale, accurate for silicon transistors and with a correction factor for germanium transistors, meets all practical requirements.

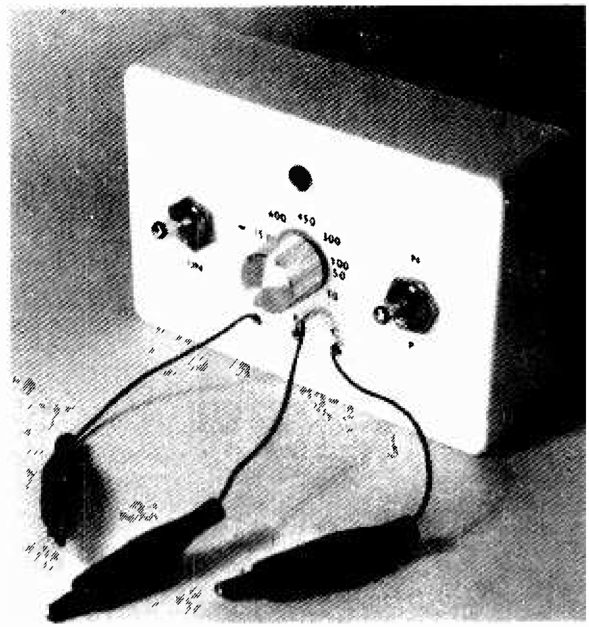
Battery voltage will also have an effect on accuracy and it is advisable to discard the battery (for possible use in other equipment) when its voltage falls below about 8.5 volts. A PP3-P battery will retain a terminal voltage above 8.5 volts for a considerably longer period than a PP3 battery.

The tester can also be used to give diodes and rec-

GAIN	BASE CURRENT	RESISTANCE $(VR_1 + R_3)$
10	200µA	19kΩ
50	40µA	96kΩ
100	20µA	190kΩ
300	6·7µA	570kΩ
450	4·4µA	880kΩ
600	3·3µA	1·2MΩ
750	2·7µA	1·4MΩ
1,000	2µA	1·9MΩ

Fig. 6. Calibration table giving base current and series base resistance values for selected gain figures

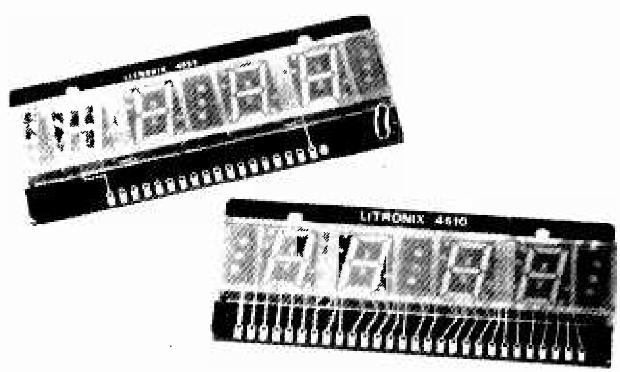
tifiers a rough check and to find their polarity. If the diode or rectifier cathode is connected to the emitter test lead and the anode to the collector test lead, the l.e.d. will be extinguished with S1 in the n.p.n. position. The l.e.d. should remain extinguished when S1 is set to the p.n.p. position. ■



The completed tester is small and is extremely easy to handle and use

TRADE NOTE

MULTIPLEXED DIGITAL LED DISPLAYS



Messrs. Litronix of 24 Sun Street, Hitchin, Herts., announce the availability of two new additions to their range of p.c.b.-mounted numeric LED displays.

Designated DL-4510 and -4533, the displays are intended for use in digital instrumentation and consumer products such as electronic digital clocks. Each incorporates four 7-segment numeric LED displays which, together with three colon/point indicators, are mounted on an edge-connected p.c.b. for ease of assembly into the end product. These displays exactly mate with existing GI clock chips, the CK-3100 and CK-3300, and thus allow the user's circuitry to be mounted on a single-sided p.c.b.

Both displays are dimensionally identical, and are fitted with contrast enhancing filters for increased character definition. They are available with optional red polypropylene filters.

Typical electrical characteristics include a forward voltage of 1.8V at 20mA per segment, and a luminous intensity of 1.0mcd.

NEWS . . . AND .

AVOMETER MODEL 73

Avo Ltd., of Archcliffe Road, Dover, Kent, recently announced the introduction of the AVOMETER Model 73, a multimeter combining small size, wide range coverage and genuine overload protection. The overload protection system overcomes the expensive and frustrating tendency of many small multimeters to burn out if 240 volts is accidentally connected to current or resistance ranges. The saving in repair charges and replacement costs will quickly pay for the instrument.

The AVOMETER Model 73 has the robustness and ease of operation long associated with AVO products including clear scales, simple range selection controls and only two sockets for all measurements. The ranges include 150 mV to 750 volts d.c., 7.5 volts to 750 volts a.c., 75 μA to 3 A d.c., 3 mA to 3 A a.c. and 2 kΩ to 20 MΩ resistance. Sensitivities are 20 kΩ/volt d.c. and 2 kΩ/volt a.c. with a frequency bandwidth of over 50 kHz on many ranges.

The Model 73 uses a shockproof moulded case with no external metal parts and is supplied complete with leads, prods and clips and an operating instructions card. A range of accessories is available which includes a carrying case, plug-in shunts and a 30 kV d.c. probe.

NEW CATALOGUE AND CONSTRUCTION KIT BROCHURE FROM DORAM

Doram Electronics Limited, one of Britain's leading mail-order distributors of electronic components, construction kits and accessories specifically servicing amateur radio, electronic and hi-fi enthusiasts have published a new "Edition 3" catalogue priced at 60p and a new bumper-packed construction kit brochure priced 25p.

Should customers order both publications together Doram are offering a special price reduction of 15p so customers only pay a total of 70p and, in addition each customer will receive two 25p vouchers which may be used at any time as a refund when placing orders for Doram's vast range of electronic components, accessories and construction kits.

A special feature of the main catalogue is that during the life span of the catalogue customers will receive, absolutely free, up-date amendment leaflets giving information on new lines and price changes.

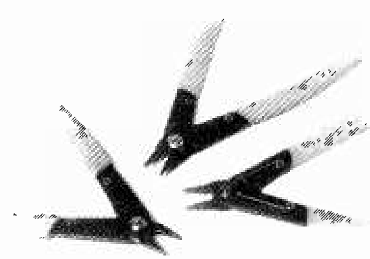
Many new products have been added at the request of customers which include an extension to Doram's formidable range of NPN, PNP, Unijunction and Field Effect Transistors; an extension to the range of specific p.c. boards; a Constant Current Charger and Rhythm Generator IC; many more essential tools and accessories including Soldering Irons, battery and mains operated drills and attachments; new super quality 2 meter wave Mobile Antennae plus many more books and constructional aids.

In addition to the main catalogue, Doram have published a fully illustrated brochure containing information on no less than twenty-six new "easy-to-construct" Kits.

Principally designed for the beginner wishing to take up electronics as a hobby, Doram's new kit range will also be welcomed by schools for electronic product training, and by professionals who like to get their teeth into the more absorbing projects such as Doram's de-luxe FM Tuner.

VERO ELECTRONICS MICRONOSE PLIER

Vero Electronics of Industrial Estate, Chandler's Ford, Eastleigh, Hants, are pleased to announce the addition of an economical micronose plier. The tool's thin profile enables the tool to be used for awkward situations where conventional pliers cannot reach. The standard jaw is serrated but plain jaws are available at no extra cost. Designed on the Microshear principle, the excellent mechanical advantage reduces muscle fatigue in squeezing the handle. The double coil return results in automatic clearance of the plier. The plier is lightweight 1.5 ounces and is 5in. long.



. . . COMMENT

LASKY'S OBTAIN EXCLUSIVE DISTRIBUTORSHIP

A turntable enclosed in glass is to be sold exclusively by Laskys through its chain of 30 retail shops, including major stores in Oxford Street and Tottenham Court Road.

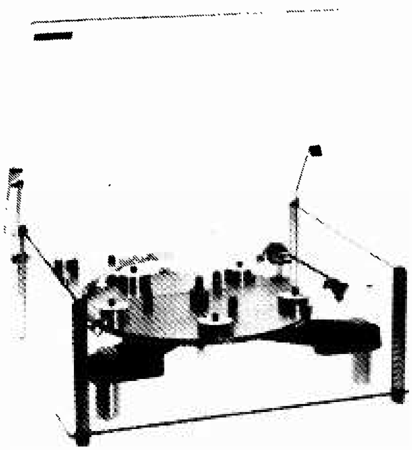
The Transcriptor Skeleton turntable — on show in the Design Centre, London, the Museum of Modern Art in New York and featured in the film "The Clockwork Orange" — will sell at £131.00 (including VAT).

The turntable is now on sale under a sole U.K. distributorship arrangement.

Laskys were selected by Transcriptor Limited, because of the comprehensive facilities they can offer in all audio areas. Not only do Laskys have 30 shops, and a big mail order business, but they also have a dynamic expansion programme.

Derek Smith, Managing Director of Laskys, said: "We are especially delighted to have this exclusive dealership, as it complements our range of top quality and technically advanced equipment."

Laskys will be selling at the following prices, inclusive of VAT: Transcriptor Skeleton Turntable with Vestigal Arm: £131.00; New Vestigal Arm: £43.75; Transcriptor Stylus Scales: £7.44.



OSCAR 8 LAUNCHING POSTPONED

We understand from *Ham Radio* Report No. 104 that Oscar 8 may not be launched until well into 1980. In the meantime another satellite, similar to Oscars 6 and 7, is being considered for launching in late 1977.

We also learn from the H.R. Report that low power days for Oscar 7 mode B will become a regular event from October 1st. Every other Monday, when the satellite is in mode B, it will be restricted to QRP use. From our own observations of the last series of QRP tests, we would say that they were very successful. The QRP restriction appeared to be being respected by practically every user, and in spite of the low power, good strong QSO's were being easily carried out.

BARGAIN OFFER

Due to a special purchase on advantageous terms, Home Radio Ltd., of 234-240 London Road, Mitcham, Surrey, are offering ferrite rod, in various lengths, and paxolin aerial formers at a very attractive price.

The offer consists of 20 inches of rod, of which at least 3 pieces will be 4 inches in length, and 6 formers for 45p (including VAT) plus 20p postage and packing. As ferrite rod often costs 5p per inch the above would seem a very good "buy".

I.C. LECTURE COURSE

Commencing on 14th October there will be a course of 9 lectures on Thursday evenings at South London College, Knight's Hill, London SE27 0TX.

The course fee is £3.00 and application should be made to the Senior Administrative Officer at the college.

NEXT MONTH'S SPECIAL ISSUE

Following the great success of the Wall Chart, Design Data Tables 1, given away with our February issue, readers will be pleased to learn that in next month's issue we are giving away another Wall Chart.

Design Data Tables 2 will consist of Millimetre — Inch Conversion, Inch — Millimetre Conversion, Phase Shift Oscillator C – R Values, 2 πf Values, Wavelength — Frequency Conversion Chart, Audio Output Powers, Parallel — R Series — C values and E — R Dissipation.

Owing to heavy demand make sure you have the issue on order.

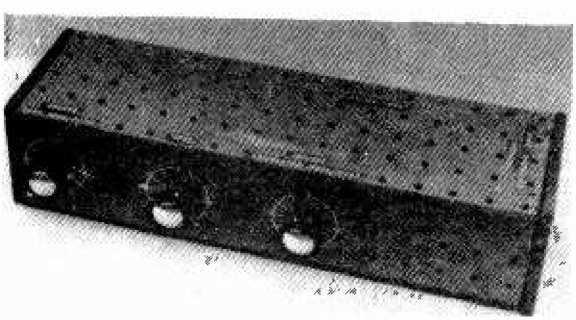
"Smoke signal say Tube belong to Big Chief Kicking Bull Gone for Burton!"

The 'PORT & STARBOARD' STEREO AMPLIFIER

Part 1
by
Sir Douglas Hall, K.C.M.G.

This unusual record player stereo amplifier has an extremely simple circuit incorporating a Class A output stage and a novel dual channel tone control incorporating a single gang potentiometer. Circuit operation, construction and setting up are all described here. Connections to the gram deck and the assembly of a suitable case are covered in next month's concluding article.

This stereo amplifier is intended for use with a ceramic cartridge, and an unusual feature is that it does not employ any ganged potentiometers. There are two separate volume controls together with a single gang tone control potentiometer. The use of separate volume controls is not uncommon, but the author has not previously seen a tone control circuit for a stereo amplifier using a single gang potentiometer. There are no undesirable cross-talk effects with the design employed here.



The completed amplifier in its case. The two panel lamps between the control knobs are part of the dual channel tone control circuit

CIRCUIT OPERATION

The circuit is shown in Fig. 1, and the basic principles can be more easily followed if the section below the earth line is studied. This consists of the amplifier for one channel without the tone control circuitry confusing the issue. It will be seen that there is an f.e.t., TR2, at the input, and that the signal from one side of the cartridge is fed to its gate by way of the network formed by R3, VR2 and R4. This network ensures that the load across the cartridge is never less than about 480kΩ, which is given at full volume. The cartridge load resistance rises as volume is backed down, with a consequent small advantage to the bass register. At the same time the input impedance of the amplifier never exceeds about 210kΩ. The outcome is reasonable matching for the ceramic cartridge and an input impedance for the amplifier which is low enough to keep hum at an unobjectionable level. It was not found necessary, with the prototype, to screen the leads and components connected to VR1 and VR2.

C2 is included in circuit to check a tendency towards parasitic oscillation and to introduce a small amount of fixed treble cut to compensate for recording characteristics. TR2 is directly coupled to a p.n.p. transistor, TR4, which acts as a common emitter amplifier. In turn, TR4 is directly coupled to TR6, a germanium n.p.n. output power transistor functioning as an emitter follower with a 25Ω speaker in its emitter circuit. Correct bias for the whole cir-

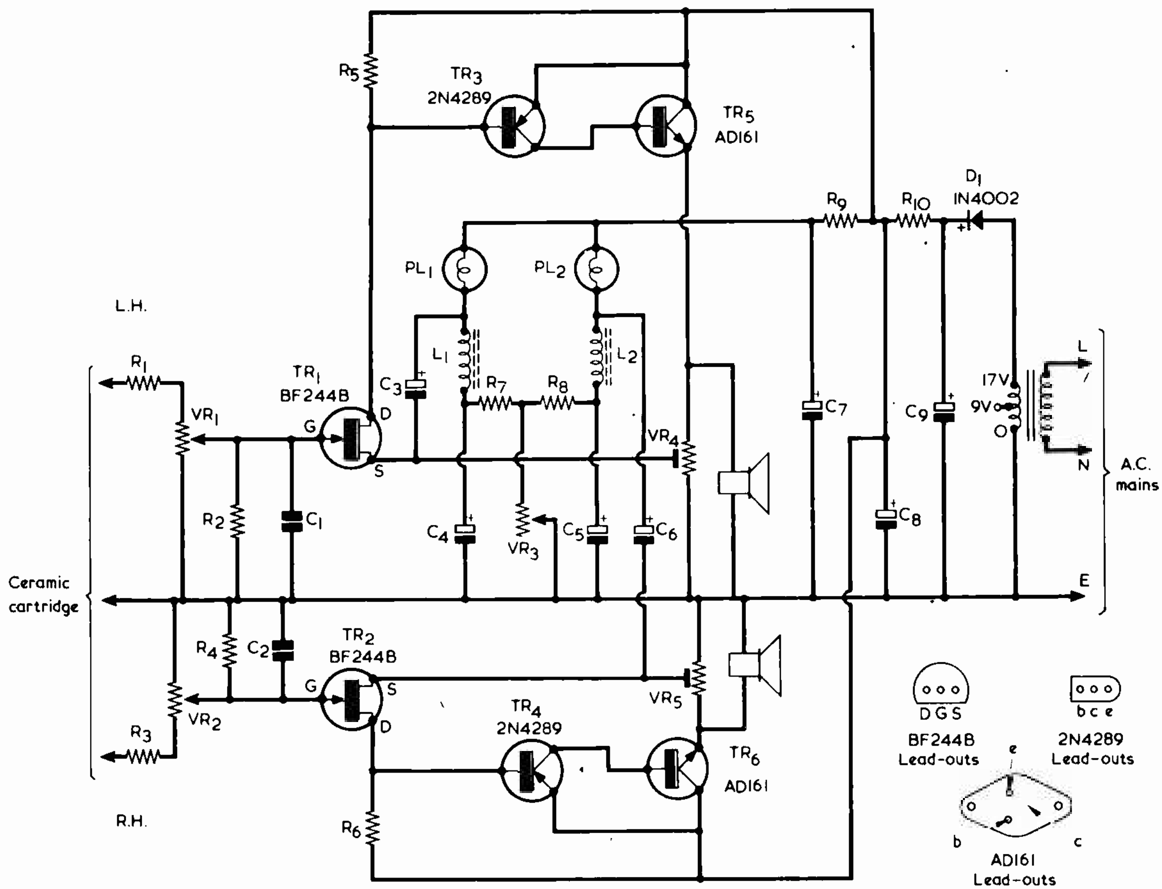


Fig. 1. The circuit of the "Port and Starboard" stereo amplifier. Tone control is achieved by varying the current in PL1 and PL2, and thereby changing their resistance

cuit is set by VR5, this component introducing a large amount of negative feedback both at d.c. and at signal frequency. VR5 is adjusted so that TR6 passes about 280mA. This direct current flows through the speaker and, in practice, does not detract from the output quality provided that the conditions detailed later in this article are met.

Let us next consider the tone control circuit, which appears above the earth line. So far as the lower amplifier is concerned the relevant components are PL2, L2, C5, C6, R8 and the tone control VR3, which also looks after the upper amplifier. PL2 is a 6 volt 0.04 amp (40mA) pilot lamp, and the tone control functions by taking advantage of the fact that its resistance is low when it passes a small current and is considerably higher when its rated current flows through it. It will be seen that a direct voltage is available across C7, and that this is applied to the pilot lamp in series with L2, R8 and VR3. If VR3 is set to insert zero resistance there will be about 4 volts across PL2, which will then offer a resistance of about 100Ω. (Experiments with various different makes and samples of 6 volt 0.04 amp pilot lamps showed that they all passed their rated 0.04 amp with only 4 volts across them.) Due to the presence of C5 and C6, L2 is effectively connected between the earth line and the source of TR2, and it therefore tends to cancel out some of the negative feedback in the VR5 circuit. L2 is especially wound to offer about 10mH inductance with about 8Ω resistance, and this offers an overall impedance of the order of 10Ω at the lowest audio frequencies and some hundreds of ohms at the highest audio frequencies. With PL2, which is in parallel with L2 at a.f., offering a resistance of about 100Ω, the frequency selective effect of L2 is modified somewhat but, even so, the overall effect is a considerable reduction of negative feedback at the lower audio frequencies, and bass boost results.

If VR2 is now set to insert its full 500Ω resistance into circuit the filament of PL2 becomes relatively cold and offers only about 10Ω in parallel with L2. The frequency discriminating properties of L2 are therefore swamped, and negative feedback is reduced for all audio frequencies in fairly equal proportions. The result is a corresponding rise in amplification of all frequencies which, when compared with the bass boost given when VR3 inserts zero resistance, gives a subjective impression of treble boost. Intermediate settings of VR3 give intermediate frequency responses.

COMPONENTS

Resistors
(All fixed values $\frac{1}{4}$ watt 10% unless otherwise stated)

R1 270kΩ	R6 1kΩ
R2 270kΩ	R7 150Ω $\frac{1}{2}$ watt
R3 270kΩ	R8 150Ω $\frac{1}{2}$ watt
R4 270kΩ	R9 27Ω $\frac{1}{2}$ watt
R5 1kΩ	R10 3.3Ω 3 watt

VR1 1M potentiometer, log
VR2 1MΩ potentiometer, log
VR3 500Ω potentiometer, wire-wound (see text)
VR4 1kΩ pre-set potentiometer, skeleton
VR5 1kΩ pre-set potentiometer, skeleton

Capacitors
C1 100pF silvered mica or ceramic
C2 100pF silvered mica or ceramic
C3 100μF electrolytic, 16 V. Wkg.
C4 100μF electrolytic, 16 V. Wkg.
C5 100μF electrolytic, 16 V. Wkg.
C6 100μF electrolytic, 16 V. Wkg.
C7 4,700μF electrolytic, 16 V. Wkg. (see text)
C8 4,700μF electrolytic, 16 V. Wkg. (see text)
C9 2,200μF electrolytic, 25 V. Wkg. (see text)

Inductors
L1 Home-wound (see text)
L2 Home-wound (see text)
T1 Mains transformer, secondary 0-9-17V at 1A (see text)

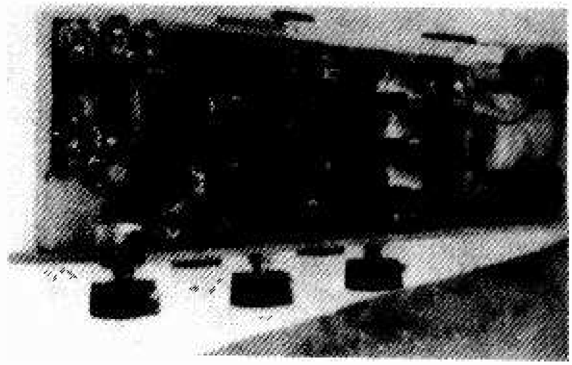
Semiconductors
TR1 BF244B
TR2 BF244B
TR3 2N4289
TR4 2N4289
TR5 AD161
TR6 AD161
D1 1N4002

Pilot Lamps
PL1 6V 0.04A filament panel indicator, red (see text)
PL2 6V 0.04A filament panel indicator, green (see text)

Heat Sink
Heat sink type 17C2 (Electrovalue)

Plugs and Sockets
Plug and socket assembly type P360 (Bulgin)
3-way jack plug
3-way jack socket
2 phono plugs
2 phono sockets

Miscellaneous
3 control knobs
2 6-way group boards (see text)
2 ferrite rods, 2 x $\frac{3}{8}$in. (see text)
Plywood, $\frac{1}{4}$in.
Peg board, $\frac{1}{8}$in.
Nuts, bolts, wire ,etc.



Looking into the amplifier at the end remote from the mains transformer

Pilot lamp PL1 and L1 offer the same effect with the upper amplifier. Since the two controls are isolated from each other by C4 and C5 there is no interaction between them, and they can be controlled by the single potentiometer, VR3. For best results it is important that speakers having a good treble response be employed with the amplifier.

A secondary effect is that the incremental inductance of L1 and L2 decreases as more current flows through them due to the consequent reduction in the permeability of the cores on which they are wound. This effect is taken up in practice by providing the coils with a suitable number of turns. It should be added that a great deal of experiment was undertaken to find the optimum inductance and resistance values for L1 and L2. These should be home-wound, as described later, and must employ the particular gauge of wire specified. So far as the author is aware there are no suitable commercially made coils or chokes which can take their place.

Simple m.e.s. 6 volt 0.04 amp bulbs may be employed for PL1 and PL2, but the author used 6 volt 0.04 amp filament panel mounting lamps, one being green and the other red. These are available from several suppliers. The potentiometer employed for VR3 in the prototype was a Colvern type CLR905C with a body diameter of 1.375in. and a rating of 3 watts. This is retailed by Electrovalue.

The power supply needs little comment. A 17 volt mains transformer is used, and good smoothing is provided by C7, C8 and C9 in conjunction with R9 and R10. The transformer employed in the prototype was a charger transformer type CT1 (available from Electrovalue) having a secondary rated at 1 amp with a 9 volt tap. No connection is made to the tap.

Before proceeding to constructional details, several further points concerning components need to be mentioned. C7, C8 and C9 need to be small types if they are to fit in the space available. The author used Siemens axial lead capacitors obtained from Electrovalue. TR5 and TR6 are mounted on a special anodised heat sink. This is Electrovalue type 17C2. There are two 6-way group panels (i.e tag boards), these being the R.S. Components "Standard" types. If difficulty is experienced in obtaining these, two 6-way sections can be cut from a "Standard" 18-way group board available from Doram Electronics. The mains input to the amplifier is carried by a 3-way plug and socket assembly, Bulgin type P360.

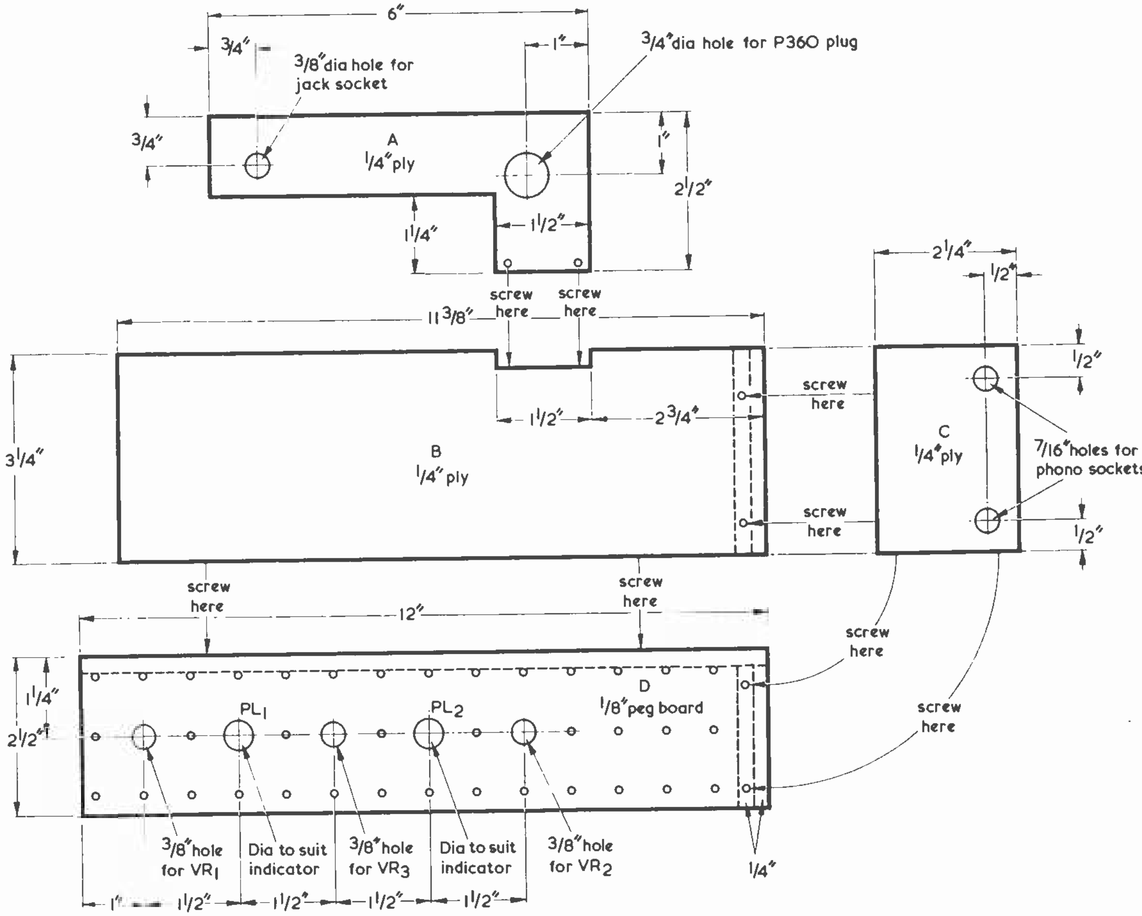
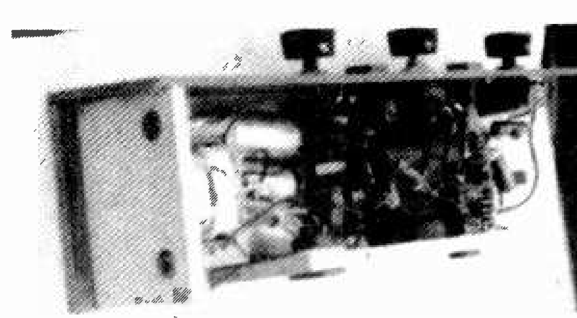


Fig. 2. The four plywood or peg board sections on which the amplifier components are assembled

CONSTRUCTION

Refer next to Fig. 2 for the first constructional details. There is a plywood baseboard B, an upright section C which carries the mains transformer and speaker phono sockets, and an upright section A which takes the mains plug and a 3-way jack socket for the input from the cartridge. A third upright panel, D, consists of peg board to allow ventilation, as some heat is given off by the transformer, by R10, and by the output transistors. The peg board panel should be drilled as shown and, if standard material with holes $\frac{3}{4}$in. apart is used, it will be found that all the larger holes for the panel components can be made by enlarging existing small holes. This makes drilling an easy process.

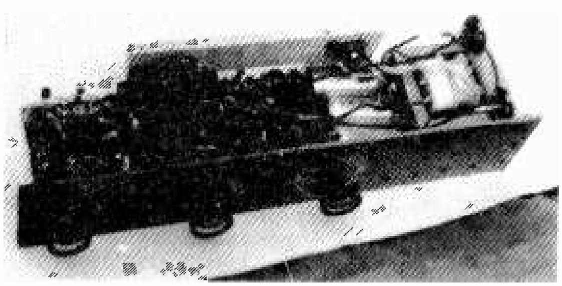
Turn next to Fig. 3(a) and fit the mains plug and



The amplifier, as seen from the transformer end jack socket to panel A, as shown. The flanged section of the P360 plug and socket assembly is secured to the panel, the 3-way mains lead being connected to the other section of the assembly. Follow this by mounting the two phono sockets and the mains transformer to panel C, as shown in Fig. 3(b), using short wood screws (or, preferably, countersunk bolts and nuts with the nuts on the inside). The transformer may be supplied with tags or flying leads; if it is fitted with tags these should appear on its upper surface when panel C is assembled to panel B. Note that a solder tag is secured under one of the transformer mounting screws (or nuts), to enable the transformer frame to be earthed. Assemble panels, A, B, C and D in the manner illustrated in Fig. 2.

the rod at its centre. (4in. by ⅜in. "Orange grade" ferrite rods may be obtained from Amatronix Ltd., 396 Selsdon Road, South Croydon, Surrey, CR2 0DE.) Each coil consists of 500 turns of 34 s.w.g. enamelled wire. The coils are pile wound and no great care is needed in carrying out this process, although the general aim is to distribute the wire fairly evenly along the paper sleeve. The resulting coils should each offer a resistance of about 8Ω., but an ohm or so either side of this figure will be within tolerable limits.

The components on panel D are then mounted, after which the wiring shown in Fig. 3(a) is carried out. L1 and L2 are fitted loosely in their holes in panel B for the time being.



Another view of the amplifier assembly

The heat sink is next mounted on panel B, and is secured in the manner illustrated in Figs 3(a) and (c). Two 1¼in. countersunk 4BA bolts pass through panel B and are secured with 4BA nuts immediately above the panel. Each bolt then passes through one hole of each transistor and through the appropriate hole of the heat sink, with a nut underneath for spacing and a solder tag and a nut on the top for final securing. The transistors are mounted below the heat sink with their base and emitter lead-outs projecting upwards, and the remaining hole of each is secured to the heat sink with a short 4BA bolt and nut. The solder tags under the upper nuts on the 1¼in. bolts allow connection to be made to the collectors. Drill the requisite two 4BA clear holes in panel B, then mount the heat sink and the two transistors in the manner just described. The heat sink takes up the position shown in Fig. 3(a).

L1 and L2 consist of coils wound on lengths of ⅜in. ferrite rod. They are fitted with their axes vertical into slightly oversize ⅜in. holes drilled in panel B, so that they take up the approximate positions shown in Fig. 3(a). Drill these holes, then mount the two 6-way group boards by means of short wood screws.

Coils L1 and L2 are identical, and each is wound on a paper sleeve 1¾in. long fitted over a 2in. length of ⅜in. ferrite rod. The author obtained the 2in. lengths by snapping in two a 4in. length of "Orange grade" rod after filing a V-cut around the circumference of

SPEAKERS

The two speakers employed with the amplifier should have an impedance of 25Ω. Single speakers with a lower impedance must not be used, although it is in order to employ three 8Ω speakers in series, or two 15Ω speakers in series, per channel. Alternatively, one 35Ω speaker per channel may be used, with a slight drop in undistorted output available. If multiple speakers are used, all should be identical and they should be full-range models as opposed to woofers and tweeters.

Because of the 280mA standing current in the speakers, miniature types must not be employed. In general, sizes from 7 by 4in. upward will be suitable, and a speaker (or set of series connected speakers) which is capable of handling 6 watts or more will be operated within its linear range by the amplifier. The amplifier output itself is 1 watt per channel and offers excellent quality for normal domestic listening; the necessity for a larger speaker is the price imposed by the extreme simplicity of its circuit.

Each speaker must, of course, be in phase and it must be connected such that its cone moves *outwards* when the 280mA standing current flows through it. This is an important point, and has to be carefully observed.

After completing the wiring and checking for errors, connect two 25Ω speakers, or the alternative speakers just referred to, to the out-

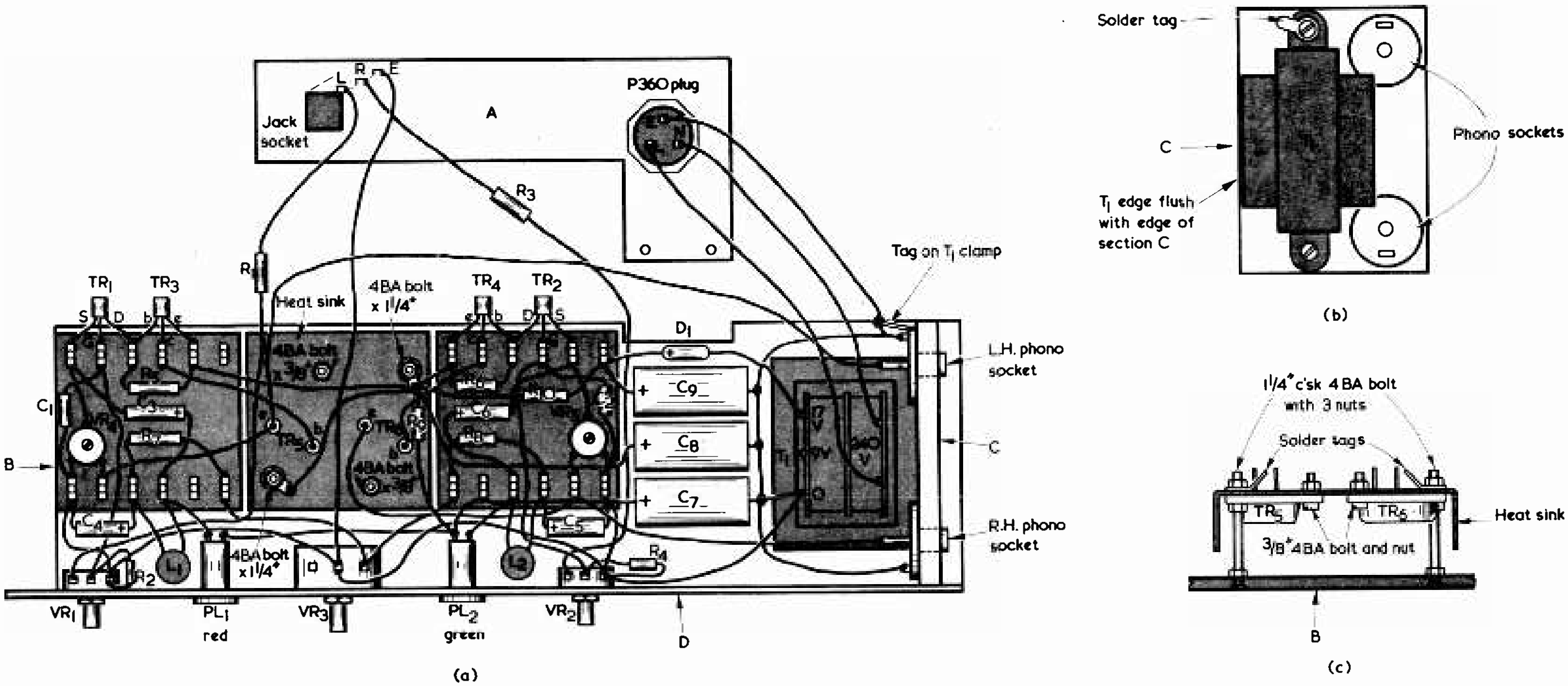


Fig. 3(a). The wiring the layout of the amplifier components
(b). The mains transformer and phono output sockets are fitted to section C as shown here
(c). Detail illustrating the manner in which the heat sink and output transistors are assembled

puts. The speakers should be arranged so that their cone movement may be observed visually. Set the sliders of VR4 and VR5 to the track ends which connect to the appropriate output transistor emitter. This means fully clockwise for VR4 and fully anticlockwise for VR5, as seen in Fig. 3(a). Connect a meter switched to give a clear indication of 7 volts across the left hand channel output, with negative to the earth line. Take great care to ensure that there is no risk of a short-circuit between the test leads as this can cause the output transistor to burn out. The same need to avoid short-circuits at the speaker outputs applies also, of course, when the amplifier is in use.

Connect the mains input to a power socket having a switch on it. This is a temporary switching arrangement for checking and setting up.

Switch on the mains supply. Slowly advance VR4 whilst watching the cone movement of the left hand speaker. If the cone moves outwards all is well. Should the cone move inwards, return VR4 to its initial setting, switch off and reverse the connections to the speaker. When cone movement is satisfactory, advance VR4 slowly until a voltage of 7 volts is given across the speaker. If there is a series combination of speakers then the 7 volts appears across them all, and it is necessary to monitor the direction of cone movement in each speaker.

Switch off, then repeat the process with the right hand channel output, checking for cone movement and voltage as VR5 is adjusted. Check back to the left hand channel output, and make any slight readjustment required in VR4, and finally again with the right hand channel. VR4 and VR5 are then set up. At this juncture the choice of the transistor employed for TR1 and TR2 may be mentioned. The BF244B has a much smaller spread in characteristics than other f.e.t.'s, such as the 2N3819. This feature not only ensures virtually equal amplification in each channel but also enables the setting up procedure just described to be successfully accomplished. With other f.e.t.'s it may be found impossible to obtain the 7 volt reading across each speaker output.

A further setting up process remains. Turn both volume controls to zero and listen for hum from the left hand speaker. If there is anything above a very soft background of hum rock L1 with one finger, a degree or two at a time and in different directions, until a position is found at which the hum disappears. Then apply adhesive to the bottom of L1 core and let it set with the choke in the "null" position. Repeat this exercise with L2, listening for hum in the right hand speaker. Hum here is more likely than with the left hand amplifier, as L2 is closer to the mains transformer than is L1. It might be mentioned that in the first design of the amplifier T1 was mounted directly on the baseboard so that its core was parallel to the cores of L1 and L2, and hum from the right hand speaker was quite intolerable. This form of hum pick-up is not reduced by setting back the volume controls as it is induced into the chokes after TR1 and TR2.

NEXT MONTH

In next month's concluding article details will be given of the connections between the amplifier and the gram deck. Also to be described will be a case for the amplifier.

(To be concluded)

SUGGESTED CIRCUIT

LINEAR SCALE OHMMETER

By G. A. French

Accurate measurement of resistance with the more inexpensive type of multi-testmeter is notoriously difficult to achieve. The resistance scale in such a testmeter is extremely non-linear and becomes considerably cramped at the high resistance end. The accuracy varies also with the voltage of the internal testmeter battery, and a high degree of error can be introduced if the battery voltage is low.

The ohmmeter to be described in this article employs a simple circuit which overcomes both of these shortcomings. First, the scale is linear with the result that readings are clear and unambiguous. Second, the resistance to be measured has a constant current passed through it, with the result that indications are independent of battery voltage. The instrument has four ranges, these being 0-1kΩ, 0-10kΩ, 0-100kΩ and 0-1MΩ, and it can in consequence measure resistances from about 50Ω to 1MΩ. Performance to precision laboratory standards is not claimed: there is a known and accepted inaccuracy on the 0-1kΩ range, and there is a very slight possibility of an inaccuracy on the 0-1MΩ range. The overall accuracy is still superior, nevertheless, to that of a lower cost testmeter switched to an ohms range. If desired, the ohmmeter can be built in a form in which indications are given by a testmeter switched to a volts range, whereupon it requires only a few components and three inexpensive transistors. A testmeter capable of reading currents from 10μA to 10mA and having a sensitivity of 10,000Ω per volt or better on its voltage ranges is needed for setting up.

CIRCUIT OPERATION

The circuit of the testmeter appears in Fig. 1. Here TR1 functions as a constant current generator, its base being held at a fixed potential relative to the upper positive rail by the forward voltage dropped across the two silicon rectifiers, D1 and D2. The range switch, S2, selects one of the four pre-set variable resistors VR1 to VR4, these controlling the emitter current, and hence the constant collector current, of the transistor. When S2 is set to position 1, the constant current is a nominal 10mA. At position 2 the constant current is an exact 1mA, at position 3 an exact 100μA and at position 4 an exact 10μA. The constant current selected flows, when push-button S1 is pressed, through any resistance connected across the test terminals. With S2 at position 1 there is a drop of 10 volts across the test terminals when the test resistance is 1kΩ. The same result is given in position 2 with a test resistance of 10kΩ, at position 3 with 100kΩ and at position 4 with 1MΩ. If lower values of test resistance are connected the voltages across them will be proportionately lower. Since a constant current flows through the test resistance the voltage dropped across it is directly proportional to the resistance value.

The voltage across the test resistance is read by the very high impedance electronic voltmeter consisting of TR2, TR3, R3, VR5 and M1. VR5 is set up such that the meter gives full-scale deflection when the voltage between the emitter of TR3 and the slider of VR6 is 10 volts. Thus, the meter offers an f.s.d. indication for the test resistances of 1kΩ, 10kΩ, 100kΩ and 1MΩ which have just been mentioned. Lower values of resistance can then be read directly from the meter scale. If, for instance, a reading of 57μA is given with S2 in position 4 (0-1MΩ) then the test resistance has a value of 570kΩ.

The voltage at the emitter of TR3 is about 1.2 volts below that at the upper test terminal, this voltage being the sum of the forward voltage drops in the base-emitter junctions of TR2 and TR3. The negative terminal of M1 has to be returned to a potential which is similarly negative of the lower test terminal, and this is achieved by connecting it to the slider of VR6. VR6 is a panel-mounted potentiometer and it is adjusted for a zero reading in the meter when the test terminals are short-circuited by S1. Resistor R2 ensures that a reverse current flows through the meter if VR6 slider is positive of the set zero position, and helps in finding the correct meter zero setting. A separate 3 volt battery is incorporated to provide the negative voltage for the meter as this enables the constant current from the test resistance to be routed direct to the negative terminal of the main 18 volt battery. In practice, VR6 has to be adjusted only occasionally, and then merely to take up falling voltage in the 3 volt battery.

There is a very high gain amplifying chain from the emitter of TR1 to the collector of TR3 and, unless suitable precautions were taken, this could result in r.f. oscillation if TR3 collector wiring approached that in the emitter circuit of TR1. The possibility of such oscillation is removed by the two bypass capacitors, C1 and C2; these

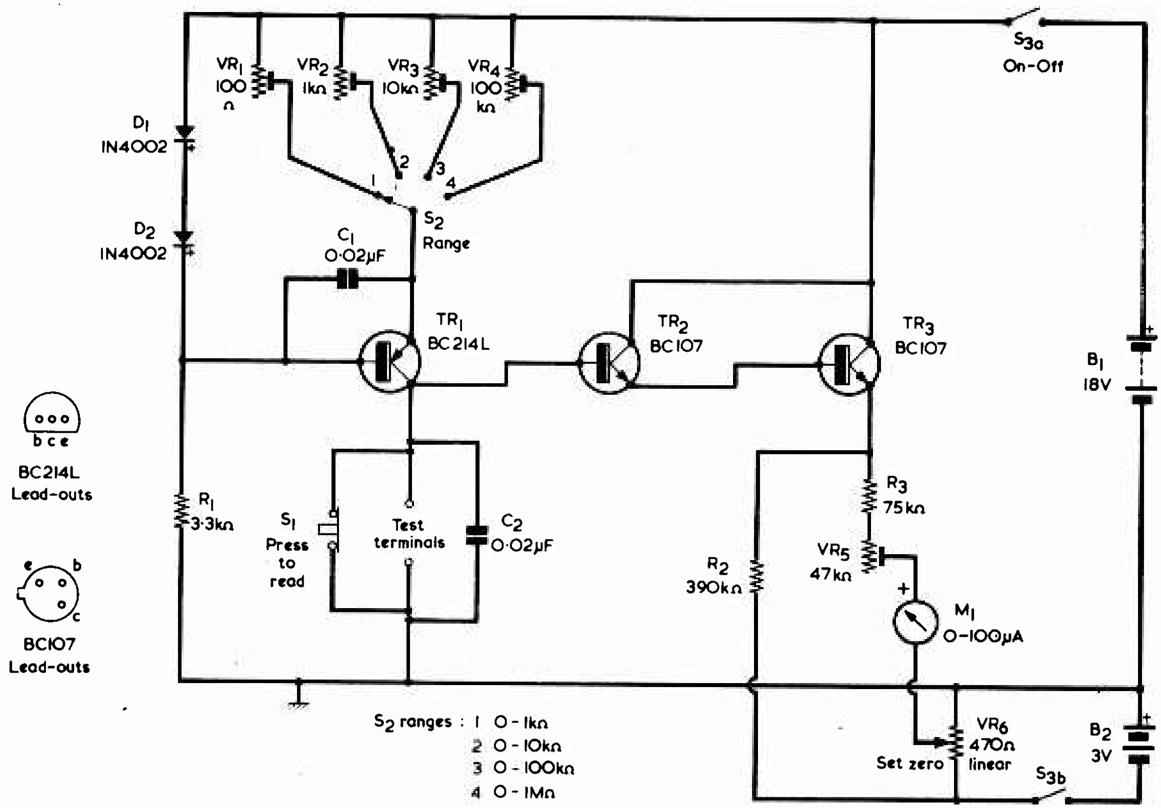


Fig. 1. The circuit of the ohmmeter. This provides linear scale resistance readings over the ranges shown

capacitors cause the circuit to be quite stable, and no precautions have to be taken in wiring layout.

S1 is included to ensure that the meter reading is at zero when no resistance measurement is being taken. If S1 is pressed when the test terminals are open-circuit or when too high a resistance is connected to them, the meter needle passes the f.s.d. point. The highest voltage which can be applied to the electronic voltmeter is about 17 volts, causing the meter to pass 170μA. A current of this value, which is less than twice f.s.d., should not cause any damage to the meter movement.

S3(a)(b) is a d.p.s.t. on-off switch. It disconnects both the 18 volt and the 3 volt batteries when it is turned off. The 18 volt battery can consist of two 9 volt batteries in series, and the 3 volt battery can be given by two 1.5 volt cells in series. The current drawn from the 18 volt battery is about 6mA on Ranges 2, 3 and 4, rising to 16mA on Range 1. The current drawn from the 3 volt battery is a little in excess of 6mA. The 18 volt battery should preferably be discarded when its voltage has fallen to about 15.5 volts. The 3 volt battery is discarded when its voltage is too low to allow a zero setting to be achieved.

Before concluding on circuit operation, a few words are needed concerning the electronic voltmeter incorporating TR2 and TR3. This configuration has been successfully employed several times as a very high impedance voltmeter in published designs, and it functions well in practice although it assumes leakage currents in the transistors which are below the maximum figures quoted by the manufacturer. A similar comment can be applied to TR1 when S2 selects the 10μA constant current at position 4. However, the author has employed silicon transistors such as the BC214L in low value constant current circuits in the past without any trouble whatsoever. The fact that there is theoretically a possibility of transistor leakage currents upsetting operation at low current is the reason for the comment concerning the 0-1MΩ range at the beginning of this article. The author has experienced no problems in this respect in practice but, for completeness, the point has had to be mentioned.

The components are all standard parts. R1, R2 and R3 are ¼ watt 5% resistors, whilst VR1 to VR5 are standard (i.e. not miniature) skeleton potentiometers. VR6 may be a small wirewound potentiometer if difficulty is experienced in obtaining a carbon track component with the low value specified. Alternative values for VR5 and VR6 are 50kΩ and 500Ω respectively. S1 is a push-button whose contacts open when it is pressed. S2 is a rotary switch, and could be one section of a 3-pole 4-way switch. S3(a)(b) is a d.p.s.t. toggle switch. C1 and C2 are plastic foil capacitors.

ASSEMBLY

The unit may be assembled in a metal or plastic case with the three switches, VR6, the test terminals and meter M1 on the front panel. If a metal case is used it is made common with the negative terminal of the 18 volt battery, as indicated by the chassis symbol in the circuit diagram. The chassis symbol is ignored if the unit is housed in a plastic case.

After construction has been completed, adjust the pre-set potentiometers VR1 to VR5 so that they all insert maximum resistance into circuit. This point is of particular importance with respect to VR1 to VR4 inclusive; if any of these potentiometers inserts too low a resistance an excessive current may be passed which could damage the potentiometer, TR1 and, during setting-up, the monitoring current meter. Switch on, and adjust VR6 for a zero reading in meter M1. Set S2 to Range 4 and connect a testmeter switched to read current to the test terminals, with positive to the terminal connecting to TR1 collector. Since this is a newly constructed circuit, it is wise to initially switch the meter to a high current range, changing down by steps to the required low current range only when the higher range readings indicate that it is safe to do so. The meter will indicate current when S1 is pressed. If all is well, select a testmeter range which will enable a current of 10μA to be read, then slowly and carefully reduce the resistance inserted by VR4 until this current is indicated. Set S2 to Range 3 and repeat the process with VR3 for a current reading of 100μA. After this, select Range 2 and similarly adjust VR2 for a current of 1mA.

This leaves Range 1, and here the constructor can employ one of two alternatives. As was stated earlier, the constant current offered on this range is a nominal 10mA. In practice the current is not truly constant, and it is found that if VR1 is set up for 10mA when there is 10 volts across the test terminals (as is given by a test resistance of 1kΩ) the current rises to 10.2mA when the test terminals are short-circuited. In consequence it is possible to set up VR1 either for 10mA when there is 500Ω across the test terminals or for 10mA when there is 1kΩ across the test terminals. If the first course is adopted the ohmmeter will read accurately on Range 1 at scale centre with a gradually increasing error up to the scale ends of approximately 1% low at the high resistance end and 1% high near the zero resistance end. Taking the second alternative means that the meter reads accurately at the 1kΩ end, reads about 1% high at scale centre and about 2% high near the zero resistance end. In the author's view the second alternative is the better as the inaccuracy increases as reading resolution decreases. The level of the inaccuracy is, of course, quite low for an instrument of this nature.

If it is desired to adjust VR1 for 10mA at scale centre, the testmeter is connected to the test terminals via a resistor of around 400Ω. Should the second method be adopted, the meter is connected to the test terminals in series with a resistor of around 900Ω. In either case, VR1 is then adjusted for the current of 10mA. The series resistors are 100Ω lower than 500Ω or 1kΩ respectively, because it can be expected that there will be a voltage drop of the order of 1 volt across the

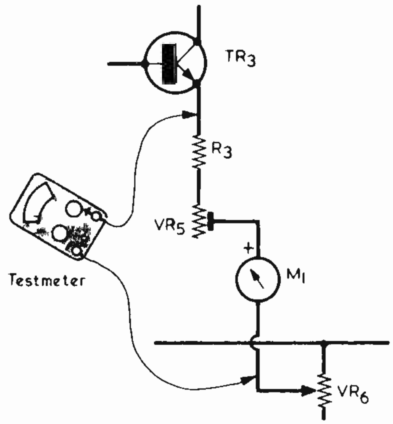


Fig. 2. Illustrating how VR5 is set up

testmeter. (Multi-testmeters, with their "universal shunt" current range circuits, drop higher voltages on their current ranges than is generally realised).

The constant current potentiometers are now set up and it is necessary next to adjust VR5. Switch the monitoring testmeter to a range which allows voltages up to 10 volts to be indicated and connect it to the emitter of TR3 and the slider of VR6 in the manner shown in Fig. 2. Connect a resistor across the test terminals whose value is close to the maximum for any range and select that range. The resistor could, for instance, be 9.1kΩ with S2 set to Range 2. Press S1 and note the reading in the testmeter, then adjust VR5 for a corresponding reading in M1. As an example, if the testmeter gives a reading of 9.4 volts, adjust VR5 for an indication of 94μA in M1.

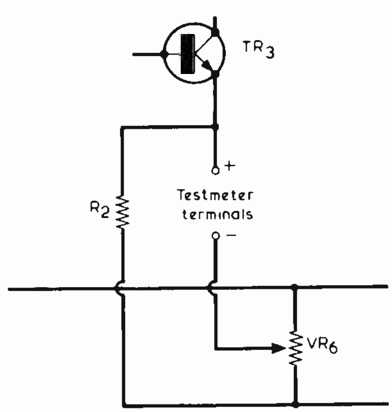


Fig. 3. A modification which allows an external testmeter to be employed instead of the internal meter

All the ohmmeter adjustments are now completed and the unit is ready for use.

EXTERNAL VOLTMETER

A significant saving in components including, in particular, the 0-100μA meter, can be achieved by employing an external voltmeter. This can be a multi-testmeter switched to read voltages up to 10 volts and having a sensitivity of 10,000Ω per volt or better. If it has a 0-10 volt range it will prove ideal. Voltage readings up to 10 volts are then converted mentally to the appropriate test resistance value.

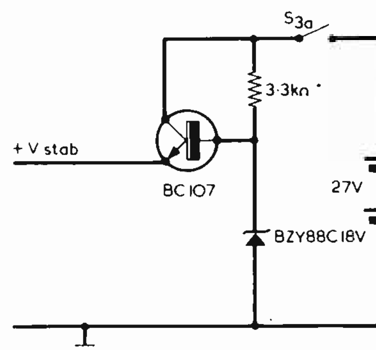


Fig. 4. An improved performance, at the expense of an increased battery voltage, is given by the use of a stabilised

To employ the ohmmeter in this way, assemble it without R3, VR5 and M1. Add two further terminals, these connecting into circuit as illustrated in Fig. 3. The testmeter is connected to these terminals whenever the ohmmeter is required.

The testmeter does not need to be connected to the two added terminals when initially setting up the constant currents and it can be used as a current indicating meter for this purpose, if desired. There is now, of course, no necessity to set up VR5.

The author has not felt it necessary to provide a stabilized supply for a circuit as simple as the present one. Readers who wish to do so may, however, employ the zener stabilizer shown in Fig. 4, which replaces the 18 volt supply of Fig. 1. This has the disadvantage that an extra 9 volt battery is required, giving a total of 27 volts. There is the compensatory advantage that the supply voltage remains reasonably stable for battery voltages down to about a volt above zener voltage. ■

REGENERATIVE

SUPE

Part 1

Covering 1.6 to 25MHz, or operated superhet will funct headphones. The coils and mi: compact coilpack module, and sion of adjustable regeneration details will be completed in th appear n

Regeneration in a radio receiver can provide an enormous increase in the Q and selectivity of a tuned circuit, and it allows the reception of single sideband (s.s.b.) and c.w. (Morse) signals without the necessity of employing a b.f.o. It is for these reasons that regeneration is used in the receiver to be described. As a consequence, a relatively simple circuit gives results which would otherwise be unobtainable without extra stages.

The aerial and oscillator coils. range switch and other associated components are all assembled as a separate unit, giving what is effectively a 3-band coilpack for the 1.6MHz to 25MHz range. This approach allows the wiring of these circuits to be more accessible, and the finished pack is easily incorporated in the receiver.

The tuning of amateur and other congested bands is quite critical and so a simple form of fine tuning is incorporated. This will be found very helpful, particularly when tuning in s.s.b. and c.w. signals.

S.S.B. and c.w. signals are resolved by taking the regeneration at the receiver detector beyond the oscillation point, and so a b.f.o. is not necessary. Provided that the controls are adjusted in the manner to be described, good s.s.b. and c.w. reception is obtained. This is in addition, of course, to the usual a.m. broadcasts.

MIXER COILPACK

Fig. 1 gives the circuit of the mixer coilpack and the components which connect to it. Not included in the actual pack assembly are VR1, VC1(a)(b), VC2 and TC4, although these are shown in Fig. 1.

VR1 functions as an r.f. gain control and allows strong signals to be attenuated. This is a particularly desirable facility with strong s.s.b. and c.w. signals, as these should not be presented to the detector at too high a level. In a more elaborate receiver a similar function would be provided by an r.f. stage gain control, but it will be found that VR1 serves the purpose in a perfectly satisfactory manner here.

L1, L2 and L3 are the three aerial coils. Their tuned windings are selected by S1(a), which is one section of the 3-way range switch and which couples the selected winding to VC1(a). The three aerial coupling windings are connected in series and require no switching; the same applies to the three base coupling windings. Each tuned winding has its own trimmer, these being TC1, TC2 and TC3. Base bias for the mixer transistor, TR1, is obtained from the junction of R1 and R2.

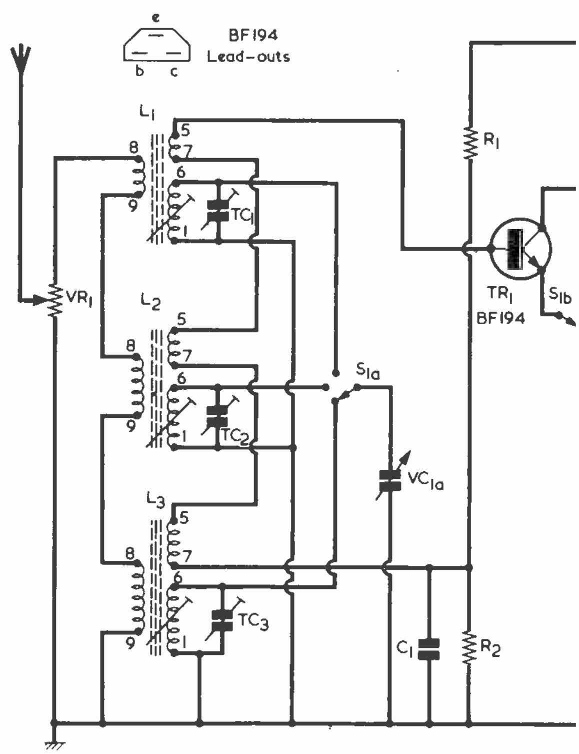
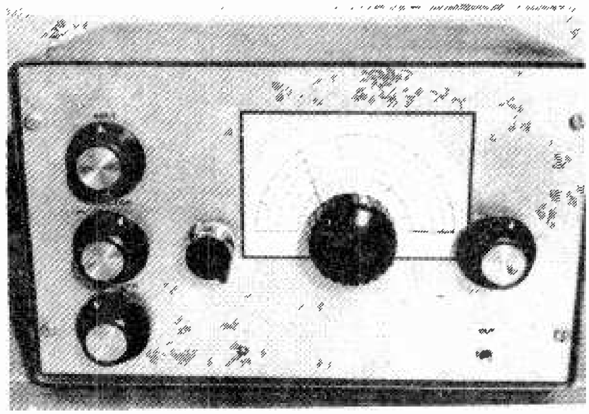


Fig. 1. The circuit of the coilpack module incorpo coils and associ

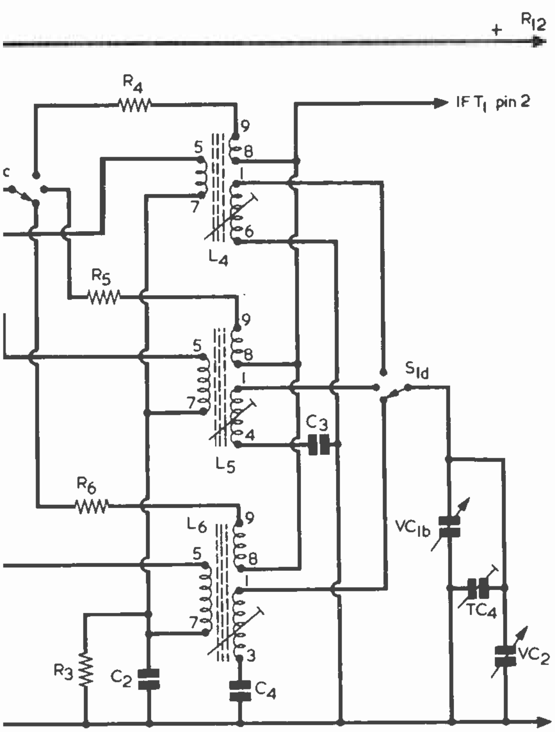
SHORT WAVE
RHET

by F. G. Rayer

)0 to 12 metres, this battery n both with a speaker or ' transistor are wired up in a attractive feature is the provi- t the detector. Constructional concluding article, which will : month.



Front panel layout of the receiver. The tuning scale is taken from "Panel Signs" Set No. 5

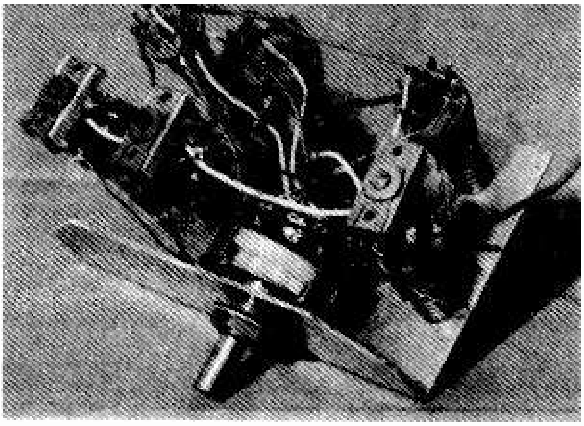


'ng the mixer transistor, the aerial and oscillator d components

The oscillator coils are L4, L5 and L6. L6 has a padding capacitor, C4, in series with its tuned winding, whilst the padding capacitor for L5 is C3. L4 requires no padding capacitor and the earthy end of its tuned winding connects direct to chassis. S1(b) selects the emitter windings, which are terminated at the emitter bias resistor, R3, and bypass capacitor, C2. S1(c) switches in the collector windings. The resistors R4, R5 and R6 are inserted in series with the collector windings to prevent excessive oscillation, which could cause whistles at the high frequency ends of the tuning ranges.

S1(d) couples the tuned windings to VC1(b), the second section of the 2-gang main tuning capacitor. Only the single trimmer, TC4, is used in the oscillator stage; this can be set to approximately half its maximum capacitance with signal trimming carried out by TC1, TC2 and TC3 in the aerial circuit. VC2 is a fine tuning capacitor having a very low value, and it allows exact tuning of signals which would otherwise be difficult to select. Tuning with VC2 is smooth, and its presence ensures that a high ratio drive for VC1(a)(b) is not necessary. Also, VC2 is so small in value that there is no need to fit a corresponding aerial trimmer for L1, L2 and L3. The peaks of the aerial coils are broader than the small frequency coverage available with VC2.

Approximate band coverages are 1.6 to 4.5MHz (190 to 67 metres) with L3 and L6, 4.5 to 12MHz (67



The mixer coilpack assembly. Mounting the coils and associated components in a separate module makes for easier overall wiring

to 25 metres) with L2 and L5, 10 to 25MHz (30 to 12 metres) with L1 and L4. It is thus possible to tune all the amateur bands with the exception of 10 metres and v.h.f., as well as the most important short wave broadcast bands. As is customary with all short wave listening, the frequencies at which reception is best depend on the time of day and propagation conditions, but some amateur and broadcast bands within the range covered should be active at virtually any hour.

Of the components so far encountered, one which requires special mention is the 2-gang capacitor VC1(a)(b). This is a Jackson type "02" with concentric spindle slow motion and is available from Home Radio. C3 can be 2,700pF and 300pF in parallel if a single 3,000pF capacitor cannot be obtained. The low value potentiometer required for VR1 may be obtained from Electrovalue.

COMPONENTS

Resistors
(All fixed values ¼ watt 5%)
R1 18kΩ
R2 15kΩ
R3 2.7kΩ
R4 820Ω (see text)
R5 680Ω (see text)
R6 100Ω (see text)
R7 270kΩ
R8 82Ω (see text)
R9 2.2MΩ
R10 5.6kΩ
R11 3.9kΩ
R12 100Ω
R13 2.2MΩ
R14 12kΩ
R15 5.6kΩ
R16 10kΩ
VR1 470Ω potentiometer, linear
VR2 2.2kΩ or 2.5kΩ potentiometer, linear
VR3 100kΩ potentiometer, log, with switch S2

Capacitors
C1 0.01μF plastic foil
C2 0.01μF plastic foil
C3 3,000pF silvered mica or polystyrene, 2% (see text)
C4 1,000pF silvered mica or polystyrene, 2%
C5 0.1μF plastic foil
C6 4,700pF plastic foil or polystyrene
C7 0.1μF plastic foil
C8 0.02μF plastic foil
C9 25μF electrolytic, 10V. Wkg.
C10 0.1μF plastic foil
C11 0.1μF plastic foil
C12 25μF electrolytic, 10V. Wkg.
C13 4μF electrolytic, 6V Wkg.
C14 0.01μF plastic foil
C15 320μF electrolytic, 6V Wkg.
C16 125μF electrolytic, 10V Wkg.
VC1(a)(b) 365 + 365pF 2-gang variable, with slow motion (Jackson — see text)
VC2 5pF variable, type C804 (Jackson)
TC1 60pF trimmer, mica
TC2 60pF trimmer, mica
TC3 60pF trimmer, mica
TC4 60pF trimmer, mica
TC5 10pF Tetfer trimmer (see text)

Inductors
L1 Transistor Tuning Coil, Blue, Range 5T (Denco)
L2 Transistor Tuning Coil, Blue, Range 4T (Denco)
L3 Transistor Tuning Coil, Blue, Range 3T (Denco)
L4 Transistor Tuning Coil, Red Range 5T (Denco)
L5 Transistor Tuning Coil, Red, Range 4T (Denco)
L6 Transistor Tuning Coil, Red, Range 3T (Denco)
IFT1 I.F. transformer type IFT18/465 (Denco)
IFT2 I.F. transformer type IFT18/465 (Denco)

Semiconductors
IC1 MFC4000B
TR1 BF194
TR2 BF195
TR3 BC108
TR4 BC147

Switches
S1(a)(b)(c)(d) 4-pole 3-way rotary
S2 s.p.s.t., toggle, part of VR3

Sockets
3.5mm. jack socket or insulated sockets (see Text)
Aerial socket
Earth socket

Miscellaneous
6 control knobs (see text)
9 volt battery
Battery connectors
Plain perforated board, 0.15in. matrix, as required
"Universal Chassis" flanged side, 6x4in.
Front panel 10x6in.
Case (see text) consisting of:
2 flanged sides, 6x4in.
2 flanged sides, 10x 4in.
1 plate, 10x6in.
1 Hardware Kit.

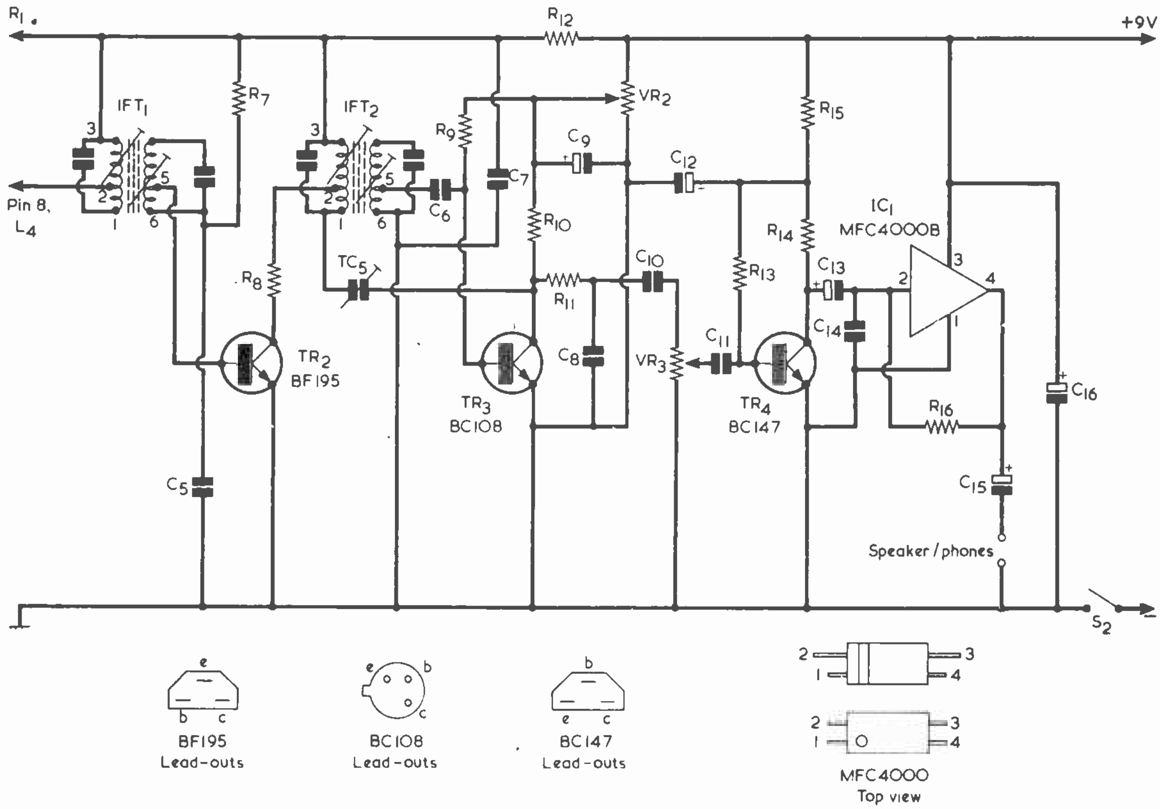


Fig. 2. The circuit of the i.f. and a.f. amplifier sections of the receiver

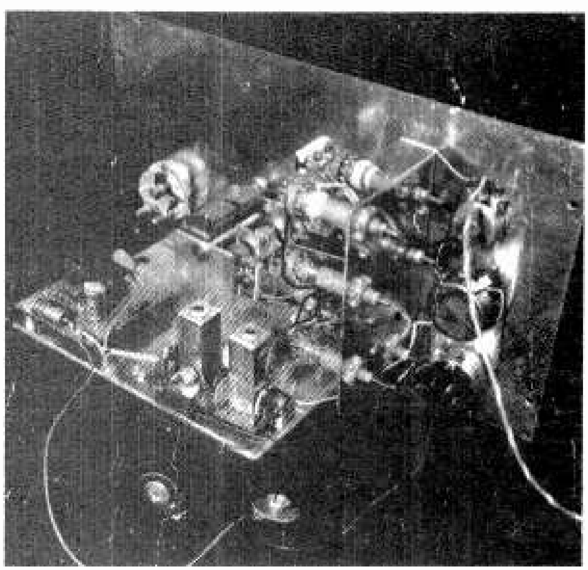
I.F. AND A.F. STAGES

The circuit of the i.f., detector and a.f. stages is given in Fig. 2. Two double-tuned i.f. transformers are employed. TR2 is the i.f. amplifier and TR3 the detector, the latter having regenerative feedback via TC5, with panel control of regeneration by means of VR2.

It has to be emphasised that the regeneration control VR2 does not function in the same way as a volume or gain control, and that it would be useless to advance VR2 to a maximum position. For a.m. reception VR2 is *not* advanced beyond the point at which oscillation takes place, instead it is taken up to the point just below that at which oscillation occurs. For s.s.b. and c.w. reception VR2 is advanced just beyond the oscillation point, VR1 being adjusted such that the wanted signal does not swamp the detector.

As users of regenerative t.r.f. receivers will know, regeneration can increase sensitivity enormously. But it is quite critical in adjustment and VR2 must be adjusted carefully, bearing this factor in mind.

In the a.f. section, VR3 is the usual volume control. The a.f. amplifier, TR4, is followed by the MFC4000B integrated circuit, which has low current drain, requires few additional components and gives adequate speaker output. Any speaker load from 16Ω to 75Ω is satisfactory, with the greatest power output being given with 16Ω. Output loads of less than 16Ω must not be used. Alternatively, for personal short



Illustrating how the coilpack assembly fits into the general receiver layout wave listening without annoyance to others, a comfortable pair of headphones will be found ideal.

The MFC4000B has the pin layout shown in the inset, with pins 2 and 3 longer than pins 1 and 4. The MFC4000 is also available in an encapsulation having four pins of equal length, and for convenience this is also shown. The wiring diagram given later shows the MFC4000B encapsulation.

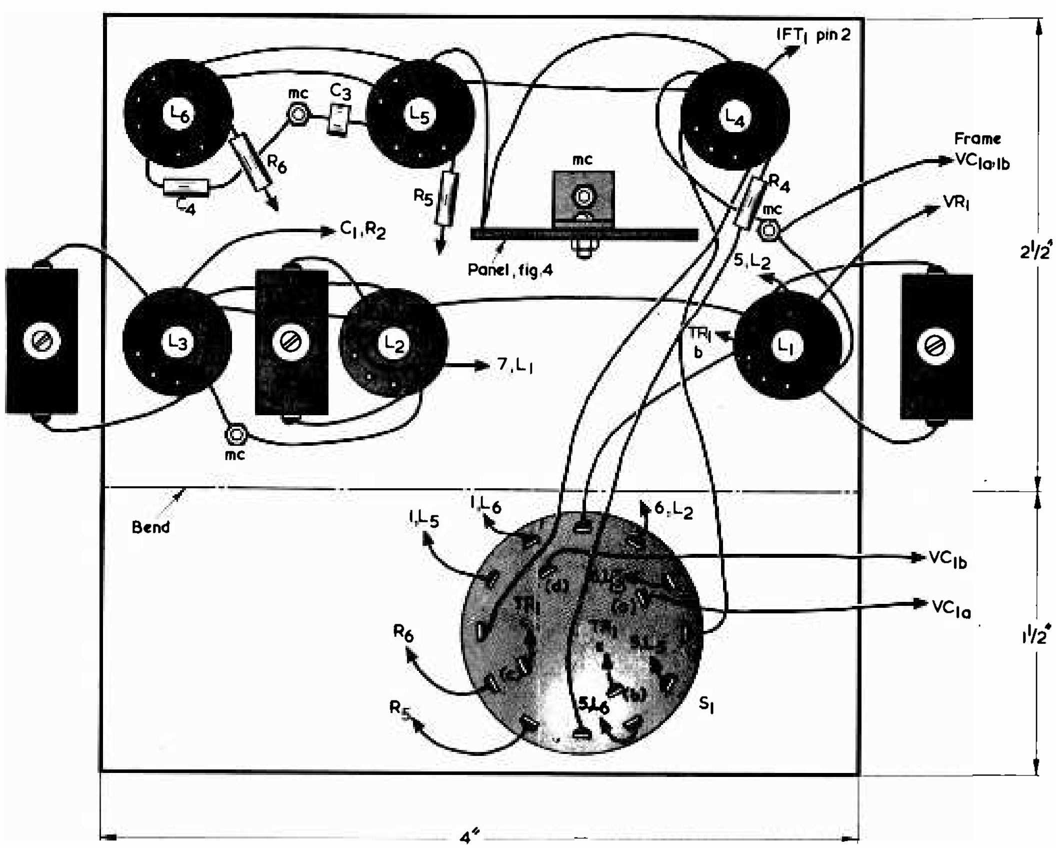
The regeneration feedback trimmer, TC5, is a Jackson "Tetfer" component having a maximum capacitance of 10pF and a minimum capacitance of less than 2pF. It is available from Doram Electronics. R8 may need to be increased slightly in value after the i.f. amplifier has been assembled. Its function is to maintain stability in the i.f. amplifier by introducing a small impedance between TR2 collector and the primary of the second i.f. transformer.

COILPACK ASSEMBLY

The mixer coilpack is compact, but its wiring is quite easily carried out in the order to be described. A piece of aluminium sheet measuring 4 by 4in. is bent to provide a 1½in. flange for the switch, as in Fig. 3. To be fitted on the L-shaped piece of aluminium are the six coils, the switch, three 6BA nuts and bolts at the "MC" positions to provide chassis connections, and the item of Fig. 4, which is also mounted by means of a 6BA nut and bolt. Drill all the holes required for these parts. When they are fitted, the coils are held in position by means of their plastic nuts, which should not be tightened excessively. Precise positioning of the components is not important provided they take up the general layout shown in Fig. 3.

Fit the nuts and bolts at the "MC" positions. Each has two solder tags under the nut, which are not shown in the diagram. Fit the switch. In the switch wiring which follows, ensure that the correct outer tags are connected into circuit with the aid of a continuity tester or an ohmmeter; with some switches the relative positions of the inner and outer tags may be different from those shown in Fig. 3. If in doubt about a switch connection, refer back to the circuit of Fig. 1.

Mount coils L1, L2 and L3, then complete the wiring to S1(a) and S1(d). The leads which travel to L4, L5 and L6 can be left a few inches long and shortened as necessary later when the remote ends are connected. Two flying leads for later connection to VC1(a) and VC1(b) fixed vanes are also fitted, as is a lead to the capacitor metal frame. Complete all the wiring to L1, L2 and L3, with the exception of the three trimmers. Note that there is another flying lead, this being from pin 8 of L1 for later connection to VR1. The leads from pin 5 of L1 and pin 7 of L3 are not fitted yet. Great care has to be taken when



mc - chassis connection

Fig. 3. Layout of components and wiring in the mixer coilpack

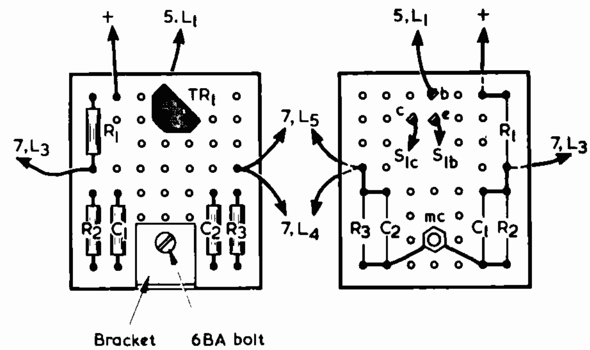
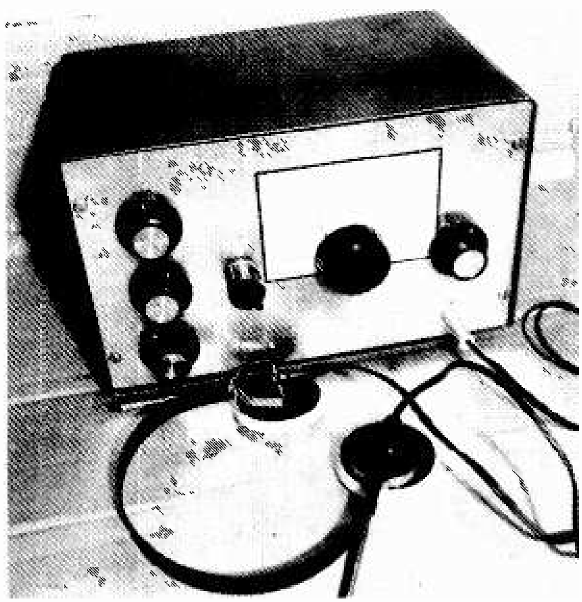


Fig. 4. The component panel which forms part of the coilpack module

making connections to the coil pins. The soldering iron must be applied and removed very quickly as the plastic coil former material melts readily with heat.

The mixer board of Fig. 4 is next prepared. The components are mounted on a piece of plain perforated board of 0.15in. matrix having 8 by 7 holes, and wired up as shown. Fit wires about ½in. long from the emitter and collector of TR1, and a wire about 3in. long from the junction of R1 and R2. The positive supply connection to R1 will be made later. The leads to pin 7 of L5 and pin 7 of L4 can be some 3in. long and will be cut back as necessary later.



The receiver will operate both with a speaker or, as here, with headphones

Fit the mixer board to the coilpack by means of the bracket and complete the outstanding wiring to L1 and L3. Then fit L4, L5 and L6, and complete all the wiring in Fig. 3, with a flying lead from pin 8 of L4 for later connection to IFT1.

Trimmers TC1, TC2 and TC3 are mounted directly over the coils by means of short stiff connections to pins 1 and 6 in each case.

At this stage the coil cores may be adjusted so that a little less than ½in. of the threaded brass rod protudes from the former. The coils are supplied with the brass rods screwed fully in for packing purposes, and this is not the correct setting for use in the present circuit.

The three resistors, R4, R5 and R6 have values which should be suitable with the majority of transistors employed in the TR1 position. If a transistor having very high gain is employed it may be necessary to increase the value of one or more of the resistors. Should uncontrollable whistles appear at the high frequency end of a band the value of the appropriate resistor is then slightly increased, i.e. the existing resistor is replaced by one having a slightly higher value.

NEXT MONTH

In next month's concluding article details will be given of the i.f. amplifier board, the a.f. board and the assembly and alignment of the complete receiver. The full Components List accompanies the present article. Some of the items listed, such as the metalwork, will be discussed in detail next month.

(To be concluded)

BACK NUMBERS

For the benefit of new readers we would draw attention to our back number service.

We retain past issues for a period of two years and we can, occasionally, supply copies more than two years old. The cost is the cover price stated on the issue, plus 11p postage.

Before undertaking any constructional project described in a back issue, it must be borne in mind that components readily available at the time of publication may no longer be so.

We regret that we are unable to supply photo copies of articles where an issue is not available. Libraries and members of local radio clubs can often be very helpful where an issue is not available for sale.

FORTY - SEVEN AND STILL GOING STRONG

By Ron Ham

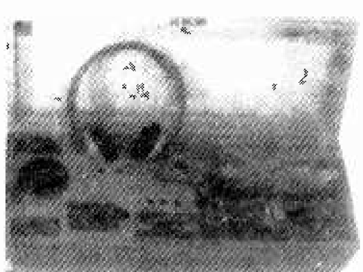
A vintage radio from the late 1920's which still offers an acceptable performance

The crystal set shown in the photographs was built in 1929 by Mr. Oswald Reynolds of Angmering, Sussex, and is now part of the author's private collection of early radios.

This receiver is typical of the loving care which went into the home-constructed sets of those pioneering days. Mr. Reynolds designed this set to receive 2LO and used a Varley permanent detector. His coils are beautifully wound with silk covered solid copper wire, air spaced and neatly laced with string. The coil on the right in the second photograph is larger and is mounted inside a wooden framework.

Inside the right hand compartment of the polished cabinet, which measures 20 by 7½ by 9in. deep, are two pairs of Gecophone headphones. Both pairs are still in working order, and they carry the approval label of the BBC and the Postmaster General.

A view of the receiver components. The coils are home-made and required a considerable amount of skill and care in winding



This veteran from the past boasts a highly polished cabinet and two pairs of BBC approved Gecophone headphones

Mr. Reynolds died in 1974, aged 93, and this set was found on a shelf in his workshop where it had stood for more than 40 years.

On arrival at the author's museum, a long wire aerial and an earth were connected to the set and, after a slight adjustment of the detector, the BBC World Service came in with amazing clarity.

Apart from exhibitions, the author uses this receiver to test cat's-whisker and crystal units and other permanent detectors to compare their relative sensitivities.

■

IN NEXT MONTH'S RADIO & ELECTRONICS CONSTRUCTOR

FREE WALL CHART

DESIGN DATA TABLES—2

SAVE TIRESOME CALCULATIONS WITH THESE TABLES

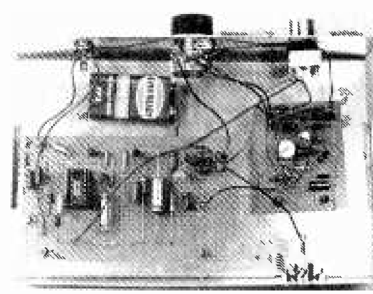
Design Data Tables 2 contain the following tables — MILLIMETRE-INCH CONVERSION, PHASE SHIFT OSCILLATOR C-R VALUES, 2πf VALUES, AUDIO OUTPUT POWERS, PARALLEL-R SERIES-C VALUES, E-R DISSIPATION, INCH-MILLIMETRE CONVERSION.

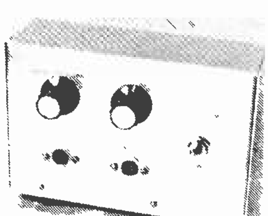
Full notes given on how to make good use of the tables to obtain the maximum benefit.

SPECIAL FEATURES

PHASE LOCKED LOOP F.M. TUNER—PART 1 (2 parts)

Incorporating a recent COS/MOS phase locked loop i.c., this f.m. tuner has no more than two tuned circuits and of these only one has to be adjusted during setting up. Intended primarily for mono reception, the tuner nevertheless gives an acceptable stereo performance in areas of good signal strength. The circuit is described, as also are the first steps in construction. The remainder of the construction will be covered in the following month's concluding article.





T.T.L. CALIBRATION GENERATOR

This unusual design employs an LC oscillator which is set to correct frequency by zero-beating with the long wave Radio 2 transmission on 200kHz. Another novel feature is the use of a t.t.l. decade counter to obtain division by 2 and by 10 of the oscillator frequency.

ORDER NOW! ON SALE 2nd NOVEMBER 35p

THE 'ACADEMY' STEREO F.M. TUNER

Part 2 by R. A. Penfold

This concluding article completes the constructional details for the power supply and main tuner boards. It then describes the operation of the stereo decoder section and ends by showing how this is made up.

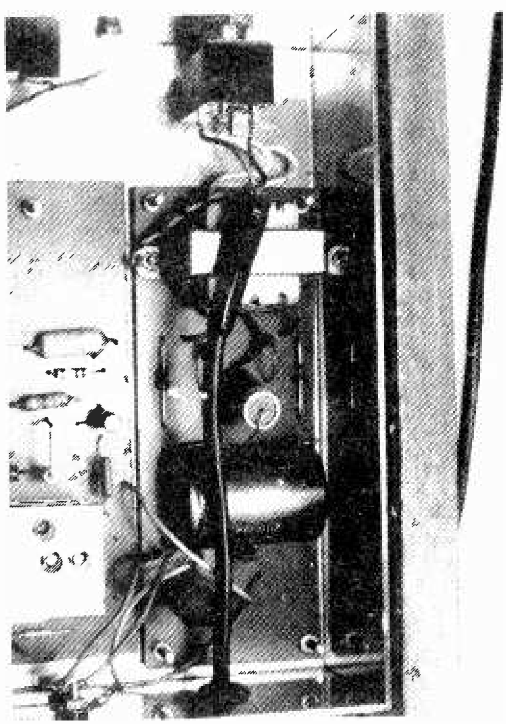
In last month's issue details were given of the circuits for the main tuner and power supply sections, together with a description of the construction of the case.

We now proceed to the power supply and tuner printed circuit boards.

POWER SUPPLY BOARD

All the power supply components, with the exception of S2 and TR3, are wired up on a printed circuit board measuring 5¼ by 2in. The etching pattern and component layout of the board are shown in Fig. 5, where the board is reproduced full size for tracing. The two transformer mounting holes are, however, best marked out with the aid of the transformer itself in case there are any small discrepancies here.

Before mounting the finished board to the chassis, flexible insulated leads are fitted for the external connections to TR3, and for carrying the positive outputs to the tuner board and (if it is to be fitted) the decoder board. Metal spacers, or additional nuts, are used to space the board underside from the chassis, and two of these provide the chassis connection to the board. The board is mounted in the position shown in Fig. 4 (published last month) with the mains transformer at the front, close to S2. The mains input wiring may then be completed. The mains earth wire connects to a solder tag secured under one of the transformer mounting nuts.



The power supply board appears at one end of the chassis, behind the on-off switch

TUNER BOARD

The tuner components are assembled on a board measuring 5 by 4½in. This is shown in Fig. 6, where the copper pattern is reproduced full size. The groups of holes for R1 to R5 have spacing applicable to the potentiometers employed in the prototype, and this spacing may need to be modified for other potentiometers. The potentiometers employed should be standard sized skeleton components and not miniature types.

Insulated leads leave the board for S1(a) (b), VR1, the aerial socket and the decoder (or output socket with the mono version). The connection to the aerial socket is given by a single short lead to the socket centre connector; a coaxial wire is not used here. All these leads may be a little longer than is necessary, being finally cut to length when their remote ends are connected. Connecting to the board is the lead carrying the positive supply from the power supply section. The board is secured to the chassis with the LP1186 module at the rear. As with the power supply, metal spacers or extra nuts are fitted to the mounting bolts to space the board underside away from the chassis. Also, the board takes its chassis connection from these.

Since the board is secured at two points only, the chassis surface underneath it may be covered by a piece of thin s.r.b.p. or by strips of plastic insulating tape. This will prevent short-circuits to the chassis if

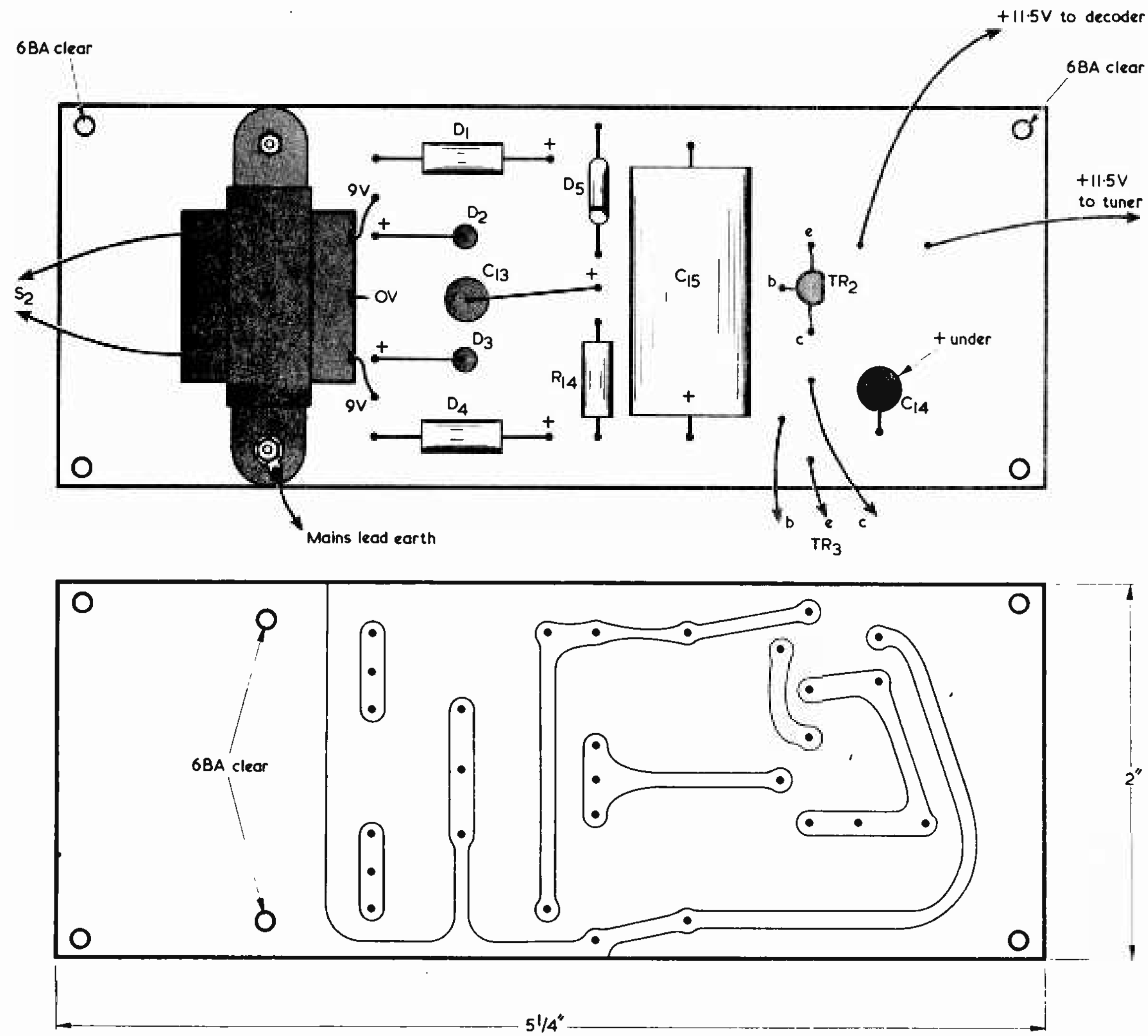


Fig. 5. The component and copper sides of the power supply board. This is reproduced full size and the copper pattern may be traced

the board flexes.

The wiring to S1(a) (b) is fairly complex, and Fig. 7, in conjunction with the circuit diagram of Fig. 2, should help to clarify this wiring if a standard 2-pole 6-way switch is used (but not if the switch is a type having an adjustable end stop). In any event it is desirable to confirm the centre and outside tags at each switch setting with the aid of a continuity tester or ohmmeter.

Note that the de-emphasis capacitor, C10, is not fitted to the tuner board if the stereo version is being made up.

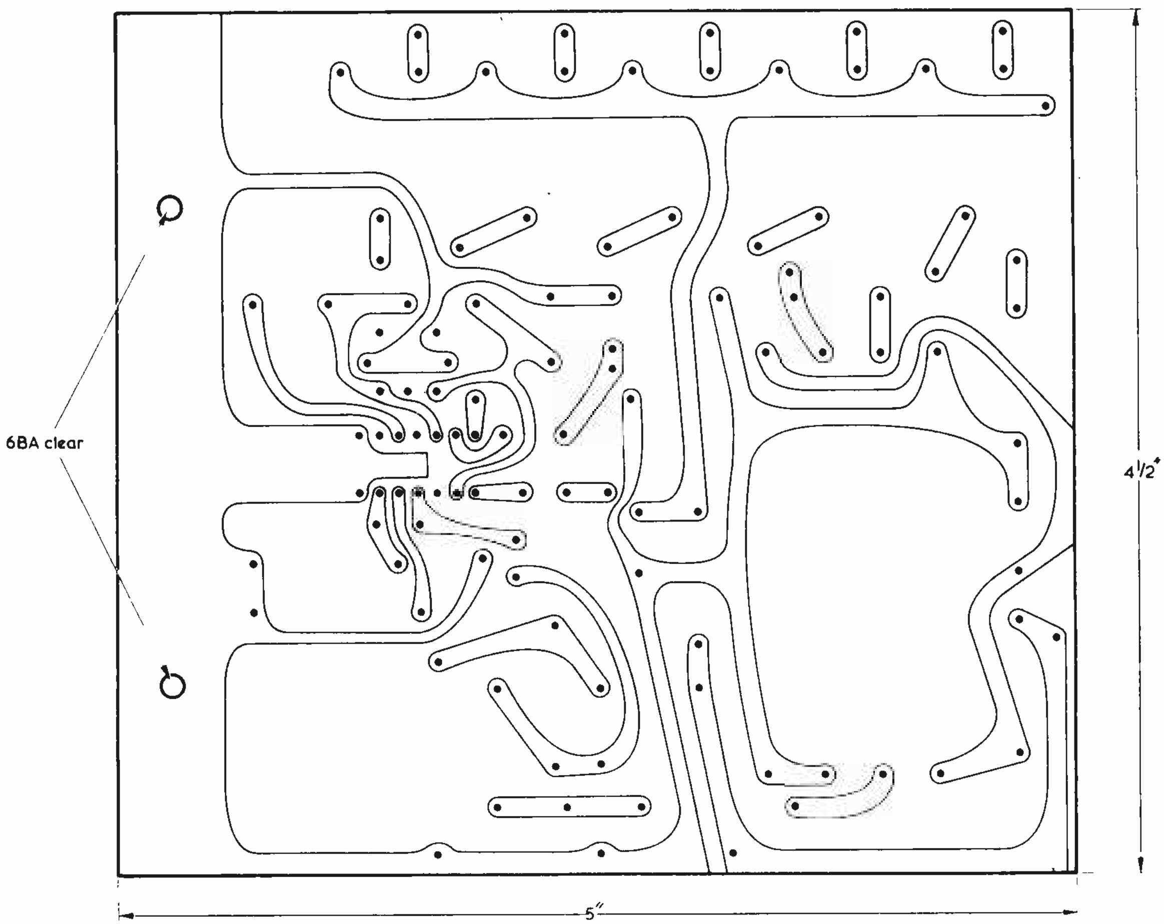
Before concluding on constructional details, a check should be made to ensure that the rear flange of the case lid does not come into contact with the collector connection of TR3 when the lid is fitted into place. Should there be any risk of this occurring, the lid rear flange should be filed down as necessary at the appropriate point.

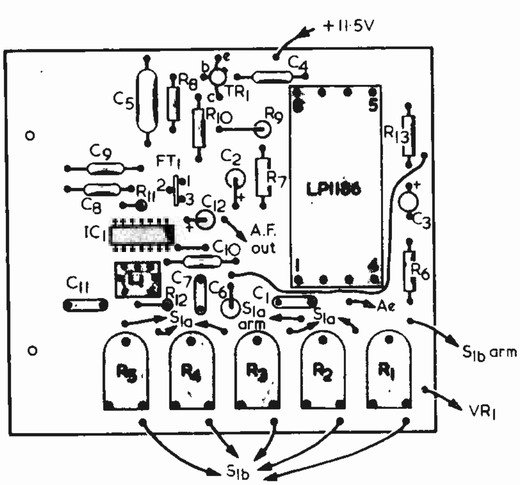
ADJUSTMENT

As so far assembled, the tuner may next be adjusted. Its output is connected to an amplifier and speaker. The amplifier can have an input impedance of 5kΩ or more. If the de-emphasis capacitor, C10, is not fitted a slight excess of treble may be noted. There is also a very slight risk of instability in a wide band a.f. amplifier with C10 absent, whereupon a small capacitor of around 200 to 400pF may be temporarily connected across the tuner output during the adjustment.

There is only one adjustment needed to align the tuner, and this is to the core of L1. L1 should be close to its final adjustment as supplied, and so its core must not be tampered with beforehand.

Set S1 to the manual tuning position, and then switch the unit on. With the tuner connected to the amplifier and an aerial a fairly loud background noise is likely to be evident. It should be possible to tune in





COMPONENTS

Resistors
(All fixed values ¼ watt 5%)
- R15 50kΩ pre-set potentiometer, horizontal 0.1 watt (see text)
- R16 1.2k Ω
- R17 1k Ω
- R18 8.2k Ω
- R19 8.2k Ω
- R20 1k Ω

Capacitors
- C16 100μF electrolytic, 16 V. Wkg.
- C17 5μF electrolytic, 16 V. Wkg.
- C18 470pF polystyrene
- C19 0.47μF type C280 (Mullard)
- C20 0.22μF type C280 (Mullard)
- C21 0.22μF type C280 (Mullard)
- C22 0.047μF type C280 (Mullard)
- C23 5,600pF polystyrene
- C24 5,600pF polystyrene
- C25 10μF electrolytic, 16 V. Wkg.
- C26 10μF electrolytic, 16 V. Wkg.

Semiconductors
- IC2 MC1310P
- D6 l.e.d. with panel mounting bush (see text)

Fig. 6. Details of the main tuner board. The copper pattern is again reproduced full size

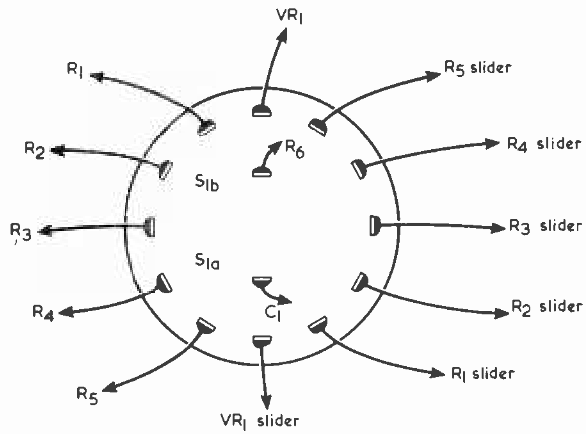


Fig. 7. This diagram will prove helpful in making the connections to S1(a) (b). The relative positions of inner and outer tags should, nevertheless, be confirmed with the aid of a continuity tester or ohmmeter

a station or two by adjusting VR1, although reception may not be very good at this stage. Tune to any station as accurately as possible, and then adjust the core of L1 for maximum volume. Tune accurately to another station and once again adjust the core of L1 for maximum volume, this being necessary as a check that the tuner was originally tuned accurately.

Each of the five pre-set potentiometers can then be tuned to a different station. All five may not be needed in some areas of the country, whereas in others as many as seven stations may be available. In the case of the latter the five pre-set potentiometers are set to the five stations most often required, and the other two can then be received using the manual variable tuning. In the case of the former the pre-set potentiometers can be tuned to the stations available, arranging matters such that a minimum of switching is required when switching from one station to another. The extra tuning positions are then still available should they be required at some future date.

No adjustment should be made to the LP1186 module, which is supplied pre-aligned.

STEREO DECODER

The stereo decoder is based on a modern integrated circuit incorporating a phase locked loop (p.l.l.). This type of decoder has the advantage of requiring few adjustments during alignment, and the i.c. employed in the present design can be used in a circuit where only a single component needs to be adjusted to bring the unit into alignment with the stereo pilot tone. The i.c. is the Motorola MC1310P. There are a number of equivalents to this device, although it is generally advertised under the above type number whatever manufacturer it actually originates from.

The MC1310P has quite an impressive performance, with distortion being typically only some 0.3% and with a typical channel separation of 40dB at 1kHz. Few discrete components are required to complete the circuit, which makes the unit economical despite the relatively high cost of the device.

STEREO SIGNAL

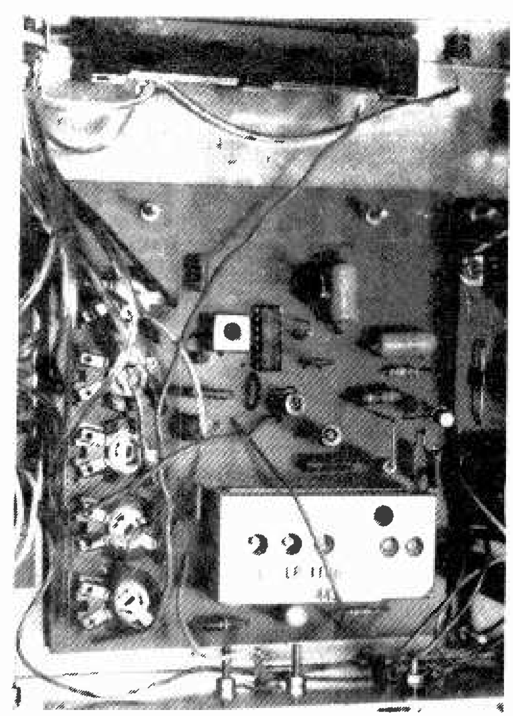
A stereo encoded f.m. signal consists of three basic constituents. Firstly there is the L+R signal which is modulated onto the carrier in the normal way, and it is this part of the signal to which an ordinary mono receiver responds. The second part of the signal consists of the L-R information which is modulated onto a 38kHz sub-carrier. This sub-carrier is suppressed at the transmitter. A pilot tone at half the frequency, 19kHz, is derived from the same source as the 38kHz sub-carrier, and this pilot tone modulates the main carrier at a level of approximately 9%.

The most common type of stereo decoder is the switching type, and here the 19kHz pilot tone is amplified and frequency multiplied to replace the original 38kHz sub-carrier. The 38kHz modulation is then fed to a matrix circuit together with the composite input signal. Here the original L and R signals are recovered and finally fed to the de-emphasis network and on to the stereo a.f. amplifier.

PHASE LOCKED LOOP

A phase locked loop is a circuit which contains a voltage controlled oscillator. This can be a relaxation oscillator which operates by having a capacitor continually charged and discharged through a resistive circuit, whereupon no tuned circuits are required. The purpose of the p.l.l. is to maintain the frequency of the voltage controlled oscillator at precisely the same frequency as an input signal. Moreover, it also keeps the v.c.o. signal precisely in phase with the input signal.

The basic arrangement of a phase locked loop is



The main tuner board is in the centre, and occupies most of the chassis area

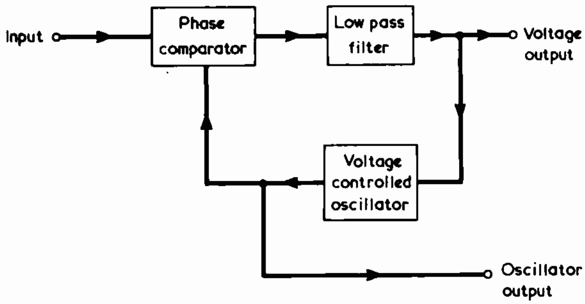


Fig. 8. Block diagram illustrating the essentials of a phase locked loop

shown in Fig. 8. As can be seen from this, the input signal and the output from the v.c.o. are fed to a phase comparator. The output voltage of the comparator is proportional to the difference in phase between the two signals, and in practice only a very small difference in phase is required to send the output of the comparator fully positive or negative. A low pass filter removes any oscillator signal present at the output of the phase comparator, and the output from the filter is then used to control the v.c.o.

The v.c.o. is therefore precisely locked to the same phase and frequency as the input signal since, if it should deviate slightly from this condition, the control voltage will change and bring it back to the correct relationship.

An important feature of the p.1.1., especially in the application being discussed here, is its ability to remain locked onto the input signal even if the signal is nearly swamped in noise or other signals.

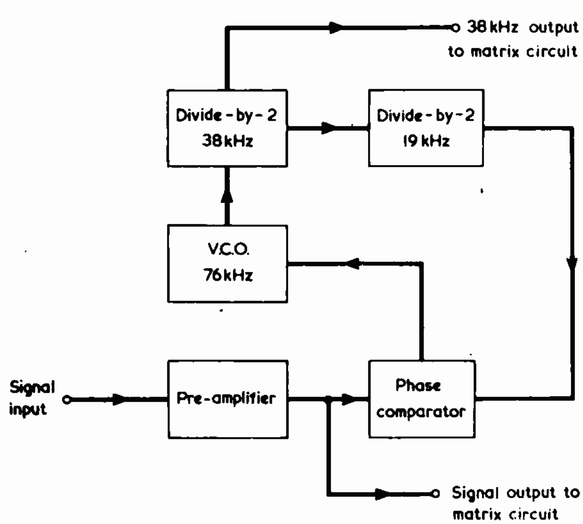
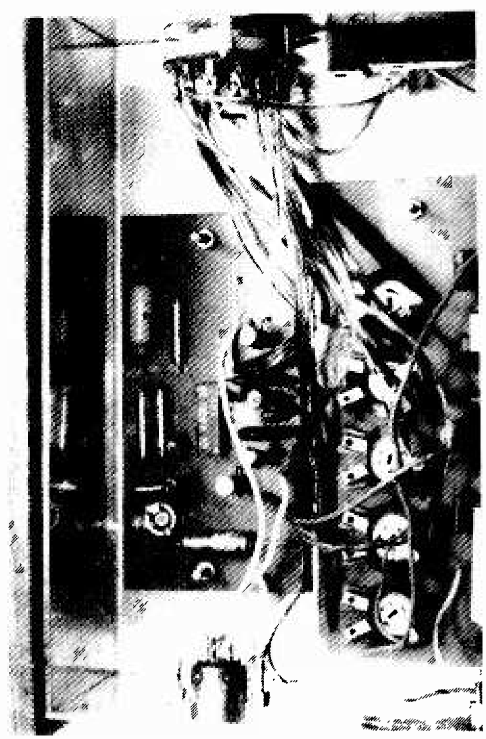


Fig. 9. Simplified diagram illustrating how the phase locked loop in the MC1310P produces a frequency which is twice that of the 19kHz pilot tone

P.L.L. DECODER

The phase locked loop readily lends itself to use in a stereo decoder as, instead of using tuned amplifiers to filter and frequency double the 19kHz pilot tone, a p.l.l. can be employed instead. The only complication is in the doubling of the 19kHz pilot tone to 38kHz.

This facility is provided by using the arrangement shown in Fig. 9. Here the v.c.o. operates at 76kHz, and is fed to the phase comparator via two digital divide-by-two circuits. The 76kHz v.c.o. thus remains phase locked at the 19kHz pilot tone, and the 38kHz sub-carrier can be taken from the output of the first of the divide-by-two circuits. In this ingenious manner the 19kHz pilot tone is both filtered and frequency doubled without using a single tuned circuit.



The stereo decoder board is behind the station selector switch

DECODER SECTION

Fig. 10 shows the complete circuit of the stereo decoder section of the tuner. The composite signal input is coupled to the input of a pre-amplifier inside the MC1310P via C17. R15, R16 and C18 are the frequency selective components of the v.c.o., and R15 is adjusted to cause the v.c.o. to lock on to the 19kHz pilot tone.

D6 is the stereo indicator beacon and is fed from an internal lamp driver circuit in the i.c. by way of R17, which acts as a current limiting resistor. The MC1310P has a maximum beacon lamp current drive capability of 75mA, but with the l.e.d. indicator used here the beacon current is a mere 10mA.

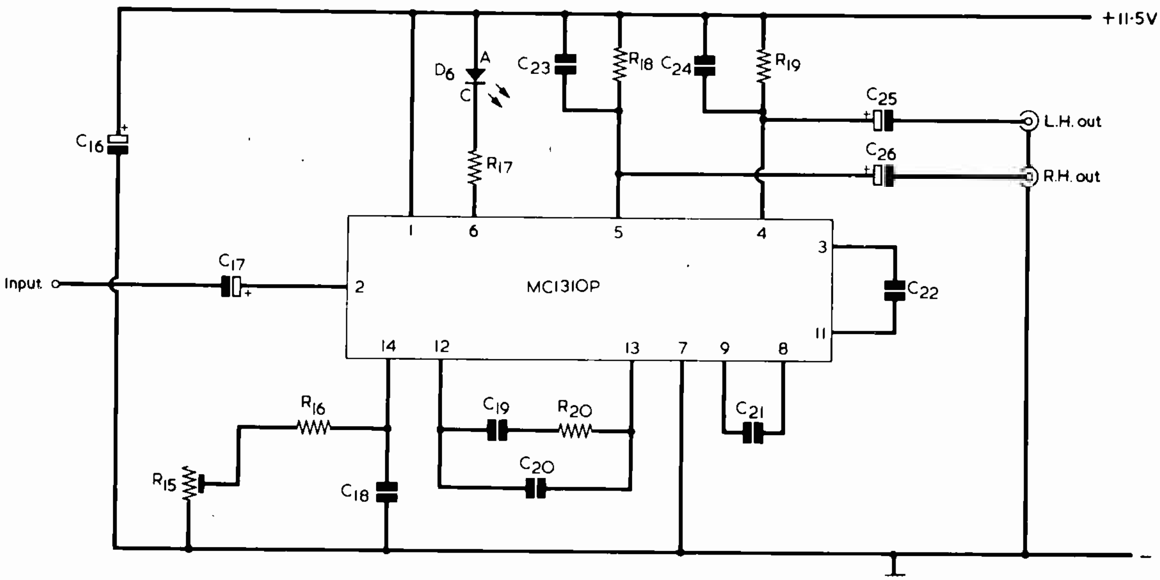


Fig. 10. The circuit of the decoder section. Using an MC1310P, this requires no tuned circuits

R18 and R19 are collector load resistors for the output transistors in the device, and the parallel connected capacitors, C23 and C24, provide de-emphasis. R20, C19 and C20 are the p.l.l. filter components. C21 is the filter capacitor for the integral mono/stereo switch detector. C22 is a coupling capacitor between two of the circuits in the i.c. C16 provides supply decoupling, and C25 and C26 give d.c. blocking at the outputs.

It will be noted that C17 is in series with C12 at the output of the tuner section. This arrangement functions quite satisfactorily in practice.

CONSTRUCTION

The decoder components are assembled on a printed board measuring 4 by 2in., and this is shown full size in Fig. 11. Two wires from the board pass to D6. The left and right hand outputs, employing unscreened wires, pass to the 3-way DIN socket on the rear panel. A chassis connection to the DIN socket is also provided from the board. The input connection from the tuner section is temporary at this stage since a potentiometer is inserted in the input lead for alignment purposes. Also connected to the decoder board is the positive supply lead from the power supply section. Note that R15 is a miniature skeleton potentiometer, having 0.2in. spacing between track pins and 0.4in. spacing between the track and slider pins.

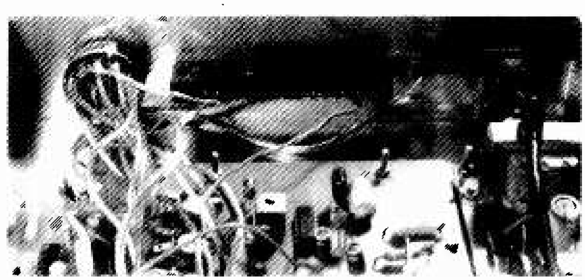
The board is mounted to the chassis in the same way as the other two boards, and it obtains a chassis connection via one of the mounting spacers or nuts. C16 is towards the rear of the chassis.

ADJUSTMENT

The decoder section can be adjusted without advanced test equipment, and what is probably the easiest way of doing this will now be described.

Temporarily break the lead connecting the tuner board output to the decoder input. Connect a 250k potentiometer, or pre-set potentiometer, in series with the tuner output and decoder input. Set the potentiometer so that it inserts minimum resistance into circuit, switch on the unit and tune in a stereo broadcast. Adjust R15 until the stereo beacon lights. Increase the resistance inserted by the 250kΩ potentiometer until the stereo beacon extinguishes, then readjust R15 till the beacon lights once more.

Keep repeating this procedure until a setting is given in the 250kΩ potentiometer at which it is im-



Looking into the chassis from the rear

possible to light the stereo beacon. Then slightly reduce the resistance inserted by the 250kΩ potentiometer, and adjust R15 for the beacon to light up again. R15 should then have the correct setting. The 250kΩ potentiometer can be removed and the output of the tuner section connected directly to the decoder board input.

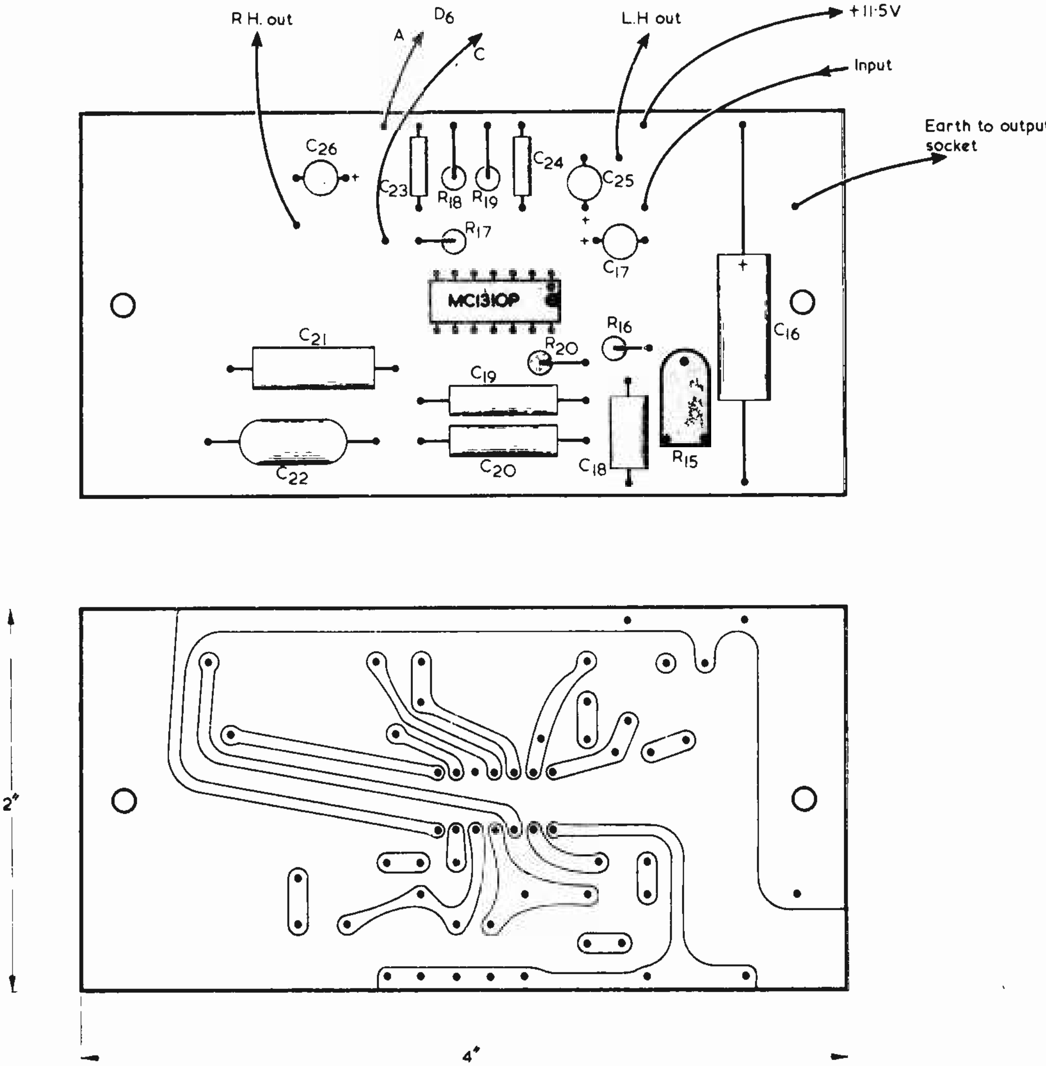
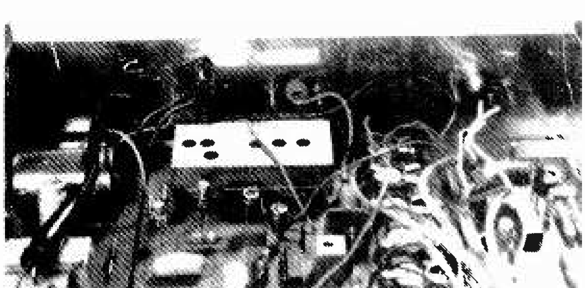


Fig. 11. The component and copper sides of the stereo decoder board, once again reproduced full size

AERIALS

It should be noted that the noise level obtained from the stereo version of the tuner will inevitably be significantly higher than that obtained from the mono version for any given level of input signal. The mono version requires only a relatively small aerial signal to give a really low noise level.



The rear of the chassis, as seen from the front

Also the difference in the aerial signal levels required to reduce the noise level from, say, –20dB to –40dB is quite small with the mono version, but with the stereo version a very large increase in aerial signal would be required to have this effect on the noise level. This is a feature common to all stereo tuners, and is due to the increased bandwidth used for the reception of stereo.

The practical result of this is that in order to obtain a really low noise level from stereo transmissions, in all but the strongest reception areas, a proper roof or loft aerial is needed. The prototype tuner is used at a distance of about 25 miles from the BBC Wrotham transmitter, and gives excellent results on stereo when used in conjunction with a 4-element loft mounted aerial, at about 10 feet above ground level. ■

SHORT WAVE NEWS
FOR DX LISTENERS

By Frank A. Baldwin

Times = GMT *Frequencies* = kHz

Clandestine transmitters continue to claim the attention of many Dxers, the writer among them, there is something fascinating about listening to such stations — perhaps it is that we all secretly nurture some piratical ambitions within our normally law-abiding minds. For those of my readers who would like to swashbuckle the short wave main, unfurl your sails and set course for:

"Voice of the Revolutionary Party for Reunification", thought to be located somewhere in North Korea, which transmits programmes of a pro-communist nature to the South in various time-periods through the day. Probably the best chance of logging this one here in the U.K. would be between 2300 and 2330 when they are in English on **4552**. A further English programme is radiated from 0530 to 0600 on the same channel.

"Voice of the People of Malaya", in Malay "Suara Rakyat Malaya". This one is pro-Peking and anti-Malaysian Government, broadcasting in Standard Chinese, Malay and Cantonese on **7080** variable. Try from 2200 to 2245 when they are in Malay or from 2245 to 2315 when they use Standard Chinese.

"Voice of the Communist Party of Turkey" broadcasts in that language daily at 0810 on **6200** and **9585**.

Another Turkish language clandestine, thought to be located in East Germany and Romania, is on the air several times daily — listen from 1445 to 1515 on **9500**, from 1910 to 1925 on **9585**, from 2005 to 2020 on **6200** or from 2030 to 2100 on **5915**.

"Voice of Lebanon" operated by the Lebanese Phalangist Party is on **6580** in English at 1645.

You may not hear the tap, tap, tap of Blind Pugh's stick, the roisterous chorus "Yo ho ho and a bottle of rum" or even Gehenna's hoofbeats on the turf of Romney Marsh but you may hear voices of pirates — even if they are in Turkish!

CURRENT SCHEDULES

● POLAND

"Radio Warsaw" has an External Service in which English programmes are radiated to Europe from 0630 to 0700 on **7285, 9540** and **9675**; from 1200 to 1230 on **7285** and **9540**; from 1600 to 1630 on **6095, 7125, 7285** and on **9540**; from 1830 to 1900 on **6095, 7125, 7285** and on **9540**; from 2030 to 2100 on **7285** and **9540** and from 2230 to 2300 on **3955, 5995, 6135, 7285** and on **9540.**

● ALBANIA

"Radio Tirana" transmits English programmes to Europe as follows — from 0630 to 0700 on **7065** and **9500**; from 1630 to 1700 on **7065** and **9480**; from 1830 to 1900; from 2030 to 2100 and from 2200 to 2230 on **7065** and **9480.**

● BELGIUM

The International Service of the Belgian Radio and Television only radiates in English to North America and Africa. The former transmission may be heard from 0015 to 0045 on **9725** and the latter from 1730 to 1800 on **9745** and **11940.**

● YUGOSLAVIA

"Radio Belgrade" operates an External Service in English to Europe and other target areas as follows — from 1530 to 1600 to Europe, Middle East, Far East and South and South East Asia on **9620, 11735** and on **15240**; from 1830 to 1900 and from 2000 to 2030 to Europe, Middle East and Africa, from 2200 to 2215 to Europe and North America on **6100, 7240** and on **9620.**

● BULGARIA

"Radio Sofia" offers programmes in English directed to the U.K. and Eire from 1930 to 2000 on **6070** and **9700** and from 2130 to 2200 on **9700.**

● ROMANIA

"Radio Bucharest" presents an External Service in which are listed the following transmissions in English to Europe. From 1300 to 1330 on **9690, 11940** and on **15250**; from 1930 to 2030 on **7225** and **9510** and from 2100 to 2130 on **7195** and **9690.**

● HUNGARY

"Radio Budapest" in its External Service broadcasts programmes in English to Europe from 1200 to 1240 (not on Saturdays or Sundays) on **6025, 7155, 9585, 11910, 15160, 17715** and on **21525**; from 1515 to 1530 on Tuesdays and Fridays (DX Programme) on **6150, 7155, 7200, 7215, 9585, 11910, 15160** and on **17780**; from 2130 to 2200 on **5965, 7180, 7200, 9655, 11910, 15415** and on **17780**

● U.S.S.R.

"Radio Moscow" operates extensive External Services in which the following transmissions to the U.K. and Eire, in English, are featured. From 1130 to 1230 on **9450, 9720, 11705, 11745, 11830** and on **15305**; from 1900 to 1930 on **11725, 12055, 15130, 15230, 15450, 17730** and on **17885**; from 2000 to 2030 on **7205, 7250, 7390, 9550, 9610** and on **9720**; from 2100 to 2200 on **7250, 7390, 9550, 9610, 9720** and on **11805**; from 2200 to 2230 on **7250, 7390, 9610, 9720** and on **11805.**

● **PORTUGAL**

"Radiodifusao Portuguesa", Lisbon, offers an English programme directed to Europe from 2030 to 2100 on **6025** and **9740**. A relay of the domestic National Programme directed to the Portuguese Islands in the Atlantic (Azores, Cape Verde and Madeira) may be heard from 0700 to 2400 on **11925.**

● **SWITZERLAND**

The "Overseas Service of S.B.C.", Berne, radiates in English to Europe and to the other target areas as shown as follows — from 0700 to 0730 to Australasia; Far East, S. and S.E. Asia on **3985, 6165, 9535, 9590, 11775, 15305** and on **17840**; from 1100 to 1130 to Africa on **3985, 6165, 9535, 15140, 15430, 17830** and on **21520**; from 1530 to 1600 to Near and Middle East, Africa on **3985, 6165, 9535, 11870, 15430** and on **17830**; from 2100 to 2130 to Africa on **3985, 6165, 9535, 9590, 11720, 11870** and on **15305.**

● **KUWAIT**

Radio Kuwait schedules a Domestic Service in English which is also intended for listeners abroad. From 0500 to 0800 to East and Southeast Asia on **15345** and to Europe from 1700 to 2000 on **9555** and **11845**. A programme in Urdu is listed from 1500 to 1700 on **9555.**

● **GHANA**

"The External Service of Radio Ghana — The Voice of the Revolution", Accra, broadcasts in English to Europe from 2030 to 2200 on **9545** and **15285**. Accra may also be heard in English to East Africa from 1400 to 1430 on **21720**; to Central South and East Africa and Australasia from 1445 to 1530 on **15285, 21545** and on **21720**; to West Africa from 1600 to 1700 on **6130**; to East Africa from 1645 to 1730 on **15285**; to East Africa from 1815 to 1900 on **15285**; to North America and the Caribbean from 2000 to 2100 on **11850** and to West Africa from 2000 to 2300 on **6130.**

● **AUSTRIA**

"Radio Austria, Vienna, transmits programmes in English to Europe and the target areas as listed from 0830 to 0900 on **6155, 15280, 15410** and **17810** to the Middle East, South East Asia, Far East and Australasia; from 1230 to 1300 on **6155, 9770, 11970** and on **17765** to South East Asia and Australasia; from 1830 to 1900 on **6155, 9690, 15535** and on **17770** to West and South Africa.

● **ZAMBIA**

"Radio Zambia", Lusaka, has an External Service in which the English programmes are as follows — Newscast (relay of General Service) from 0700 to 0715 and from 1115 to 1130 on **7235, 11880** and on **17895**; Newscast from 1600 to 1615, Commentary until 1620, Newscast from 1800 to 1815, Commentary until 1830 (not Sundays) Press Review (Sundays only), World News Magazine from 1930 to 2000 (Fridays only), 2000 to 2010 Newscast (Sundays only), Newscast 2000 to 2015 (Weekdays only), all on **6165, 7235** and **9580.**

AROUND THE DIAL

In which are listed some of the more interesting transmissions that have recently been logged

● **CHINA**

Radio Peking on **4460** at 2049, programme of local music and songs in the Domestic Service 1st Programme which is scheduled from 2000 to 2220 on this channel.

Radio Peking on **7620** at 2052, YL with a talk in English about Chinese shipping in a programme directed to North and West Africa, scheduled from 2030 to 2100 on this frequency and in parallel on **7590.**

Radio Peking on **11100** at 2024, OM and YL alternate in Standard Chinese in a transmission directed to Taiwan, scheduled from 2000 to 0610 (Sundays to 0655) and from 0830 to 1900 on this channel.

Radio Peking on **8005** at 2116, local music and YL with songs in the Domestic Service 2nd Programme which is scheduled from 2100 to 2400 and from 0700 to 1600 on this channel.

Radio Peking on **7935** at 2040, OM in Standard Chinese in a programme of the Domestic 1st Programme scheduled from 2000 to 2300 and may also be heard in parallel on **6665** and **6750.**

Radio Peking on **4500** at 2030, OM in Russian to USSR, heavily jammed by a relay of the Moscow 2 programme! Scheduled on this channel and in parallel on **4110, 4220** and **4815** from 2000 to 2055.

● **MOZAMBIQUE**

Maputo on a measured **4924** at 1945, OM in Portuguese, piano solo; also heard on **3210** at 1925, YL with songs and guitar music.

● **SAO TOME**

Radio Nacional Sao Tome e Principe on a measured **4807** at 1955, OM in Portuguese, African-type music at 2008. The schedule is from 0530 to 2300 and the power is 1kW.

● **EQUATORIAL GUINEA**

Radio Equatorial, Bata, on a measured **4926** at 2012, African music, YL's in chorus. Identification in Spanish at 2017 preceded by a single chime. The schedule is from 0430 to 0630, 1000 to 1600, 1700 to 2140 and the power is 5kW.

● **SOMALIA**

Radio Hargeisa on **11645** at 1604, drama in Somali, Arabic-type music and songs at 1615. Schedule is from 1100 to 1330 and from 1500 to 1630 and the power is 5kW.

● **PORTUGAL**

Lisbon on **11925** at 1056, OM with announcements in Portuguese, guitar music and songs in the Domestic Service relay to Portuguese Atlantic Islands (Azores, Cape Verde and Madeira). The schedule is from 0700 to 2400 and the power is 10kW.

● **CLANDESTINE**

Bizim Radio (Our Radio) on a measured **9586** at 1105, OM with a harangue in Turkish, jammed by a continuous heterodyne. This pro-communist clandestine is scheduled from 1050 to 1115 on this channel — see opening paragraphs.

New Products

'GREASELESS' LUBRICANT FROM THE STATES

The new greaseless lubricant now available from Metprotek in the UK

A light greaseless protective lubricant and rust inhibitor developed in the United States for delicate mechanisms is now being introduced into the UK under the brand name LPS1. It is being marketed by Metprotek Ltd., LPS Centre, 15 Station Parade, Virginia Water, Surrey.

With an infinite number of uses in the leisure field, LPS1, which is a household name in the USA, is available in aerosol form and is supplied with a probe for application to a particular "spot". It is guaranteed to contain no silicones or chlorinated solvents as is usual with products of this kind and is harmless to rubber, plastic, paints, etc.

The dual action of the product makes it an ideal protector of fishing tackle, golf clubs, firearms, camping equipment, cycles, electronic and electrical appliances, photographic equipment, garden and workshop tools, as well as an excellent light lubricant.

Apart from preventing the equipment corroding, LPS1 also displaces water, drying out motor ignition systems, electric power tools, fishing reels and cameras, covering the delicate mechanism in a thin, clear, greaseless film.

LPS1 is sold in 2oz, 7oz and 16oz aerosols at a recommended price of 48p, 84p and £1.68 respectively.

PEN WHICH PRODUCES GOLD LETTERS ON MANY SURFACES

The Goldriter Pen by Kenro Photographic Products, High Street, Kempsford, Glos. enables the user to write in gold on a wide variety of surfaces, without any mess or fuss.

The pen has already been warmly received in photographic circles because of its ability to write on photographic paper and film. However, it is equally useful for inscriptions on wood, leather, paper and many plastic materials, so a wide field of applications is envisaged.

The Goldriter operates from a normal electrical supply, which is used to heat the pen's tip. A special gold-coloured foil is used to provide the image. All the user has to do is write his signature or other message on the foil, which is then peeled from the surface of the material to be inscribed, leaving the gold image behind.

The versatility of the pen is indicated by the fact that it is equally efficient for making inscriptions on bottles and other cylindrical surfaces.

The Kenro Goldriter Pen is available direct from Kenro Photographic Products and is priced at £7.50 (incl. VAT postage and packaging).

MOUNTING VARIABLE CAPACITORS

By R. J. Caborn

Applying simple trigonometry to the solution of a perennial problem in the construction of radio receivers.

As readers who have assembled many published receiver designs will be aware, variable air-spaced capacitors in the Jackson type 'O' and type 'OO' class are mounted by means of three short 4BA bolts passed into tapped holes in the capacitor front plate. Quite a fiddling performance is required in marking out the corresponding 4BA clearance holes in the front panel of the receiver, and the usual advice is to cut a small hole in a piece of paper, pass this over the capacitor spindle and mark the positions of the capacitor front plate holes on the paper with a pencil. The paper is then used as a template, with the pencilled hole positions being transferred to the receiver front panel.

PLATE DIMENSIONS

The author felt it would be of interest to see whether the group of holes on the receiver front panel could be marked out by more conventional means, and he decided to take a closer look at the situation.

The major dimensions of the front plate of a type 'O' or type 'OO' variable capacitor are given in Fig. 1. Here, it will be seen that the three tapped 4BA holes are spaced at equal distances around a circle of 1in. diameter, the circle being concentric with the capacitor spindle. The centre of the lowermost hole is immediately below the centre of the spindle, and there must obviously be a spacing of 0.5in. between these centres.

This enables us to proceed to Fig. 2(a) in which the 1in. diameter circle is drawn in full. The centre of the spindle is represented by point A and the centres of the three holes by points B, C and D. We can also draw in the triangle ABC, in which we know that AB and AC are both equal to 0.5in. Since B, C and D are equi-spaced around the circle the angle at A must be 120 degrees, which leaves 60 degrees to be shared by the angles at B and C. These two angles are obviously equal and so must each be 30 degrees.

We want to find the length of BC whereupon, dusting off the trig relationships, we see that this is equal to the sum of AB cos B and AC cos C. Both AB and AC are equal at 0.5in. and the angles at B and C are equal at 30 degrees, so BC, in inches, is equal to 1 times the cosine of 30 degrees. A quick look at the tables reveals that the cosine of 30 degrees is 0.8660, so we can say that the length of BC is 0.8660in. The length of a line joining B and D will similarly be 0.8660in.

We can, therefore, mark out the centres of the four holes on the front panel in the following manner. Fig. 2(b) illustrates the process. First mark out point A on the panel and, with this as centre, draw a circle of 0.5in. radius. Mark out point B immediately below A, and with this as centre and a radius of 0.8660in. (0.87in. in practice) draw two arcs cutting the circle at C and D. All the holes are then accurately marked out.

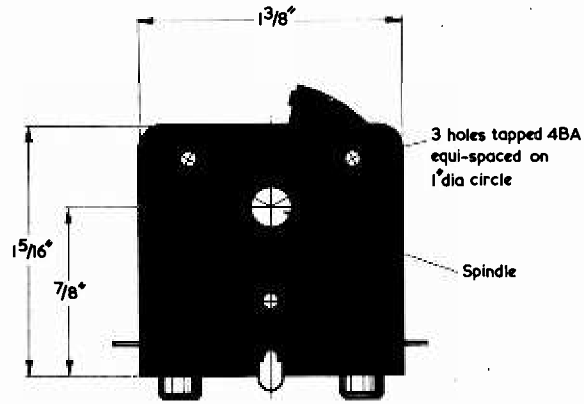


Fig. 1. Major dimensions of the front plate of a Jackson type 'O' or 'OO' variable capacitor

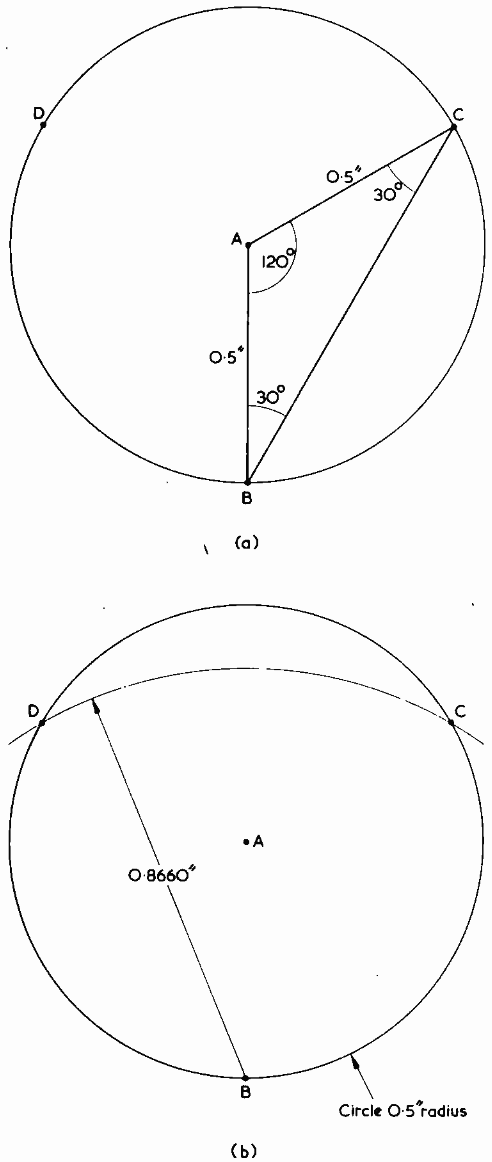


Fig. 2(a). The capacitor spindle and the three 4BA tapped holes are represented here by points A to D
(b). A marking out procedure resulting from the dimension found in (a)

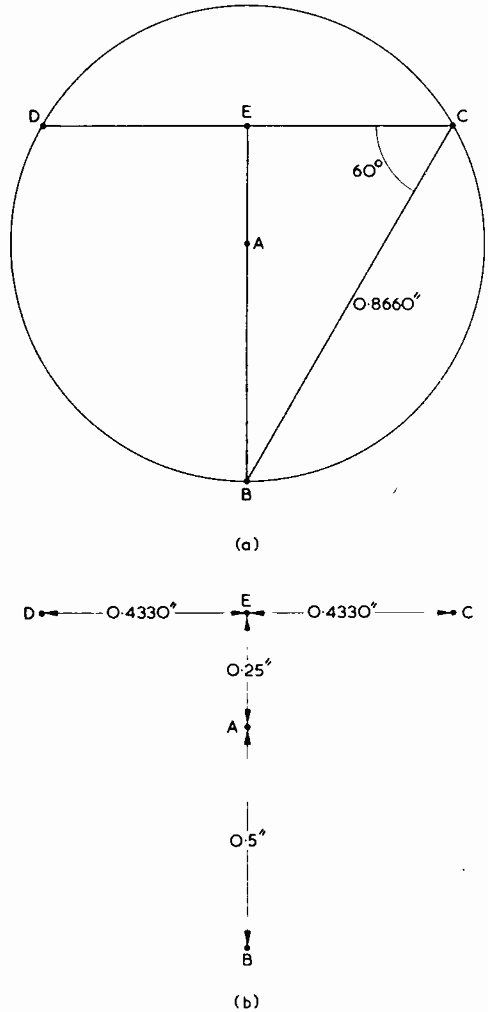


Fig. 3(a). A further construction based on the four points
(b). The construction enables the points to be marked out in the manner shown here

STRAIGHT LINE SOLUTION

Some constructors may prefer to work with a rule rather than a pair of compasses, so let's take our examination a little further and see if we can meet their requirements.

Fig. 3(a) shows the hole centres with line AC removed, a further line joining C and D added, and the line BA extended to meet CD at point E. The angle at E between BE and CE is obviously a right angle and so the length of BE is equal to BC (0.8660in.) multiplied by the sine of the angle at C. This angle has to be 60 degrees, and we find that the sine of 60 degrees is (surprise, surprise) 0.8660. If we multiply 0.8660in. by 0.8660 we find the answer to be (surprise again) 0.7500in.

In consequence, an alternative method of marking up the hole centres can be carried out as illustrated in Fig. 3(b). First mark out point A and, 0.5in. below it, point B. Mark out point E 0.25in. above A and, finally, points C and D 0.4330in. (0.43in. in practice) on either side of point E. Quite a simple matter, and much easier and more accurate than is given by the use of a paper template.

As a final note, those rather awkward 0.8660in. and 0.4330in. dimensions may be found easier to deal with if expressed in millimetres. 0.8660in. is almost exactly equal to 22mm. and 0.4330in. is almost exactly equal to 11mm. ■

In your work-shop

This month, Smithy the Serviceman introduces to his assistant, Dick, a simple l.e.d. column voltmeter in which the reference voltages are provided by the l.e.d.'s themselves. He then shows how this may be used to monitor the output voltage level of an audio amplifier.

"It's old Joe," said Dick disgruntedly. "A right old menace he's turning out to be these days."

"Joe?"

"You know, down at Joe's Caff."

Smithy stretched his legs out comfortably in front of him and gazed quizzically at his assistant. It was three-quarters of an hour before work officially finished for the day, but the pair had already cleared all the stock of faulty equipment which was in for repair.

"Do you still go there?" enquired Smithy. "I thought you'd given that place up ages ago."

"We're always giving it up," replied Dick aggrievedly. "But somehow we keep drifting back. He's started running it as a disco now on Friday evenings."

"Has he got a DJ?"

"He has."

"Who is it?"

Dick sighed.

"It's me, would you believe it?"

LEVEL INDICATOR

"Dear me," said Smithy, surprised. "You got yourself lumbered there, didn't you?"

"Well," retorted Dick. "I don't do it for nothing, you know. He pays me by the hour."

"How much?"

"One pie, chips and beans, or equivalent," replied Dick. "You know, Smithy, that's not bad for these days. If I put in three hours every Friday, that's got my suppers fixed up all over the week-end *and* on Monday. And it's quite a technical job really. Changing from one record to the other and setting up channel output levels and all that."

"How d'you know when you've got the right output levels?"

"It's fairly easy to judge," stated Dick airily. "If I see any people talking to each other I know I've got the volume too low. All the same, it would be nice to have some sort of output level indicator. Something I can see when the lights are low."

Smithy pondered on this.

"How does the idea of a column of light-emitting diodes grab you? As the output level goes up so do the number of l.e.d.'s in the column which are illuminated."

Dick's expression brightened.

"Stap me, Smithy," he responded excitedly, "that sounds good. Wouldn't it be complicated, though?"

"Not with the sort of circuit I have in mind," stated Smithy. "Mind you, the performance wouldn't be anything near that given by a proper VU meter, and the l.e.d.'s would merely respond to the audio output *voltage* of each amplifier. The circuit is rather in the nature of a novelty gimmick but, even so, it should give you a reasonable idea of the output levels you're getting."

"How would it work?"

"Come over here," said Smithy, pulling his note-pad towards him, "and I'll show you."

Eagerly, Dick rose and carried his stool over to the Serviceman's bench. The latter was already scribbling out a circuit on the top sheet of his pad. Dick waited expectantly until Smithy had finished. (Fig. 1(a).)

"Now here," said Smithy, putting his pen to one side, "is our column of l.e.d.'s. There are nine of them and they're all connected in series and fed from a constant current source. We

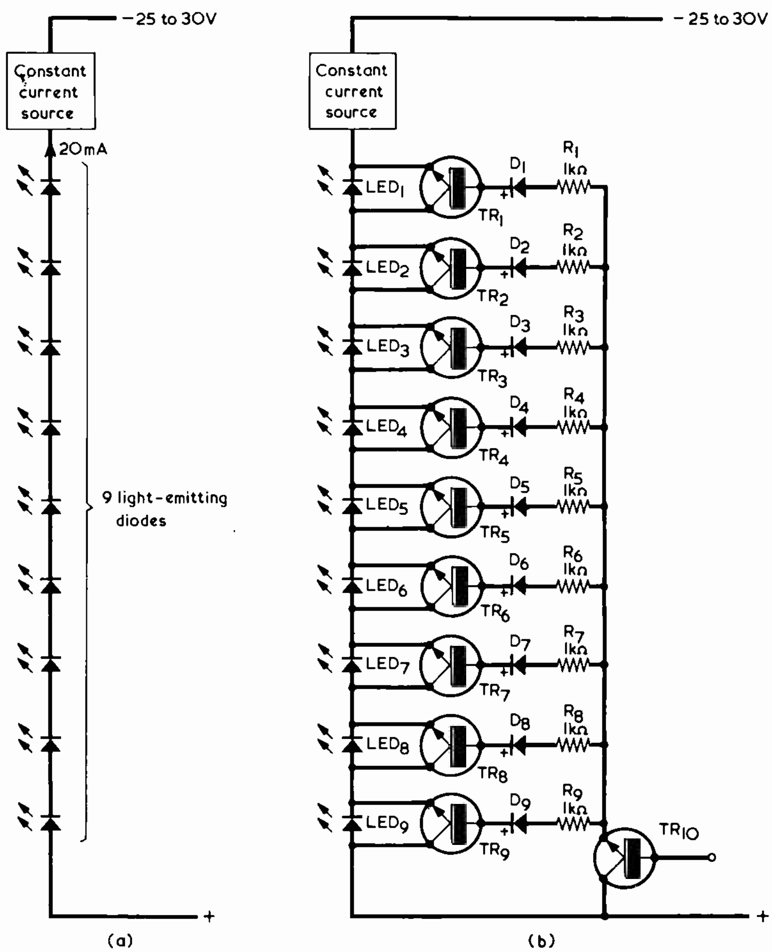


Fig. 1(a). A column of nine light-emitting diodes fed from a constant current source; (b). A silicon transistor is connected across each light-emitting diode. The diodes D1 to D9 are small silicon rectifiers

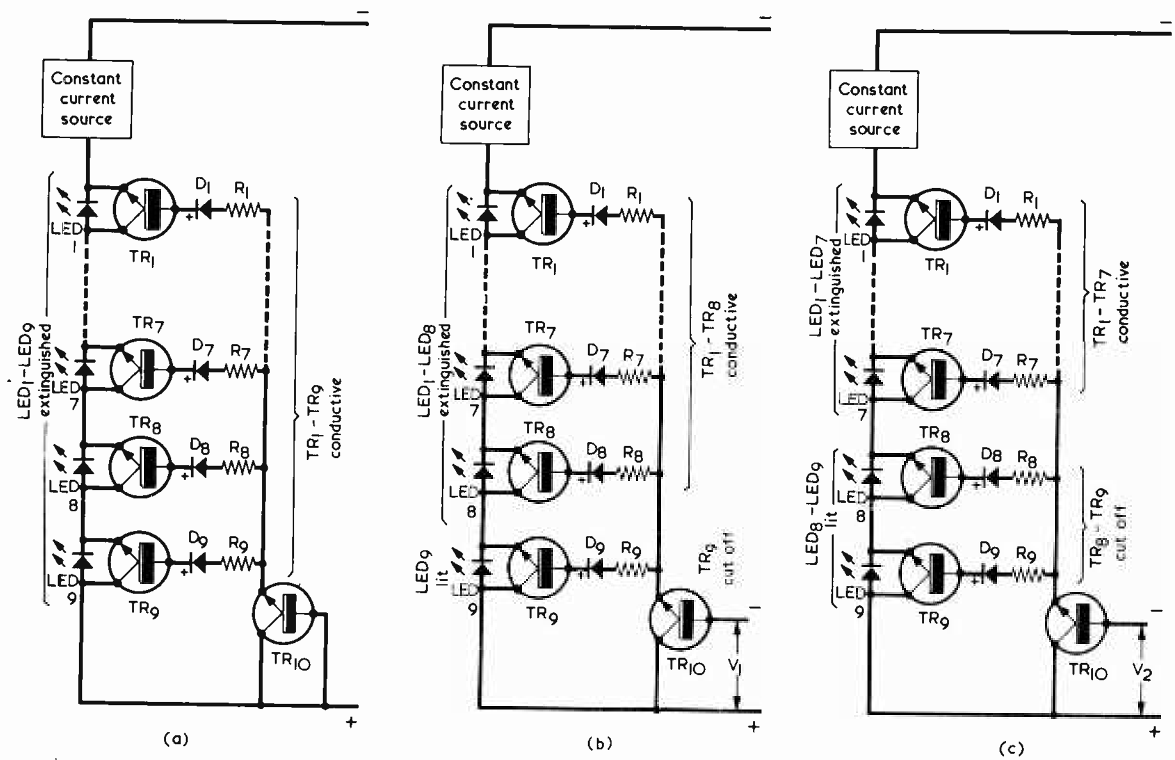


Fig. 2(a). If the base of TR10 is connected to the positive supply rail, all the transistors are turned on and all the l.e.d.'s are extinguished; (b). Taking TR10 base negative by a small amount causes TR9 to cut off and LED9 to light up; (c). With TR10 base at a higher negative voltage, TR8 also cuts off The bottom two l.e.d.'s are then lit

can say that the constant current is 20mA, which will cause the l.e.d.'s to light up nice and brightly. The l.e.d.'s will each drop something like 1.8 to 2.5 volts, so the total voltage across them can be as much as, let me see now, 22.5 volts. So a sensible supply voltage for the l.e.d.'s and the constant current source can be in the region of 25 to 30 volts."

"Hcw," asked Dick, "do you control the l.e.d.'s? Are they turned off successively?"

"They are," replied Smithy. "A silicon transistor is connected across each one, and each transistor base is coupled to a common line via a silicon diode and a low value resistor. This common line then connects to the emitter of another silicon transistor, whose collector is tied to the lower positive supply rail. Let me draw in these added points."

Smithy picked up his pen and commenced to add the components he had just mentioned to his circuit.

"You're making all the resistors 1k Ω," commented Dick, as he watched the serviceman.

"That's right," agreed Smithy. "After a little thought, that seemed to be a good value for them. I'd better give them R-numbers whilst I'm at it. And it wouldn't be a bad idea to give numbers to the l.e.d.'s and the transistors and diodes, too."

Smithy completed his circuit and once more placed his pen down on the bench. (Fig. 1(b).)

"I'm not quite certain," said Dick, frowning, "how this circuit of yours works."

"It works," replied Smithy, "by applying a control voltage to the base of TR10, this voltage varying between that on the positive supply rail and a negative voltage which allows all the l.e.d.'s to come on."

"I still don't get it," stated Dick flatly. "You'll have to go into it a bit more deeply than that."

"Fair enough," responded Smithy. "Now, let's say that the base of TR10 is connected to the positive rail. It acts as an emitter follower, and so its emitter will be about 0.6 volt negative of the positive rail. Okay?" (Fig. 2(a).)

"I think so."

"Right," said Smithy briskly. "That voltage is passed to the right hand ends of all the 1k Ω resistors, whereupon a base current flows into each transistor. Each transistor is therefore turned on, with the result that the voltage between its collector and emitter is too slow to allow the l.e.d. across which it's connected to light up. So, all the l.e.d.'s are extinguished."

"But," protested Dick, "aren't the base currents flowing to the transistors higher up going to be very large? There's only a 1kΩ resistor to limit base current to each transistor and the base voltages higher up are going to be pretty high."

"No, they're not," retorted Smithy. "You forget that the transistors are turned on and that there's only a fraction of a volt across each. With the base of TR10 connected to the positive rail, the voltage across the whole chain of l.e.d.'s will only be about 2.5 volts."

CONSTANT CURRENT

Dick pondered this.

"Won't that situation result in a heavy current being drawn from the constant current source?"

Smithy directed his eyes towards the ceiling.

"Dear, oh dear," he moaned. "You *can't* draw a heavy current from a constant current source, you great clotheared twit, because the only current the source can provide is the constant current itself! That constant current flows regardless of the voltage across the string of l.e.d.'s. In our circuit the constant current is 20mA, and this current flows through the collector and emitter of all the transistors. The current flowing into each base must be at least that required to maintain 20mA in the collector circuit. If we say that each transistor has a gain of 100 times, then each base current must be at least 0.2mA. Actually, it will only be 0.2mA with the bottom transistor, TR9. It will be successively larger with the transistors above TR9, but not at an excessively high level. This is because the voltages at the transistors higher up are still quite low."

"This arrangement of yours," remarked Dick, gazing at Smithy's circuit with a new respect, "seems to be concealing quite a few crafty ideas. What happens next?"

"We disconnect the base of TR10 from the positive rail," said Smithy, "and start to take it slowly negative. Since TR10 is an emitter follower, its emitter will go negative, too. After a short negative excursion, there will be insufficient base bias for TR9 and it will turn off." (Fig. 2(b).)

"Will it?" queried Dick. "Why, of course it will! That means that LED9 will light up, because the transistor across it isn't turned on any more."

"Hooray," commented Smithy drily. "I was beginning to despair that you'd get anywhere near understanding this circuit. Well now, the full 20mA constant current flows through LED9 and the full l.e.d. forward voltage is dropped across it, whereupon all the transistors and l.e.d.'s above it go negative by that forward voltage. This means that the base current flowing into TR8 and the transistors above it is still high enough to keep these turned on, with the l.e.d.'s across which they connect extinguished. So, all we've got so far is LED9 lit up. We now start to take the base of TR10 slowly negative once more, whereupon its emitter goes negative too. The emitter voltage will eventually rise to a level where there is insufficient base current for TR8, and this will also turn off." (Fig. 2(c).)

"Stap me," said Dick, excitedly. "I'm beginning to see it all now! LED8 will light up, the full l.e.d. forward voltage will appear across it and all the transistors and l.e.d.'s above it will go up again by that voltage."

"You've got it," stated Smithy. "And so the process continues. As TR10 base goes more and more negative, each transistor turns off in turn and allows the next l.e.d. in the column to light up. In the end, when TR10 base is sufficiently negative, the whole column of l.e.d.'s is illuminated."

"Why," exclaimed Dick, excitedly, "it's like an l.e.d. voltmeter! You apply a voltage between the base of TR10 and the positive rail, and you can measure that voltage by seeing how many l.e.d.'s light up."

"It *is* a voltmeter," agreed Smithy, "with, of course, a very low resolution."

"Are the voltage steps between each l.e.d. lighting up equal in value?"

"There are three factors affecting this aspect of performance," said Smithy. "First of all, the current drawn from the emitter of TR10 reduces as its base goes negative and more and more transistors become turned off. This means that the TR10 base-emitter voltage reduces gradually as the base goes negative. But TR10 is a silicon emitter follower and the actual change in the base-emitter voltage will, at worst, be only something like 0.2 volt or so. Compared with forward voltage drops of the order of 2 volts in each l.e.d., such a voltage change can be ignored. There may also be discrepancies between the forward voltage drops of the individual silicon diodes and the base-emitter voltages of the individual transistors at turn-off. Variance here should also not be much more than about 0.2 volt at most, and can also be fairly safely ignored. In general, of course, it would be advisable to ensure that all the transistors and all the diodes have the same type numbers."

Smithy paused.

"What," asked Dick, "is the third factor?"

"The l.e.d.'s themselves," stated Smithy. "You see, the circuit uses the l.e.d.'s not only as light indicators but also as reference voltage diodes. But forward voltage drop between different l.e.d.'s varies quite a bit so, if we want this l.e.d. voltmeter to be really linear, we should use l.e.d.'s of the same colour, the same style and the same manufacturer. If we do this there is a good probability that they will all have nearly equal forward voltage values, and the arrangement will then give quite a good linear performance."

SERIES DIODES

"This circuit certainly has some interesting points in it," commented Dick warmly. "What do those diodes in series with the bases of TR1 to TR9 do?"

"For the lower transistors," stated Smithy, "they're needed to isolate each base-emitter junction from high reverse voltages when the emitter of TR10 is at a high negative level. The reverse base-emitter voltage rating for a silicon transistor is quite low, at around 4 to 6 volts or so, and if it is exceeded the base-emitter junction is liable to act as a zener diode at the breakdown voltage. This can't be allowed to happen in the present circuit because it would mess up operation with the higher negative control voltages at TR10 base."

"If the diodes are only needed with the lower transistors," asked Dick, "why have you fitted them at the higher transistors?"

Smithy grinned.

"I've got no alternative," he chuckled. "If the upper transistors are to have the same voltage performance as the lower transistors, then they've got to have series diodes too, even if the diodes don't offer any protection against reverse base-emitter current. Which reminds me about something that's been niggling at the back of my mind ever since I drew out this circuit."

"What's that, Smithy?"

"I'm as sure as I can be," stated Smithy, "that the l.e.d.'s from LED8 up will function in practice in the manner I've just described. But I'm not too sure about LED9."

"Could it cause trouble?"

"It might do," said Smithy. "I said just now that, when TR10 base is at the same potential as the bottom positive rail, all the l.e.d.'s should be extinguished. But there are three forward biased silicon junctions between the positive rail and the upper end of LED9, these being given in

TR10, D9 and TR9. We might find, when you make up the circuit in practice, that LED9 comes on too soon."

"What do you mean," asked Dick slowly, " 'when I make up the circuit in practice'?"

"Just what I say," replied Smithy. "You can knock up this l.e.d. voltmeter circuit in lash-up form right now. After we've got any bugs out of it that it might have, you'll have a working circuit which will form the basis for the two level indicators you need for Joe's Caff."

"Gosh, Smithy, that sounds smashing," said Dick keenly. "Where will I get the nine l.e.d.'s, though?"

"That's no problem," said Smithy, opening a drawer in his bench. "I've got a whole pile of l.e.d.'s in here for some experimental work I've been playing around with recently. These happen to be Doram Type 4 red l.e.d.'s, with a nominal forward voltage of 1.9 volts. They have two leads of unequal length, and the shorter lead is the anode."

Smithy handed his assistant a small box with a quantity of l.e.d.'s in it.

"Fair enough," replied Dick, as he took the box. "Incidentally, which is the anode?"

"I've just told you," said Smithy irritably. "It's the shorter lead."

"No, I mean which is the anode in the l.e.d. symbol?"

"Oh, said Smithy, mollified. "I see what you're getting at. The anode goes to the positive side of the supply, as with a valve."

"What transistors shall I use?"

"BC107's will be as good as anything for TR1 to TR10. You'll need a 20mA constant current source and this can use a small power transistor such as the BD124. It will be underrun in the circuit and there's no need to mount it on a heatsink. All the diodes in the circuit can be IN4002's. And you can temporarily add a 10k Ω linear pot across the supply with its slider going to the base of TR10. We'll use that to check out the l.e.d. voltmeter. Here's the circuit for these additional parts."

Smithy scribbled out the extra circuit information on his pad, tore off the sheet and presented it to his assistant. (Fig. 3.)

Happily, Dick went to the spares cupboard, found the parts he required and then returned to his bench. Taking up a small flat piece of scrap aluminium he bolted a long tagstrip to this then wired up the l.e.d.'s so that they took up the form of a column with the l.e.d.'s in the same order as in the circuit. After this, he proceeded to solder the transistors across the l.e.d.'s. Smithy watched him contentedly.

"That DJ job," he remarked musingly, "must be a pretty easy number. All you've got to do is change the records over and say something into the mike every now and again."

"It's a lot harder than you seem to realise," replied Dick over his

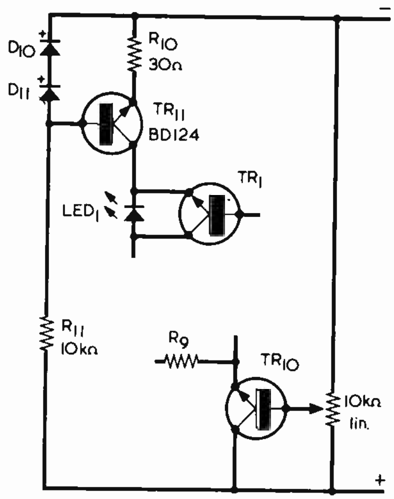


Fig. 3. The constant current source is given by TR11, D10, D11, R10 and R11 in the circuit shown here. The 10k Ω potentiometer is employed for initial tests of the l.e.d. column voltmeter

shoulder, as he applied his soldering iron to the tagstrip. "I nearly sprained my wrist the last time I did it."

"Nearly sprained your wrist?" repeated Smithy incredulously. "Changing records?"

"The record changing bit is easy," stated Dick bitterly. "It's the lights that take up all the time and trouble."

"The lights?"

"The lights," repeated Dick firmly. "You've got to have all the lights in the disco going on and off in a random sort of way, and that means really hard work."

"How come?"

"Well, Joe's a bit of an amateur electrician and he's wired each light to its own switch on a big board alongside the amplifier. There's over a dozen of them and as soon as I've got a record started I have to get weaving on those darned switches. My fingers are aching all over after an hour of that."

"Dear me," remarked Smithy, impressed by this information. "I didn't realise that you had to do all that."

CHECK-OUT

The pair fell silent. Dick continued to wire up the l.e.d. circuit, whilst Smithy pondered on the complexities involved in the calling of disc jockey.

"All finished!"

"Hey?"

Smithy roused himself from his reverie.

"I said it's all finished," repeated Dick. "I've got this trial circuit all wired up, ready for checking out."

"Oh, good," said Smithy, rising from his stool and walking over to Dick's bench. He inspected his assistant's handiwork. "You've made a nice job of that, Dick."

"I may not be all that good on the technical side," responded Dick with becoming modesty, "but when it comes to a bit of practical wiring I'm the real bee's knees!"

"Okay, okay," said Smithy hastily. "Now, we'll need your testmeter switched to a volts range that will take in readings up to 25 volts. Oh yes, and we'll need a supply, too. Three 9 volt batteries in series will give us 27 volts and that will do very nicely for the time being."

Dick reached to the back of his bench and produced three PP9 batteries. He wired these in series with crocodile clip leads.

"Where," he asked, "do I connect the meter?"

"Between the slider of the 10kΩ pot and the positive line," replied Smithy. "And turn the pot so that its slider is right at the positive end of the track. After that you can connect up the supply." (Fig. 4(a).)

Dick connected the testmeter and adjusted the potentiometer as directed by Smithy. He then connected the circuit to the three 9 volt batteries.

Nothing happened.

"Well," said Dick disappointed. "This doesn't seem to be a good start. None of the l.e.d.'s is alight and the meter's reading zero."

"Of course it's reading zero, you nit," snorted Smithy. "The pot slider is at the same end of its track as the positive terminal of the meter. Now, turn that pot spindle round. Slowly, mind."

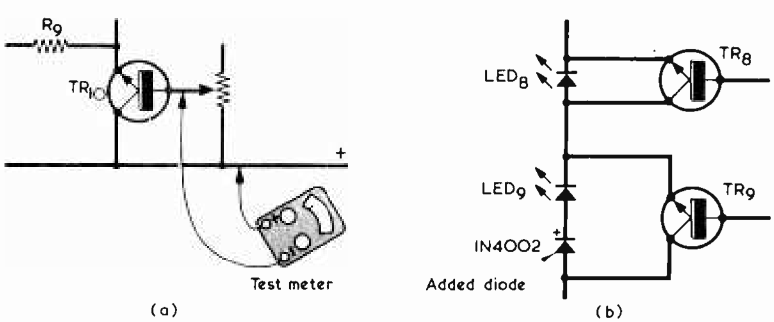


Fig. 4(a). Dick started tests by connecting a voltmeter between the slider of the 10kΩ potentiometer and the positive supply rail; (b). As a result of the checks it was found necessary to insert an additional silicon diode in series with LED9

Dick commenced to adjust the potentiometer. The bottom l.e.d. in the column immediately lit up. After further rotation of the spindle, the next l.e.d. became alight, to be followed by the third and then the fourth and so on until the complete column glowed cheerfully.

"Hey," said Dick, "this is fun."

He turned the potentiometer spindle back and forth experimentally, decreasing and increasing the number of lit l.e.d.'s in the column as he did so.

"Here," stated Smithy, "let me check it out."

He took control of the potentiometer and slowly turned its spindle, observing the testmeter as he did so.

"That's not bad at all," he remarked in a satisfied tone. "Apart from the bottom l.e.d., each l.e.d. gets illuminated at voltage steps of around 2 volts and a bit, and the whole column is lit up when the pot slider is selecting about 21 volts. The lighting up of the l.e.d.'s is reasonably linear and it's certainly good enough for our present requirements."

"What's wrong with the bottom l.e.d.?"

"It comes on too soon," replied Smithy. "I've only got to move the pot slider a tiny bit and it starts lighting up. Well, I expected this and I should imagine that all we need to do here is insert a silicon diode in series with the l.e.d. to reduce the voltage across it a little. So, could you modify the bottom end of the l.e.d. chain to take in the diode, Dick?"

Smithy took his pen and sketched out the circuit position that the added diode should take. (Fig. 4(b).)

"Righty-ho," said Dick cheerfully. "It won't take a jiffy to slip in that diode."

And indeed, Dick was able to modify the circuit in a very short time. Smithy once more took control of the potentiometer and adjusted it carefully. This time, all the l.e.d.'s including the bottom one became illuminated at reasonably equal intervals of potentiometer travel, with the whole column being alight at a meter reading slightly in excess of 21.5 volts. Satisfied, Smithy took up Dick's soldering iron and unsoldered the lead taking the negative supply to the potentiometer track. All the l.e.d.'s became extinguished and stayed extinguished at all settings of the potentiometer.

"What did you do that for, Smithy?"

"Just to confirm," explained Smithy, "that TR10 emitter is at a sufficiently low voltage to keep the l.e.d.'s turned off when its base is taken to the positive rail by a 10kΩ resistor. Well, Dick, we've now got an l.e.d. column voltmeter with a range of zero to approximately 21.5 volts. All we need do next is to add an amplifier with a gain approaching 20 times so that a voltage swing of a little more than 1 volt will turn the whole column on. We've carried out several design steps since I sketched out the first circuit, and so I'll redraw the whole thing with the amplifier added."

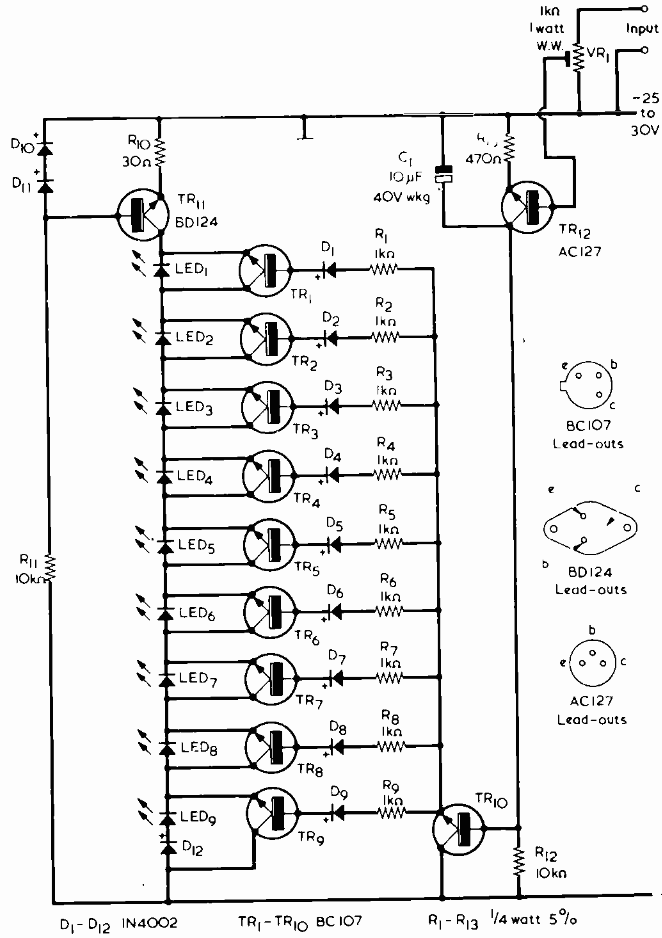


Fig. 5. Final circuit of the level indicator with input amplifier added. The l.e.d.'s may light momentarily immediately after switch-on as C1 charges

AMPLIFIER STAGE

Smithy went back to his bench, sat down and drew out the complete circuit on a fresh sheet of his note-pad. Dick walked over and watched. (Fig. 5).

"There we are," said Smithy proudly, when the circuit was complete. "Now, we can look upon this gadget in its entirety. We know how the l.e.d.'s and the transistors up to TR11 work, and so we don't need to refer to them any more. I've added another transistor, TR12, and this provides the voltage gain of about 20 times."

"How do you arrive at that gain figure, Smithy?"

"Because there's a resistor in TR12 emitter circuit," explained Smithy, "which has a value of 470Ω whilst the collector load is 10kΩ which is about 20 times greater. Actually, the practical gain will be a little lower than 20 times because this configuration doesn't work quite as well at the higher gain figures as it should at first sight theoretically do, and also because we haven't taken into account the effect of the input impedance at TR10 base. TR12 is a germanium transistor, whereupon it starts to become conductive at a low voltage between its base and emitter, and there isn't the high voltage delay you'd get with a silicon transistor. When there is zero voltage on TR12 base with respect to the negative rail it passes a negligibly low collector current. As its base goes positive, its collector goes negative by an amplified amount and the l.e.d.'s in the column light up accordingly. I've used a small germanium power transistor which I know we've got in stock for TR12, but a small signal type with a gain of 50 or more which will stand the voltages involved will do equally well."

"How do you couple TR12 to the amplifier whose output level is being monitored?"

"You connect the 1kΩ pre-set pot which I've marked as VR1 across the speaker terminals of the amplifier," replied Smithy. "I've added a chassis symbol at the negative rail of our gadget and this connects to the

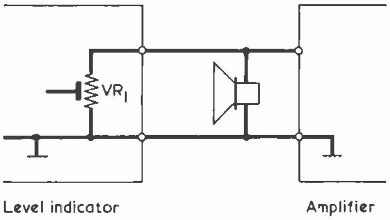


Fig. 6. The level indicator is connected to the amplifier output terminals such that the two chassis are common. With high power amplifiers, always advance VR1 slowly from the minimum setting. It should be remembered that the amplifier may be damaged if its output terminals are accidentally short-circuited

amplifier speaker terminal which is at amplifier chassis potential." (Fig. 6.)

"Oh, I see."

"What happens then," went on Smithy, "is that TR12 is conductive on positive half-cycles from the amplifier, whereupon its collector takes up a potential corresponding to the mean amplitude of those half-cycles. The a.f. at the collector is smoothed out by the 10μF electrolytic, C1, and the overall sensitivity is controlled by VR1."

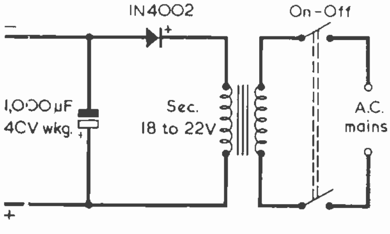
"That's neat," commented Dick. "I'll get those extra bits wired in right now."

Dick set eagerly to work whilst Smithy looked through the items on the "Repaired" rack which they had serviced earlier. He selected a stereo record player and carried it over to his bench. He connected up the speakers and added two wires to the terminals of one of the speakers. Shortly afterwards, Dick announced that he had completed the wiring around the amplifier transistor and, at Smithy's bidding, he carried the level indicator and its three batteries to Smithy's bench. Smithy connected the record player output to the 1kΩ potentiometer, turned the latter to a minimum setting, applied the 27 volt supply and switched on the player. He put on a test record and turned the record player volume control to its highest level.

"All we do now," he remarked, "is adjust the 1kΩ pot so that all the l.e.d.'s are lit up when the amplifier's delivering maximum output."

He advanced VR1 tentatively, and several of the l.e.d.'s lit up. Smithy soon found a setting which caused all the l.e.d.'s to light up at the loudest passages on the test record. At intermediate levels the length of the column of lit l.e.d.'s varied in sympathy with the level of the sound. Fascinated, Dick watched the l.e.d.'s.

Fig. 7. A simple power supply with good smoothing is quite adequate for the indicator. A single supply will power two indicators in a stereo system



JOB COMPLETE

"And," said Smithy, turning down the record player volume, "that's it. This record player has an 8Ω output, which means that there will be quite a high audio voltage passed to VR1 when the amplifier's going flat out. If the amplifier has a 3Ω output and can offer an output of 5 watts or so there should be just enough audio voltage to light up the whole column with VR1 near its maximum setting. You'll find that the average smoothed voltage with a music waveform is rather smaller than the wattage figure would lead you to believe. With a very high power amplifier, as you'd have in a disco, VR1 could have quite a low setting, and must initially be adjusted slowly from zero to avoid passing too high a voltage to TR12. Don't forget that, as I said at the beginning, this gubbins responds to output voltage only."

"What about a power supply?"

"The level indicator requires 25 to 30 volts at about 24mA. A simple half-wave rectifier circuit will be quite adequate for one or two of the indicators provided it has a high value of reservoir capacitor. The output doesn't need to be voltage regulated because the level indicator draws a steady current all the time. But the output must be well smoothed. If it isn't, the ripple voltage will be passed to the base of TR10 via C1, and this could cause one or more of the l.e.d.'s at the bottom of the column to light up, even when there's no input." (Fig. 7).

"Gosh, Smithy," said Dick enthusiastically. "This level indicator will be just what I need for Joe's Caff. Can I stay late tonight and make up two properly finished versions of it?"

Smithy glanced at his watch.

"It's already an hour past knocking-off time," he announced. "And doesn't today happen to be Friday?"

"Ye gods," exclaimed Dick. "Is it? Blimey, I'll have to rush off and get ready."

"Cheers for now, Smithy," he called out.

"Cheers," responded Smithy to his assistant's fleeting back.

Methodically, the Serviceman checked that everything was switched off, then he also made his exit from the Workshop. As he got into his car he mused on his own evening's plans, which consisted of playing a selection of his private collection of records to the local Chamber Music Society.

Smithy grinned.

There'd be no trouble with light switching there. ■

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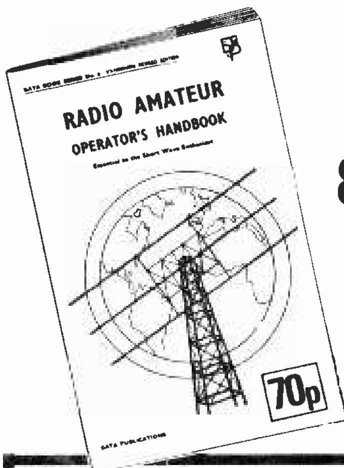

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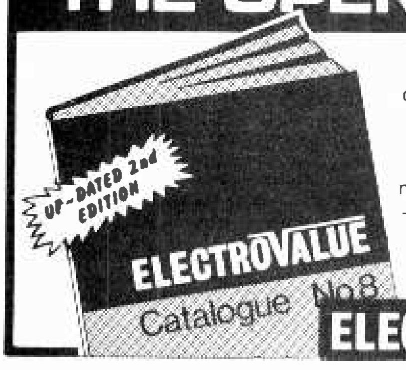

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TRANSISTOR CONFIGURATIONS

There are two main types of receiver suitable for the reception of amplitude modulation (a.m.) radio signals. These are the tuned radio frequency (t.r.f.) or "straight" receiver, and the superhet.

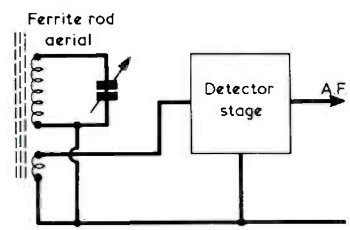
In the t.r.f. receiver station selection is achieved by means of one or more tuned circuits resonant at the frequency of the desired signal. A very simple type of t.r.f. receiver for medium wave reception may appear as in (a), where a ferrite aerial tuned circuit is applied directly to the detector stage. For short wave reception it would be more usual to employ a tuned coil and external aerial and earth connections, as in (b).

A t.r.f. receiver can have a tuned r.f. amplifier stage before the detector, as in (c). The r.f. amplifier and detector tuned circuits are tuned in unison by a ganged variable capacitor.

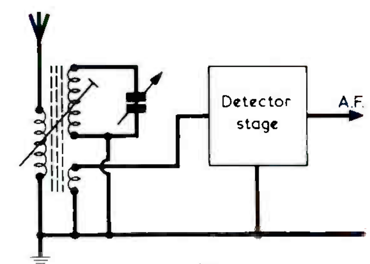
Regeneration, or reaction, is frequently incorporated at the detector. This is provided by a positive feedback control circuit which, if advanced too far, causes the detector to oscillate at the frequency of its tuned circuit. If the feedback control is taken to a level just below the oscillation point the selectivity of the detector tuned circuit and the detector sensitivity are increased by a very large amount.

An a.f. amplifier can be added after the detector for amplification of the detected signal. Alternatively, the detected signal may be coupled direct to an earphone or headphone.

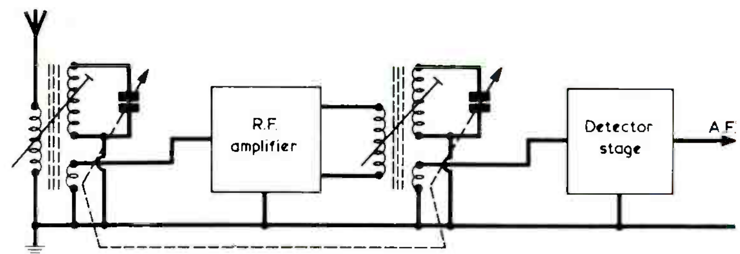
Manufactured a.m. receivers are almost invariably superhets, which have a superior performance. The t.r.f. receiver is, however, very popular with amateur constructors because of its simplicity.



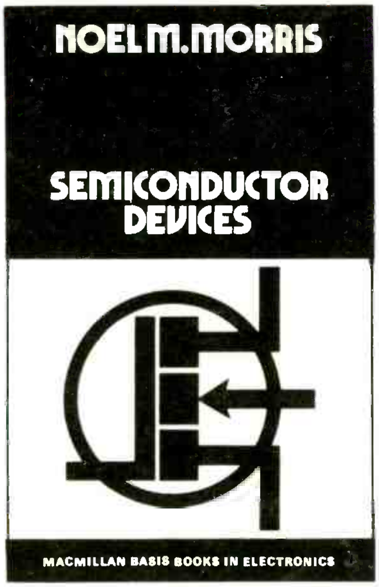
(a)



(b)



(c)



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CONTENTS

1. Semiconductors
2. Basic Semiconductor Devices
3. Semiconductor Diodes and the Unijunction Transistor
4. Bipolar Junction Transistors, Amplifiers & Logic Gates
5. Field-Effect Transistors, Amplifiers and Logic Gates
6. Monolithic Integrated Circuits
7. Charge-coupled Devices
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