15 SP

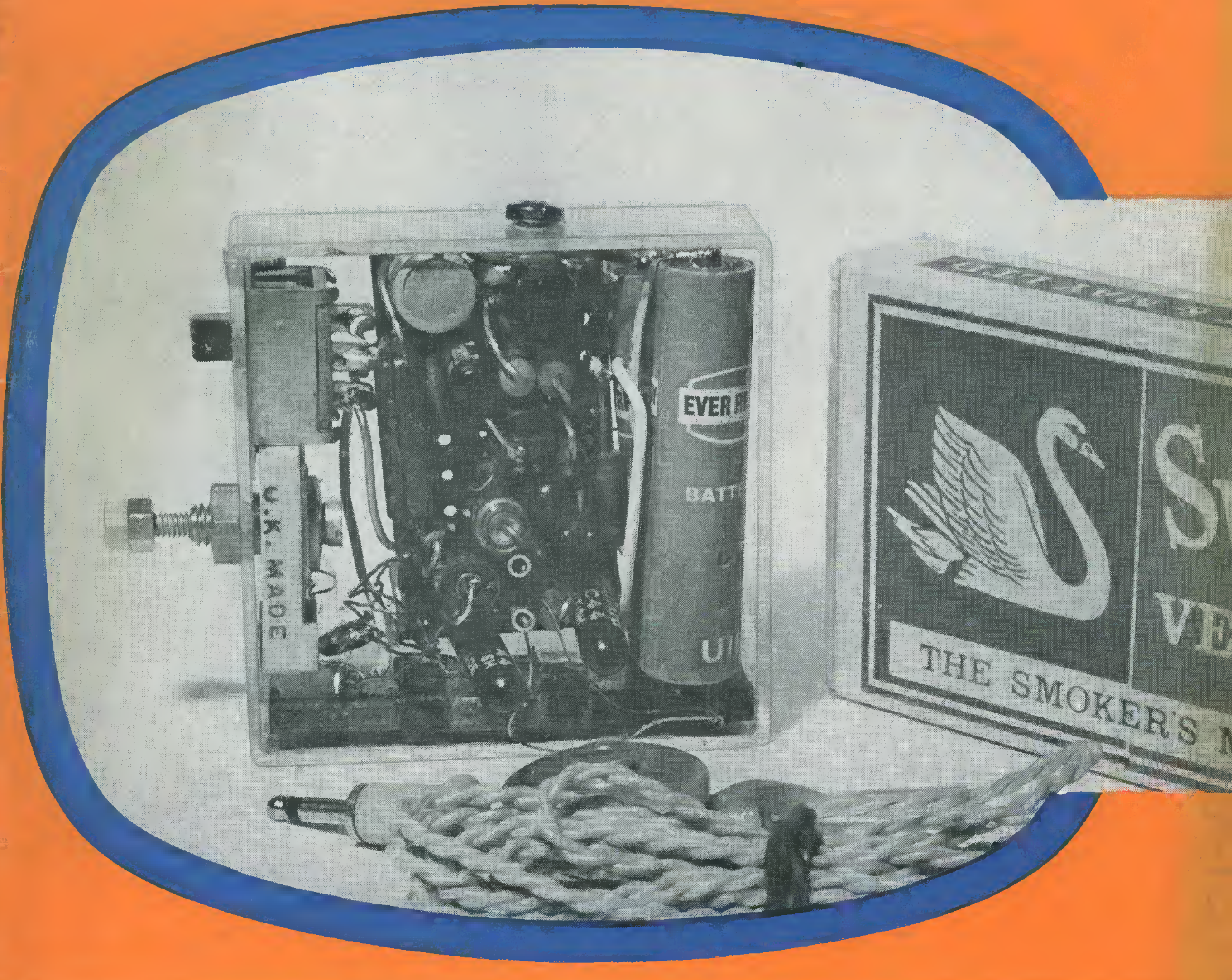
Vol 21 No 2

THE RADIO CONSTRUCTOR

SEPTEMBER 1967
2/6

A DATA PUBLICATION

Also featured
RADIO CONTROL SUPERHET
Constructional Details



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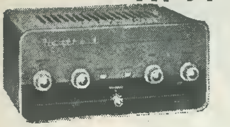
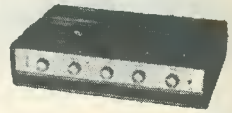


3+3W STEREO AMP. S-33H

10W POWER AMP. MA-12

GARRARD PLAYER AT-60



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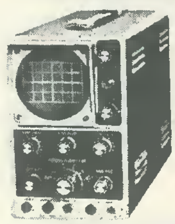

OS-2

3" LOW-PRICED SERVICE OSCILLOSCOPE. Model OS-2. Compact size 5" × 7¾" × 12" deep. Wt. only 9¾lb. "Y" bandwidth 2 c/s-3 Mc/s ±3dB. Sensitivity 100mV/cm. T/B 20 c/s-200 kc/s in four ranges, fitted mu-metal CRT Shield. Modern functional styling. Kit **£23.18.0** Assembled **£31.18.0**

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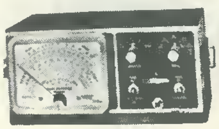

IM-13U

DE LUXE LARGE-SCALE VALVE VOLTMETER. Model IM-13U. Circuit and specification based on the well-known model V-7A but with many worth-while refinements. 6" Ernest Turner meter. Unique gimbal bracket allows operation of instrument in many positions. Modern styling. Kit **£18.18.0** Assembled **£26.18.0**

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VALVE VOLTMETER. Model V-7A. 7 voltage ranges d.c. volts to 1,500. A.c. to 1,500 r.m.s. and 4,000 peak to peak. Resistance 0.1 Ω to 1,000M Ω with internal battery. D.c. input resistance 11M Ω. dB measurement, has centre-zero scale. Complete with test prods, leads and standardising battery. Kit **£13.18.6** Assembled **£19.18.6**

RF-1U

MULTIMETER. Model MM-1U. Ranges 0–1.5V to 1,500V a.c. and d.c.; 150μA to 15A d.c.; 0.2 Ω to 20M Ω. 4½" 50μA meter. Kit **£12.18.0** Assembled **£18.11.6**

R.F. SIGNAL GENERATOR. Model RF-1U. Up to 100 Mc/s fundamental and 200 Mc/s on harmonics. Up to 100mV output. Kit **£13.18.0** Assembled **£20.8.0**

IG-82U

SINE/SQUARE GENERATOR. Model IG-82U. Freq. range 20 c/s–1 Mc/s in 5 bands less than 0.5% sine wave dist. less than 0.15μ sec. sq. wave rise time. Kit **£25.15.0** Assembled **£37.15.0**

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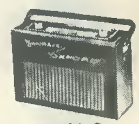

UXR-2

"OXFORD" LUXURY PORTABLE. Model UXR-2. Specially designed for use as a domestic, car or personal portable receiver. Many features, including solid leather case. Kit **£14.18.0** incl. P.T.

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STEREO TRANSISTOR FM TUNER
(Mono version also available)
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Kit (Stereo) **£24.18.0** incl. P.T.
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Cabinet extra £2.5.0.

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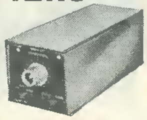
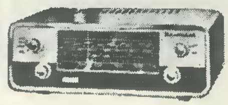
FM TUNER FM-4U



STEREO DECODER SD-1

TRUVOX DECK



AM/FM TUNER

HI-FI FM TUNER. Model FM-4U. Available in two units. R.F. tuning unit (£2.15.0 incl. P.T.) with I.F. output of 10.7 Mc/s, and I.F. amplifier unit, with power supply and valves (£13.13.0). May be used free standing or in a cabinet. Total Kit **£16.8.0**
(Multiplex adapter available. as extra.)

HI-FI AM/FM TUNER. Model AFM-1. Available in two units which, for your convenience, are sold separately. Tuning heart (AFM-T1—£4.13.6 incl. P.T.) and I.F. amplifier (AFM-A1—£22.11.6). Printed circuit board, 8 valves. Covers L.W., M.W., S.W., and F.M. Built-in power supply. Total Kit **£27.5.0**
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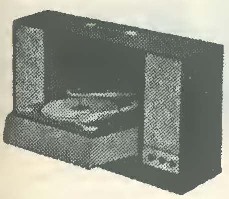
New! Portable Stereo Record Player, SRP-1



Automatic playing of 16, 33, 45 and 78 rpm records. All transistor—cool instant operation. Dual LP/78 stylus. Plays mono or stereo records. Suitcase portability. Detachable speaker enclosure for best stereo effect. Two 8in x 5in. special loudspeakers. For 220-250V a.c. mains operation. Overall cabinet size 15 7/16 x 3¾ x 10½in.

Compact, economical stereo and mono record playing for the whole Family—plays anything from the Beatles to Bartok. All solid-state circuitry gives room filling volume.
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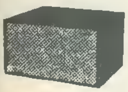
SSU-1

HI-FI SPEAKER SYSTEM, Model SSU-1
Ducted-port bass reflex cabinet in the white: Two speakers, vertical or horizontal models with legs. **KIT £12.12.0,** without legs, **KIT £11.17.6** incl. PT.



AVON MINI SPEAKER SYSTEM
6¼" Bass, 3¾" Treble speakers and crossover unit. Kit **£4.18.0** incl. PT. Beautiful. Walnut veneered fully-finished cabinet, **£8.18.0,** Total price Kit **£13.16.0** incl. PT.

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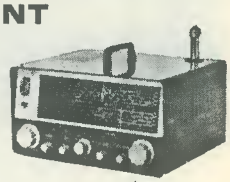

GC-1U

AMATEUR BANDS RECEIVER. Model RA-1. To cover all the Amateur Bands from 160–10 metres. Many special features, including: half-lattice crystal filter; 8 valves; signal strength "S" meter; tuned R.F. Amp. stage.
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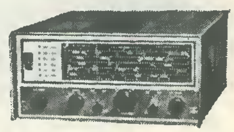

RG-1

COMMUNICATIONS TYPE RECEIVER. Model RG-1. A high performance, low cost receiver for the discriminating listener. Frequency coverage: 600 kc/s-1.5 Mc/s and 1.7 Mc/s-32 Mc/s.
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Low-cost 3 + 3W Transistor Stereo Amplifier, TS-23

Incorporating all the essential features for good quality sound reproduction from record, radio and other sources. 16 Transistor, 4 diode circuit. Good frequency response 6 position selector switch. Modern slim line styling.

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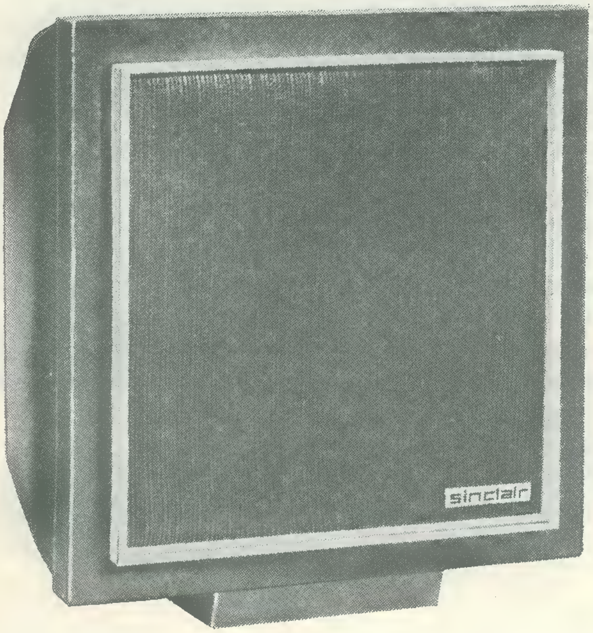

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General Purpose Meter-Oscilloscope Calibrator

by W. KEMP

This ingenious little unit offers three 1 kc/s square wave outputs at peak-to-peak values of 5V, 500mV and 50mV, these being primarily intended for oscilloscope or valve voltmeter calibration. Provided that care is observed in interpreting the results, calibration of many moving-coil bridge rectifier a.c. voltmeters is also possible. In addition, there are low-impedance d.c. calibration outputs at 5V, 500mV and 50mV, and the circuit is stable both for frequency and output over a very wide range of supply voltages

THIS SIMPLE AND HANDY LITTLE UNIT IS AN INvaluable aid for the calibration of workshop test gear, and also forms a useful standby signal injector for testing amplifiers for gain and frequency response. The device offers the following facilities.

(1). Three 1 kc/s square wave outputs for the calibration of oscilloscope timebases, or for testing the frequency response of amplifiers.

(2). Square wave outputs with a peak-to-peak amplitude of 5V, 500mV, or 50mV, for the calibration of oscilloscope Y amplifiers.

(3). Alternating square wave output voltages of 2.5V, 250mV, or 25mV, for the calibration of a.c. millivoltmeters, etc., in reading of either r.m.s. or average voltage, or for injecting standard signals into amplifiers for gain tests, etc.

(4). Three d.c. output voltages, at 5V, 500mV, or 50mV, for the calibration of multimeters and d.c. millivoltmeters, etc.

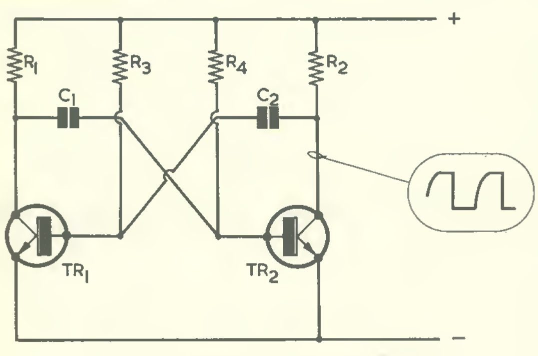


Fig. 1. A basic multivibrator circuit

The unit is designed to operate from a 12 volt battery supply, but the design is such that the overall accuracy on all ranges is better than ±2.5% over the supply voltage range 8.5V to 12.5V. The current consumption in modes 1, 2 and 3 varies between approximately 13mA at 8.5V and 25mA at 12.5V, while that in mode 4 varies between 4.5mA at 8.5V and 16mA at 12.5V.

The completed unit can be built into its own cabinet, for use as a general purpose calibrator or, if preferred, it can be built into existing equipment, such as oscilloscopes, etc., for specialised use. The unit, less switching, is built on a small piece of Veroboard panel, and measures a mere $1\frac{1}{2}$ x $3\frac{3}{8}$ x 1in.

Circuit Operation

The design of the calibrator is based on the simple multivibrator circuit shown in Fig. 1. The periods, or switching times, of the transistors in this diagram are controlled by the two time constants R_3, C_2, and R_4, C_1, and if these two time constants are equal the periods of both transistors will be equal also. The circuit will then generate an output waveform, at either collector, which has a 1 : 1 mark-space ratio and is approximately square in form.

This simple circuit is extremely useful, but suffers from the following disadvantages.

As is shown in the waveform in Fig. 1, a perfect square wave is not produced with the simple multivibrator. Secondary time constants affect the switching of the circuit and cause the production of one long transition period in the cycle. This snag can be overcome by fitting the transistors with small values of collector load resistors (R_1 and R_2), but it is then necessary to use high gain transistors

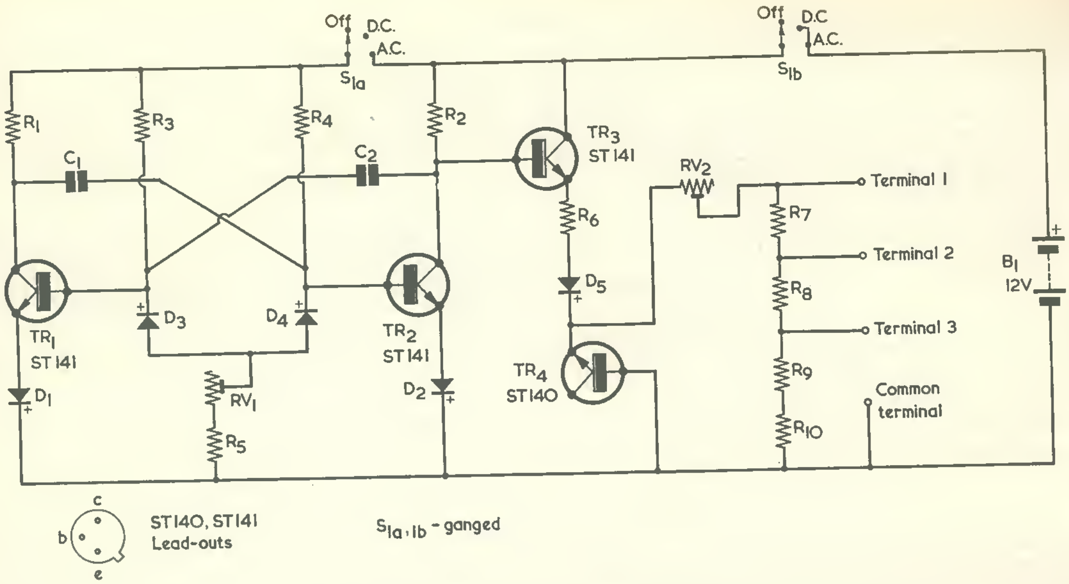


Fig. 2. The complete circuit of the general purpose calibrator. There is no connection to the collector of TR_4, whose base-emitter junction functions as a zener diode

COMPONENTS

Resistors
(All fixed values ½ watt, 5% or closer)

R_1	1.2kΩ
R_2	470Ω
R_3	22kΩ
R_4	22kΩ
R_5	470Ω
R_6	270Ω
R_7	1kΩ
R_8	100Ω
R_9	10Ω
R_{10}	1Ω (see text)
RV_1	25kΩ, skeleton pre-set potentiometer
RV_2	500Ω, skeleton pre-set potentiometer

Capacitors
(All capacitors 5%)

C_1	0.05μF or 0.047μF, paper or plastic film
C_2	0.05μF or 0.047μF, paper or plastic film

Semiconductors

TR_1	ST141 (Sinclair)
TR_2	ST141 (Sinclair)
TR_3	ST141 (Sinclair)
TR_4	ST140 (Sinclair)
D_1	OA200 or OA202 (Mullard)
D_2	OA200 or OA202 (Mullard)
D_3	OA81 (Mullard)
D_4	OA81 (Mullard)
D_5	OA200 or OA202 (Mullard)

Switch

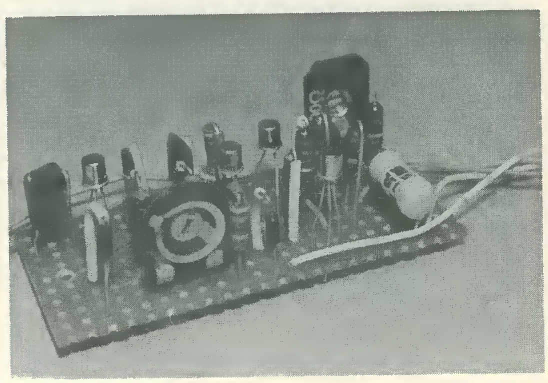
S_1 2-pole, 3-way switch

Battery

B_1 12V battery

Miscellaneous

Veroboard, 0.15in matrix, dimensions as in Fig. 3
Terminals
Connecting wire, sleeving, etc.



The completed calibrator unit

TABLE

Output Signals Provided			
S_1 Position	Terminal 1	Terminal 2	Terminal 3
A.C.	5V peak-to-peak 2.5V r.m.s. 2.5V average	500mV peak-to-peak 250mV r.m.s. 250mV average	50mV peak-to-peak 25mV r.m.s. 25mV average
D.C.	5V d.c.	500mV d.c.	50mV d.c.

in the circuit, and to operate then with a fairly high mean current.

Secondly, if the circuit is to be used as a variable frequency square wave generator, either both C_1 and C_2 or both R_3 and R_4 need to be varied in value together, and this calls for the use of twin-gang controls. If only one component, such as R_3 or C_1, were changed in value, the time constants of the circuit would become unequal and a square wave output would not be generated.

Thirdly, the circuit tends to give poor frequency stability with variations in supply voltage, since the reverse base-emitter junction impedances of the transistors can vary with voltage and cause changes in the circuit's operating characteristics.

All three of these difficulties are overcome in the final version of the calibrator unit, which is shown in Fig. 2. Here, TR_1 and TR_2 are wired as an astable multivibrator which, assuming that S_1 is in the "A.C." position, functions in the following manner.

TR_2 is operated with a low value of collector load resistor (470Ω), so that a good square wave is obtained at its collector. A medium value of collector load (1.2kΩ) is provided for TR_1, since the waveform at this point is of little importance in this circuit. TR_1 and TR_2 are transistors with a fairly high gain.

Germanium diodes D_3 and D_4 are wired as an electronic gate which effectively shunts the series combination given by RV_1 and R_5 across the two main time constants of the circuit on alternate half cycles, so that the effective values of the time constants can be varied by equal amounts. This enables the operating frequency of the circuit to be varied via RV_1 while still maintaining a square wave at the output.*

Silicon diodes D_1 and D_2 are wired between the emitters of TR_1 and TR_2 and the negative supply line, so that variations in the reverse base-emitter junction impedances of the transistors are cancelled out during cut-off, and a good frequency stability is obtained in spite of large variations in the supply line potential. Actual tests show that the operating frequency of this circuit varies by less than 4% (±2%) over supply voltage variations of 8.5V to 12.5V.

In use, the multivibrator circuit is adjusted via RV_1 to operate at 1 kc/s, and the output from TR_2 collector is direct coupled to the base of emitter follower TR_3 and then on, via R_6 and D_5, to TR_4. Only the base and emitter of TR_4 are connected in circuit, and these operate as a Zener diode working at approximately 6 volts. This "Zener diode" clips the square wave to a constant peak-to-peak amplitude of approximately 6 volts, irrespective of the amplitude of the input signal or the potential of the supply lines (within the limits 8.5V to 12.5V). It also sharpens up the shape of the square wave, which is then fed on to the potential divider network given by RV_2, R_7, R_8, R_9 and R_{10}. RV_2 is adjusted to set a 5 volt peak-to-peak signal at terminal 1, and the potential divider network then ensures that 500mV becomes available at terminal 2 and 50mV at terminal 3.

Since the signal at terminal 1 is a square wave with a peak-to-peak value of 5 volts, the r.m.s. value of the signal will equal 2.5 volts, as also will the average value, so that the single signal can be used for calibrating a number of different types of instrument.

The output impedance of the circuit is low, so that the accuracy of the calibration signals will be virtually unaffected by the shunting effects of instruments being calibrated.

When S_1 is in the "D.C." position, the multivibrator section of the unit is switched out of circuit and is inoperative. At the same time, TR_3 is driven hard on via R_2, so that approximately 6 volts appears across the "Zener diode" TR_4. 5 volts then appears at terminal 1 by voltage divider action, 500mV appears at terminal 2 and 50mV appears at terminal 3.

* We first published this circuit device (the use of two diodes and a common variable resistor to vary multivibrator frequency) in "Suggested Circuit" No. 193, by G. A. French, appearing in our December 1966 issue. A full description of circuit operation was given in that article.—Editor.

Construction

The circuit, less S_1, is wired up on a $1\frac{1}{2}$ x $3\frac{3}{8}$in piece of Veroboard panel with 0.15in hole spacing, and construction should be started by cutting this panel to size and drilling the two small mounting holes, to clear 6BA screws, as shown in Fig. 3. Next, break the copper strips, with the aid of a small drill or the special cutting tool that is available, where indicated.

The components and leads should be soldered in place on the blank side of the panel in the positions indicated in the diagram, and here it should be noted that all components except R_{10} are mounted vertically, that insulated sleeving should be used where there is any danger of components short-circuiting against one another, and that the mounting legs of RV_1 and RV_2 should be reduced in width, with the aid of a small file, before attempting to solder these components in place.

If preferred, the wiring up can be carried out in a number of stages, so that each section of the circuit can be checked and tested for faults before proceeding with the next stage. In this case the following procedure is recommended.

Solder TR_1, TR_2, D_1, D_2, R_1, R_2, R_3, R_4, C_1, and C_2 in position, wire switch S_1 to the circuit, and connect the battery supply leads. The circuit can now be given a functional check by temporarily connecting a crystal earpiece between TR_2 collector and the negative supply line, connecting a 12 volt battery to the circuit, and turning S_1 to the "A.C." position. If the circuit is working correctly, a powerful tone of less than 1 kc/s should be heard in the earpiece. If an oscilloscope is available, a check can be made that a good square wave is being generated.

If this test is satisfactory, turn S_1 off, then solder D_3, D_4, RV_1, and R_5 in place. Now turn S_1 to the "A.C." position again, and check that a tone signal is once more heard in the earpiece. The frequency of this tone can be varied about 1 kc/s by means of RV_1. If an oscilloscope is available, check that a good square wave is available at a frequency of 1 kc/s.

On satisfactory completion of this test, turn S_1 off, then wire TR_3, R_6, D_5, and TR_4 in position, as shown, turn S_1 to the "D.C." position and check

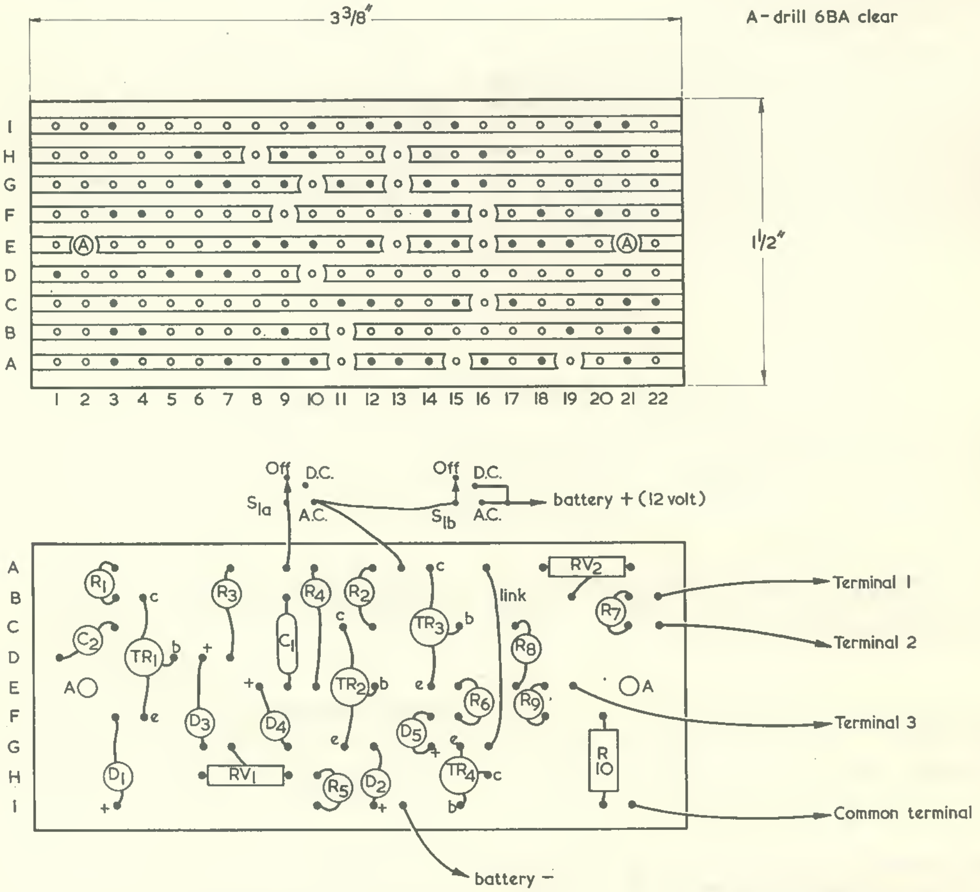
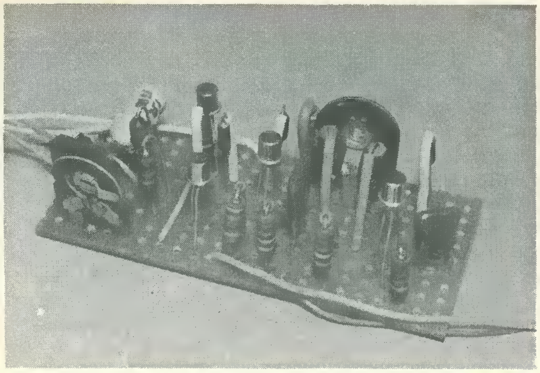


Fig. 3. Showing, above, the copper side of the Veroboard and, below, the components mounted in position



An alternative view of the completed unit

that a potential of about 6 volts appears across TR_4.

RV_2, R_7, R_8, R_9, R_{10}, the remaining connecting leads, and the link, can then be soldered in place, and a final functional check carried out. It will be noted that R_{10} has the low value of 1Ω, and it may be necessary to use a resistor larger than ½ watt here if a 1Ω ½ watt resistor cannot be obtained. In the prototype a 3 watt type was fitted, since this happened to be immediately available. After fitting these components and the connecting leads, S_1 should be set to "D.C.", and RV_2 adjusted so that exactly 5 volts appears at terminal 1; and it should then be found that when S_1 is turned to the "A.C." position a signal of 5 volts peak-to-peak or 2.5 volts r.m.s. will appear at the same terminal.

The operating frequency of the oscillator can be set to 1 kc/s by comparing it with a 50 c/s low voltage mains-derived signal on an oscilloscope.

The output of the completed unit can either be taken to three different terminals plus a common terminal, or to a single pair of terminals via suitable switching. The unit is then complete and ready for use.

Editor's Note

Several points need to be borne in mind if this unit is to be employed for checking a.c. voltmeters using rectifier-fed moving-coil meters. Such instruments read average voltage but are normally calibrated in sine wave r.m.s. figures, which are 1.11 times the sine wave average voltage. The output on terminal 1 is 2.5 volts average and, disregarding other effects, will be indicated by a rectifier-fed moving-coil meter of the type just mentioned as 2.5 x 1.11, or 2.77 volts. Since terminal 1 does not swing on either side of the common terminal it will be necessary to insert a series capacitor having negligible reactance at 1 kc/s—say, 50μF or more—between the output terminal and the meter (although this may sometimes introduce misleading results if the meter does not use a full-wave bridge rectifier).

Although usually calibrated for 50 c/s, most modern a.c. voltmeters should be reasonably accurate with a 1 kc/s square wave; but there may still be a slight drop in sensitivity due to self-capacitances in the rectifier. Before relying entirely on the calibrator unit, its output should be compared, on the meter to be checked, against a sine wave voltage which is approximately known (such as the 6.3 volts given by the loaded heater winding of a mains transformer). This procedure will eliminate any possible gross errors in interpretation of the results.

These problems do not, of course, arise when the unit is used for its primary purpose of calibrating oscilloscopes, valve voltmeters or d.c. voltmeters.

CAN ANYONE HELP ?

Requests for information are inserted in this feature free of charge, subject to space being available. Users of this service undertake to acknowledge all letters, etc., received and to reimburse all reasonable expenses incurred by correspondents. Circuits, manuals, service sheets, etc., lent by readers must be returned in good condition within a reasonable period of time

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* * *

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Wyndsor Regent Tape Recorder.—D. M. Simmons, 54 Durham Road, Southend-on-Sea, Essex—purchase or borrow service sheet.

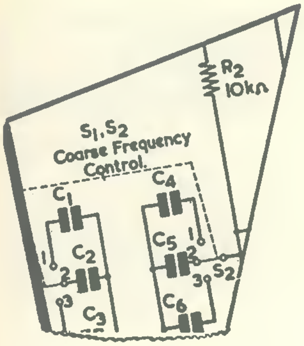
R1082 Receiver.—G. D. Woodwroth, 'Glenrowan', Dublin Road, Bray, Co. Wicklow—circuit or manual or any information.

* * *

Marconi Radiogram.—J. D. Robertson, 22 Queensway, Chelston, Torquay, Devon—circuit diagram wanted—only details are 3-gang tuning, valve line-up W42, X42, W42, DH42, N42 and U12.

* * *

PCR Receiver.—T. Bewley, Dale View, Upper Town, Wolsingham, via Bishop Auckland, Co. Durham—circuit diagram or any other information.



Circuit to Indicate Press-Button Precedence

SUGGESTED CIRCUIT No. 202

by G. A. FRENCH

As many readers will be aware, quiz programmes are a common feature on B.B.C. sound radio broadcasts. A typical quiz presentation may have two competing teams of contestants, these indicating their readiness to answer a question by pressing a button which actuates a buzzer (for one team) or a bell (for the other team). The question-master then takes an answer from the team whose buzzer or bell, as appropriate, sounds first.

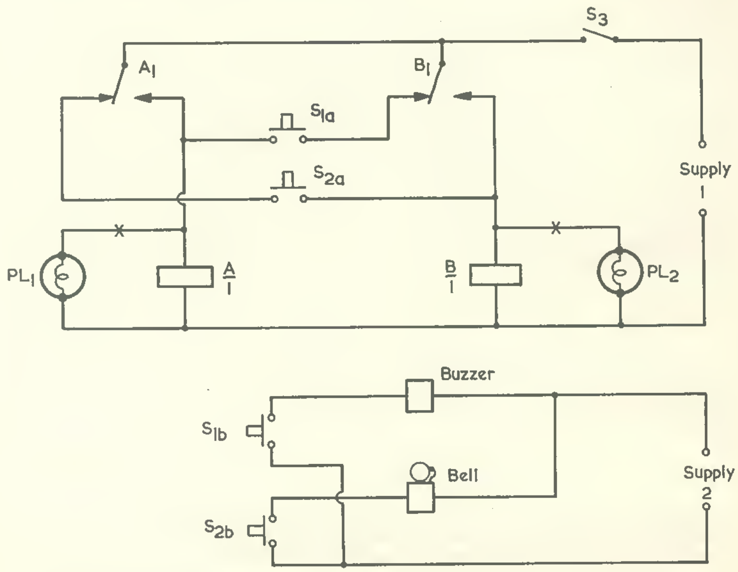
It is difficult to judge whether the buzzer or bell sounds first when these are operated almost simultaneously, and in some recent programmes the question-master has been provided with an electronic device which tells him indisputably which of the two buttons was the first to be pressed. He then takes an answer from the team thus indicated.

On listening to these programmes the writer has considered the possible forms an electronic device of this nature could take up. A reader has shown a similar interest, and has written to ask whether a simple indicator capable of carrying out the same function as that used in the B.B.C. quiz programmes could not be published in the "Suggested Circuit" series. The indicator could then be employed for educational competitions in schools based on the B.B.C. quiz programme approach. There are other applications as well, such as comparing the reflex times of two people who are asked to push a button on receipt of a stimulus, the judging of contests, and so on. Since it seems that a circuit of this type has a general interest, the writer felt that he should develop one for inclusion in this series of articles.

The Circuit

A desirable feature for the circuit is simplicity, whereupon it was decided that the best approach would be to base the indicator on two relays. The circuit adopted is shown in the accompanying diagram and it will be seen that all that is required are two relays, the buzzer and bell, two indicator lamps, two press-buttons, an on-off switch and two sources of supply. To keep the relay circuitry as simple as possible the press-buttons are double-pole types, and suitable components are readily available through home-constructor retail channels. If the energising voltage for the relay coils is higher than the rated voltages for the indicator lamps which are connected across them, two resistors in series with these lamps will also be needed.

The diagram uses the "detached" method of relay circuit presentation. The rectangle indicated as A/1 is the coil of relay A, and the rectangle indicated as B/1 is the coil of relay B. Relay A has one set of changeover contacts, these



A simple circuit which indicates which of two push-buttons has been pressed first being designated A1. Relay B similarly has one set of changeover contacts, these being designated B1. Both sets of contacts are illustrated in the position they take up when the appropriate relay is de-energised.

One press-button consists of $S_{1(a)}$ and $S_{1(b)}$, and is provided by a double-pole push-button switch which causes both poles to close when the button is pressed. The other button, consisting of $S_{2(a)}$ and $S_{2(b)}$, is of the same type. Supply 1 is a d.c. supply suitable for energising the relays, whilst Supply 2 is any supply which will operate the buzzer and bell.

To use the indicator, switch S_3 is initially closed. At this time no current flows through the relay coils or lamps because both $S_{1(a)}$ and $S_{2(a)}$ are open. Let us now assume that push-button S_1 is pressed. $S_{1(b)}$ will then operate the buzzer, whilst $S_{1(a)}$ will cause the topmost supply line to be connected, via de-energised contacts B1, to relay coil A/1 and indicator lamp PL_1. Relay A becomes energised and PL_1 lights up. The energising of relay A causes its contacts A1 to move to the energised position, whereupon a second circuit from the topmost supply line to coil A/1 is completed. As a result, relay A remains "held on" by its own contacts, and stays in the energised condition even if $S_{1(a)}$ is now opened. Similarly, lamp PL_1 remains continually illuminated.

When contacts A1 change to the energised position, the connection between the topmost supply rail and $S_{2(a)}$ becomes broken. If, therefore, push-button S_2 is pressed later than S_1, $S_{2(b)}$ will cause the bell to sound but $S_{2(a)}$ will have no effect. Once energised, relay A remains energised, and its contacts ensure that it is then impossible for relay B to become energised or for indicator lamp PL_2 to become illuminated.

By following a similar examination of the circuit it can be seen that, if push-button S_2 were the first button to be pressed, relay B would energise and indicator lamp PL_2 would become illuminated. Also, contacts B1 would keep relay B "held on", whilst preventing relay A from energising or PL_1 from becoming illuminated.

To release whichever relay has been energised and bring the circuit back to its initial condition, switch S_3 is opened and closed again.

The overall operation of the circuit may, in consequence, be summarised in the following manner. If, with switch S_3 closed, either push-button is pressed, the appropriate lamp will become illuminated (and stay illuminated) to indicate the button which has been operated. The circuit functioning is such that pressing the second button, even momentarily after the first, has no effect on the indicator lamps. At the same time, and as a secondary effect, both buttons cause the buzzer or bell to sound as applicable. After the push-buttons have been released, the indicator lamp circuit is brought back to its initial state by opening and closing S_3.

Components

It will be appreciated that, for best results, the two relays should be types which energise quickly. It is only necessary for each relay to have a set of changeover contacts, and this allows a wide range of relays to be used. A good choice would be given by any of the light-weight relays listed under Cat. Nos. Z70A to Z70D in the Home Radio (Mitcham) catalogue. These have a single set of changeover contacts and require low operating currents only, the latter being an advantage if a battery is used for Supply 1. Of the four relays just referred to, the Cat. No. Z70A has an energising voltage of 5 to 6, together with a nominal energising current of 15mA. If this relay were used, Supply 1 could be given by a 6 volt battery, and PL_1 and PL_2 could be either 6 volt 60mA pilot bulbs or 6 volt 40mA cycle dynamo bulbs. Such a combination of components would ensure a reasonable low current drain from a 6 volt battery. As was just stated, however, the choice of relay is not particularly critical and most standard types can be pressed into service. It is helpful to remember that the slower-acting relays can be speeded up quite noticeably by using a slightly higher energising voltage than is normally employed. Both relays in the indicator circuit should be of the same type.

The voltage of Supply 1 is governed by the energising requirements of the relays employed. If this voltage is higher than the rated voltage for PL_1 and PL_2, resistance should be inserted in series with the lamps at the points marked with a cross in the diagram. The value of resistance, in ohms, required for each series resistor is of course equal to the voltage to be dropped divided by the current rating of the lamp in amps. The resistor dissipation, in watts, is the voltage dropped multiplied by the lamp current rating. It will probably be found possible to use small carbon composition resistors of standard type. Supply 1 may be provided by a battery, as just mentioned, or by a simple low voltage mains power unit.

Supply 2 may be given by any battery capable of operating the buzzer and bell. Alternatively, an a.c. supply, obtained from the secondary of a bell transformer, can be used. If the voltage given by Supply 1 is suitable for the buzzer and bell, this could also be used to power the Supply 2 circuit. However, some of the cheaper electric buzzers and bells draw a high operating current, and could upset relay operation if a single supply having an appreciable internal resistance were used for both parts of the circuit. With buzzers and bells of this type, two separate supplies are preferable.

If the circuit is installed in a manner suitable for a competition of the quiz type, the two relays, the two lamps, S_3 and Supply 1 may be fitted in a box close to the question-master. External wiring can then connect this box to $S_{1(a)}$ and $S_{2(a)}$, which are installed, as part of S_1 and S_2 respectively, at the contestants' positions.

The writer checked out the circuit in prototype form using relays of the type referred to earlier as being available from Home Radio. The circuit worked as described, the appropriate lamp indicating reliably which button had been pressed first even when the time between pressing the buttons was too short to be readily evaluated by listening to a bell and buzzer. ✱

International Radio Engineering and Communications Exhibition

The annual Exhibition sponsored by the Radio Society of Great Britain has a new title (see above) and a new venue —Royal Agricultural New Hall, London, S.W.1—from Wednesday 27th to Saturday 30th September.

RECENT PUBLICATIONS

TRANSISTOR CIRCUIT DESIGN AND ANALYSIS. By E. Wolfendale, B.Sc. (Eng.), M.I.E.E. 292 pages, 8½ x 5¾ins. Published by Iliffe Books, Ltd. Price 70s.

This book provides a comprehensive approach to the design of transistor circuits for almost all applications in which these devices may be employed. The contents start with a consideration of transistor characteristics and biasing, carrying on to small signal and large signal equivalent circuits and to the use of the transistor as a switch. Next dealt with are transistors as small signal low frequency amplifiers, small signal high frequency amplifiers and power amplifiers. The remaining chapters cover oscillators, switching circuits and d.c. amplifiers.

The treatment is mathematical throughout, the book being intended mainly for engineers, physicists and undergraduates. In producing this work the author, now Technical Director at Racal Research Ltd., has drawn upon a very extensive experience of industrial semiconductor research and development. The book has been designed to be read in conjunction with an earlier volume, *The Transistor*, also by the same author.

BASIC TELEVISION, Part 1. By H. A. Cole, A.M.I.E.R.E. 145 pages, 9¾ x 6ins. Published by The Technical Press Limited. Price 21s.

This book is Part 1 of a 2-part set of volumes (the price of the set is 42s.) by H. A. Cole, in conjunction with the Editorial and Art Staff of the publishers. The presentation differs from that found in the more staid type of text book, in that considerable use is made of graphic illustration to give pictorial strength to the points being made. This approach extends, even, to the text. Thus, under "Tilt" (in "Camera Techniques") we find: "The eye of a camera leaves street level and slowly travels up, *up*, *UP* the vertical flank of a skyscraper. . . . . . ."

In Part 1 (Part 2 deals with the operation of a British dual-standard monochrome receiver) the basic principles of television are dealt with, including the picture signal, synchronisation and signal bandwidth. Both 405 and 625 line systems are considered.

The book makes a very good introduction to television for anyone who requires to attain a working understanding of the subject starting from scratch. Whilst the treatment cannot extend deeper than about block diagram level, the book is filled with hard and accurate information. It could be especially useful for a schoolboy who intends working in this field in his later years.

101 QUESTIONS AND ANSWERS ABOUT TRANSISTORS. By Leo G. Sands. 118 pages, 5½ x 8½ins. Published by W. Foulsham & Co. Ltd. Price 21s.

This book, which appears in the Foulsham-Sams Technical Book series, and has an American text with an introductory chapter for English readers, poses and answers 101 questions concerning transistor basics and circuits. The subjects covered comprise transistor characteristics, audio applications, radio applications, oscillators and control applications. The last section includes descriptions of logic circuits, flip-flops, monostable, bistable and astable multivibrators, the Schmitt trigger and the use of the transistor as a frequency divider.

The writing is straightforward and concise, and the treatment is non-mathematical. The book offers a useful reference source for the practical man who wishes to check on basic circuits or operating conditions.

UNDERSTANDING TELEMETRY CIRCUITS. By John D. Lenk. 166 pages, 5½ x 8½ins. Published by W. Foulsham & Co. Ltd. Price 25s.

Telemetry is the art of measuring quantities from a remote point, and it is of particular interest to the present-day electronic engineer because modern telemetry systems are entirely electronic in character. We are all aware that telemetry systems have enabled spacecraft to pass back to Earth details of their surroundings, but telemetry techniques are now being employed also for "ground-level" industrial applications and technicians are required for maintenance of the associated equipment. The function of the present book is to provide a text book for student technicians and a training aid for experienced technicians who wish to enter the telemetry field. A knowledge of basic electronics is assumed.

Understanding Telemetry Circuits (which is another title in the Foulsham-Sams Technical Book series) introduces the systems used, then carries on to signal conditioning circuits (dealing with the quantities to be measured, and how they are measured), the main telemetry systems, and magnetic recording techniques for such systems. A final chapter gives details of binary notation. Following the main text is a 9-page glossary and a comprehensive index. This is an informative and helpful book, covering a subject which will be new to many readers.

UNDERSTANDING AMPLITUDE MODULATION. By Irving M. Gottlieb. 166 pages, 5½ x 8½ins. Published by W. Foulsham & Co. Ltd. Price 25s.

This volume (which is also in the Foulsham-Sams Technical Book series, with an American text and an introductory chapter for English readers) deals at depth with the various methods of amplitude modulation which may be employed at the transmitter. Apart from its general interest, it will offer a particular appeal to the amateur transmitting enthusiast.

The first chapter describes the fundamentals of amplitude modulation, giving attention to the principles involved and to receiver demodulation circuits. Subsequent chapters are devoted to the transmitter and cover high-level, intermediate-level and low-level amplitude modulation. The fourth and final chapter discusses techniques for improving amplitude modulation performance.

The wide range dealt with under these general headings can be demonstrated by quoting, at random, specific chapter sub-headings: the Fourier theorem, carrier-level shift, the trapezoidal modulation pattern, pulse amplitude modulation, the balanced modulator, absorption modulation, speech clipping and single sideband. These are but a few of the many subjects discussed in the book.

No knowledge of specialised mathematics is required and the book is profusely illustrated with circuits, waveforms and similar descriptive diagrams. The writing is concise and the approach is essentially practical.

NEWS . . . AND .

Electroniques (proprietors STC Limited) the suppliers of over 11,000 electronic products to radio and electronic hobbyists, has just been appointed sole UK Agent for the internationally famous Hallicrafters range of quality radio communications equipment. Pictured here in front of a selection of Hallicrafters equipment is Neal Latorraca (right) European Manager of Hallicrafters, explaining points to Dave Little, Sales Manager, Electroniques.

ELECTRONIQUES APPOINTED EXCLUSIVE UK AGENTS FOR HALLICRAFTERS

Electroniques (proprietors STC Limited) has augmented the 11,350 products it offers to radio and electronic hobbyists with a complete range of high-grade communications equipment.

An agreement has been concluded with the Hallicrafters Company of Chicago, whereby Electroniques will market the complete range of Hallicrafters radio communications products for amateur and commercial use. The agreement applies to the United Kingdom and is exclusive.

Hallicrafters amateur equipment includes high-performance receivers, transmitters and transceivers, and covers frequencies up to and including the v.h.f. bands. All apparatus is of compact, lightweight design offering the optimum performance and ease of use.

Expected to be of considerable interest to hobbyists in the UK is a wide selection of general-coverage receivers covering the various communications and broadcast frequency bands for short-wave listening stations. The most sophisticated of these, the Model WR-4000, receives a.m./s.s.b./c.w./f.m. and covers consolan, aeronautical, trawler, and mobile frequencies as well as broadcast, amateur, international shortwave bands and entertainment v.h.f./f.m It is a portable battery-operated unit and weighs just 12lb.

Announcing the agreement, Mr. Jack Evans, Manager of Electroniques said—"We at Electroniques are extremely proud to represent the Hallicrafters product line with its hallmark, 'Quality through Craftsmanship'. The service we intend to provide will match this high standard. I am confident that the partnership of Electroniques and Hallicrafters will be of great benefit to amateur radio in the UK".

Welcoming the agreement, Mr. Ben Drezner, Vice-President, International Operations of Hallicrafters said that the alliance with Electroniques offered Hallicrafters a marketing organisation second-to-none in the UK. "I am sure" he concluded "anyone who buys Hallicrafters equipment in the UK will enjoy first-class service from the supplier as well as the equipment".

A CITIZENS' BAND?

There are those who are advocating the adoption of a Citizens Band by this country in order to stimulate amateur radio here. We think that this would be a retrograde step which would have the opposite effect.

The July issue of the American magazine 73, published by Wayne Green, W2NSD/1, refers to the falling interest in amateur transmitting in the States and blames the Citizens Band introduced in 1959. CB opened up a route into the hobby which was previously only possible through technical skill and a reasonable knowledge of radio theory—no knowledge of radio theory is required for a CB licence.

"In many High Schools, it is not unusual for the CB club to outnumber the ham club by fifty to one"—states Jim Fisk, W1DTY, author of the article. He goes on to say "This state of affairs is not only detrimental to the future of ham radio, it seriously effects the critical shortage of electronics technicians."

As we commented in this feature in our June issue (p. 662, Those Walkie-Talkie Sets) the GPO have officially denied that they are opening a Citizens Band in this country. This is indeed good news.

The privileges of Amateur Radio should only be available to those who are prepared to make the necessary effort, at present required in this country to acquire them.

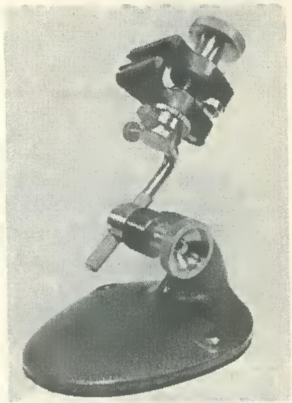
HOBBY TO CAREER

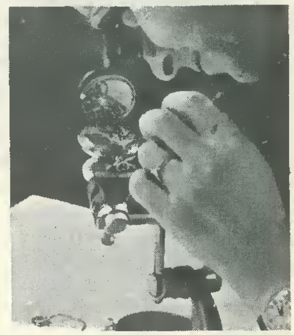
With the ever increasing application of electronics in almost every field of human activity, the demand for radio and electronics engineers and technicians grows apace.

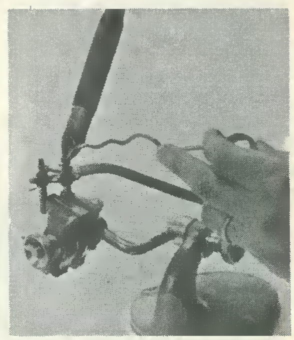
While the official channels for technical education do all they can to encourage the rapid development of electronics training schemes, one must not lose sight of the fact that a great many youngsters are introduced to electronics as a career through an early interest in radio as a hobby. As in our quotation from the American scene, above, if amateur radio is less flourishing then the shortage of electronic technicians is more acute.

. . . COMMENT

The Multi-Mini is better than a third hand







How many times do radio constructors and other hobbyists wish for a third hand? A remarkable little tool now being marketed by a Coventry instrument maker seems the answer to this plea—and a lot more besides. The most remarkable thing about it is, that someone has not thought of it before!

Called the 'Multi-Mini' universal vice and stand, the new device is basically a pin-vice on a stand—but it is a pin-vice with a difference. It is so flexible and adaptable that it can be used for virtually any light engineering holding job, as a clock repairer's vice, table-top camera stand, for tying fishing flies, model-making vice, soldering or gluing clamp—indeed, it will cope with most of those occasions when one has to call for another pair of hands to help.

The jaws of the vice have a maximum capacity of 11/16in. (17.5mm) and can be rotated 360° in any plane and lowered or raised in height to obtain exact positioning for the job in hand. A set of self-adhesive hard-rubber jaw liners is supplied loose with the vice for fitting if required for use on delicate surfaces.

Another feature is that the jaws are mounted on a 40-tooth ratchet so that they can be instantly set to different angles, such as 180°, 90°, 45°, in multiples of 9°. Not only does this facilitate final positioning for the average holding job but it is a great aid in the workshop for more sophisticated work, such as machining or drilling at precise angles.

The stand has a non-skid rubber base which will not damage highly polished or machined surfaces. Its design is such as to give exceptional stability as a non-fixture, i.e. as a truly portable "third hand" but screw holes are provided for fixing to a workbench if required.

Precision made, the jaws and main stand are of non-corrosive aluminium. The 'L' shaped mounting bar is of hardened steel and splined to give positive grip when clamping. Large knurled nuts give instant but firm finger-tip control of positioning.

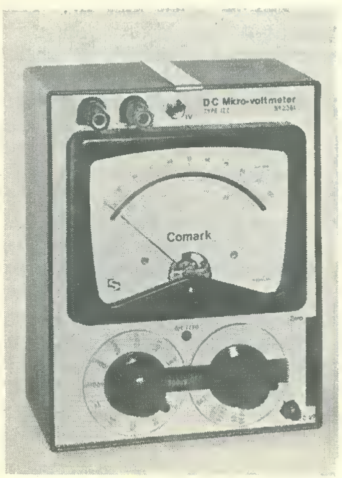
Individual parts of the vice can be separated and used independently, or re-assembled as required to offer the most convenient arrangement for any particular task.

In the home workshop the Multi-Mini can also be used as a tool or workpiece holder for milling, grinding or drilling at compound or difficult angles.

A precision-made, high quality job throughout, it was originally designed for professional trade use, but, at a recommended retail price of only 67/6d, it would seem to have unlimited application among home enthusiasts of all types.

The company is arranging distribution through leading tool merchants, hardware shops and do-it-yourself stores. In cases of difficulty contact: The Coventry Movement Co. Ltd., Burnsall Road, Canley, Coventry.

Comark D.C. Micro-Voltmeter



The D.C. Micro-voltmeter manufactured by Comark Electronics Ltd., of Gloucester Road, Littlehampton, Sussex has twelve fixed sensitivity ranges covering 100μV (FSD) to 30V (FSD) with an input resistance of 1000MΩ per Volt, except on the 3V, 10V and 30V ranges (10MΩ fixed). In addition, a variable sensitivity mode with a maximum sensitivity of 30μV (FSD) is provided, which permits the meter to be scaled directly in physical units.

The accuracy of the instrument is better than 2% of FSD, and meter drift will be negligible on all but the most sensitive ranges, being only 1μV per °C.

It is battery powered, easily portable and uses Mallory mercury cells.

The D.C. Micro-Voltmeter Type 122 may be used to measure small d.c. potentials in circuit, without appreciable loading; the input resistance on the most sensitive range is 100kΩ.

The instrument is in production and will sell at £40.

★ The SCT/RS1 Superhet

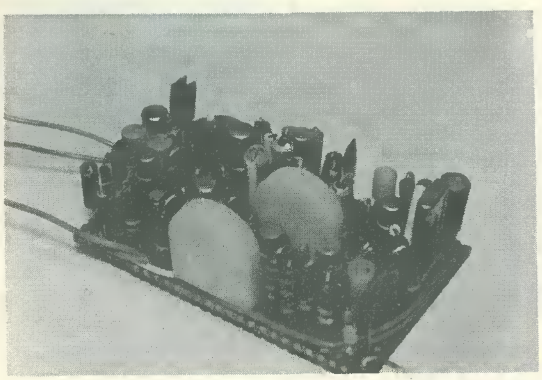
Last month's Basic Radio Control article gave full details of the circuit and operation of this highly efficient model control superhet receiver. In this issue we complete the description of the receiver by dealing with its construction, setting-up and testing.

Construction

THE UNIT IS WIRED UP ON A SMALL PIECE OF Veroboard panel with 0.1in hole spacing (available from Teleradio Electronics), and the component layout is fairly compact. To make sure that the constructor would encounter no difficulties due to over-cramping of the layout, the prototype was constructed using fairly large ½ watt resistors, as shown in the photographs, although ¼ watt resistors should, in fact, be used in the practical unit. All components used in the construction must, of course, be of the sub-miniature type.

To avoid problems during the constructional stages and to minimise any difficulties of trouble-shooting should an individual receiver fail to function correctly, it is strongly recommended that the unit be assembled in stages, each stage being tested before proceeding with the next. In this case, the assembly and test procedure which follows should be adhered to. At all times apply insulated sleeving to any leads where there is a risk of short-circuits to adjacent wires or components.

(1) Cut the Veroboard panel to size, as shown in Fig. 1, and break the copper strips, with the aid of a small drill, where indicated. Drill the L_1 and L_2 mounting holes, and then file the two small key slots on each hole so that the L_1 and L_2 coil formers form a tight fit. With the aid of a fret saw fitted with a small metal cutting blade, cut the ten small slots for the transfilters, checking that the transfilters fit in place correctly. Finally, with the aid of Araldite, Bostik, or similar adhesive, glue the L_1 and L_2 coil formers firmly in place so that they project on the plain side of the panel and put to one side to dry.



This photograph illustrates clearly the compact manner in which the crystal and the transfilters fit into the general layout

(2) Wind L_2 as follows. Bare one end of an 11in length of 28 s.w.g. enamel covered wire and solder in hole 4d; wind clockwise from the base upwards 9 turns, form a loop, and wind upwards in the same direction a further 2½ turns, finally soldering the free end of the wire in hole 6a. Remove the enamel from the loop and wire to hole 7e. The coil is close-wound.

(3) Wind L_1 as follows. Bare one end of an 11in length of 28 s.w.g. enamel covered wire and solder in hole 2k; wind clockwise from the base upwards 3½ turns, form a loop, wind a further 8¾ turns, finally taking the wire to hole 50. Remove the enamel from the loop and wire to hole 5m. This coil is also close-wound.

(4) Crystal Oscillator Section. Coat L_2 in plastic (polystyrene) dope, to bond the windings firmly to the coil former; pass a length of fine cotton through the centre of the former and screw the iron-dust core in place (the cotton prevents the core vibrating loose). Repeat this procedure with coil L_1. Take a 3-pin transistor holder, remove the centre pin, and solder in place on the Veroboard as a plug-in crystal holder. Wire TR_2, R_5, R_6, R_7, R_{12}, C_5, C_6 and C_7 in position. Wire sleeved shorting links between holes 5c and 5h, and 4e and 2j. Now wire a *temporary* positive lead to 1a and a *temporary* negative lead to 2h. Without the crystal in place, connect a 9 volt battery to the temporary leads and check that the circuit draws approximately 1mA. Insert the crystal and check that current rises to 2 or 3mA, indicating that the circuit is oscillating correctly; adjust L_2 core if necessary. If a field

Receiver for Radio Control

Basic Radio Control (8)

by F. L. Thurston

strength meter (see Part 2 of this series, published in the August 1966 issue) is available, place its antenna close to the circuit and check that a reading is obtained, indicating that the circuit is operating on the 27 Mc/s band. If satisfactory, remove the temporary battery connections.

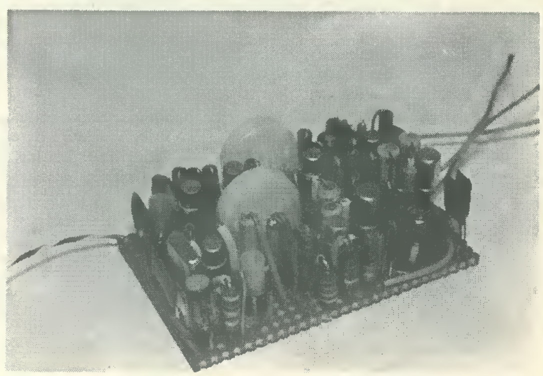
Note: the crystal should be one of a matched pair with 465 kc/s frequency spacing, the other crystal being used in the SCT/T1 transmitter.

(5) R.F./Mixer Section. Connect plain wire links between 2h and 2i, 7i and 7k, 11o and 11p, 13n and 13o. Solder in place C_1, C_2, R_2, C_3, R_1, R_4, TR_1, R_3, C_4. Solder a 34in antenna wire to hole 1p. Connect sleeved links between 1a and 5p, 7n and 8j. Solder TF_2 in place flush on the panel. Solder TF_1 in place, slightly above the surface of the panel. Wire a sleeved link between 14j and 13m, taking care to leave access to hole 14b. *Temporarily* connect a positive battery lead to 8p and a negative lead to 9h; connect a 9 volt battery and check that, with the crystal in place, current is of the order of 2 to 3mA. Make up the demodulation probe as shown in Fig. 2, and *temporarily* connect this between 15i and 12m. Retract the antenna of the SCT/T1 transmitter and place close to the receiver antenna; check that a tone modulation signal is heard in the crystal earpiece when the transmitter is operated. Adjust the cores of L_1 and L_2 for maximum signal. If this test is satisfactory, remove the temporary circuit connections.

(6) First I.F. Amplifier. Solder in place TR_3, R_9, R_8, R_{10}, R_{11}; wire sleeved links between 10k and 9n, 2b and 15n, 17l and 17p, 14l and 23o. Solder in place TF_3, R_{17} and C_8. Connect a permanent battery positive lead (red) to 21p. This lead is used for the positive battery connection on all subsequent tests and in final use. *Temporarily* connect battery negative to 9h, connect the battery, and check that current is approximately 3.4mA. Connect the demodulator probe *temporarily* between 18b and 15i and check that a tone is heard when the transmitter is operated. If satisfactory, remove the temporary connections.

(7) Second I.F. Amplifier. Connect a plain wire link between 17j and 18k. Solder in place R_{13}, R_{14}, TR_4, TF_4, R_{16} and R_{15}. *Temporarily* connect battery negative to 9h, connect the battery and check that current is approximately 3.9mA. Connect the demodulator probe *temporarily* between 19m and 20i. *Completely* remove the antenna from the transmitter, and check that a tone signal is heard in the earpiece when the transmitter is operated. If satisfactory, remove the temporary connections.

(8) Detector/A.F. and A.G.C. Amplifier. Wire a plain link between 23b and 22m, and a sleeved link between 25j and 26o. Solder in place C_9, R_{18}, R_{19}, R_{20}, R_{22}, TR_5, R_{21}, C_{11}, C_{13}, D_1, C_{10}, C_{12}, D_2, D_3, and R_{23}. *Temporarily* wire battery negative to 9h; wire the crystal earpiece (*not* the probe) between 22n and 23i; connect the battery and check that current is approximately 3.9mA (negligible increase on the reading obtained in (7)). Check that the tone signal is heard when the transmitter is operated. The a.g.c. action of the circuit can be checked by connecting a multimeter, on its 2.5 volt d.c. range, with its negative terminal to the negative supply line and its positive terminal to the junction of R_{23} and D_3. In the absence of a transmitter signal a reading of about 350mV should



Another view of the superhet receiver. This again emphasises its small size and compactness

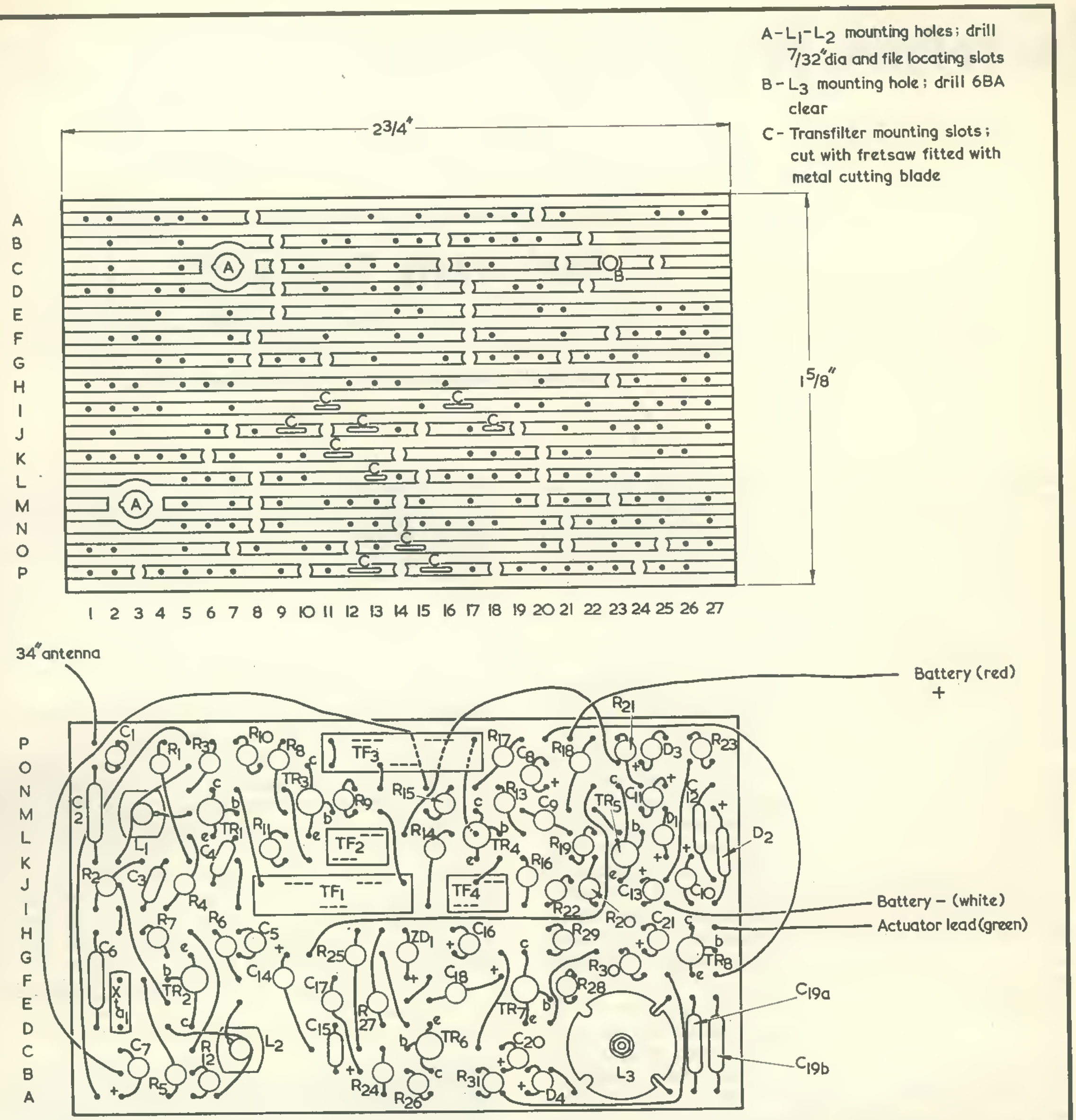


Fig. 1. The copper and component sides of the Veroboard. The 0.1 in hole matrix enables a very compact layout to be achieved

be obtained, and with a very strong transmitter signal at the receiver antenna this reading should rise to about 1.5 volts. If satisfactory, remove the temporary connections.

(9) A.F. Amplifier/Limiter. Connect a plain link between 14e and 15f, and sleeved links between 10g and 22n, and 14d and 13g. Solder in place C_{14}, C_{15}, C_{17}, R_{25}, R_{27}, R_{24}, TR_6, R_{26}, ZD_1 and C_{16}. The lead-out of ZD_1 marked with a plus sign in Fig. 1 is its positive lead when used as a zener diode. Connect a permanent battery negative lead (white) to 25i. *Temporarily* connect a sleeved lead between 10a and 20p, connect the crystal earpiece between 15e and 18h; connect a 9 volt battery and check that current is approximately 4.6mA, and that a tone signal is heard when the transmitter is operated. Remove the temporary connections.

(10) Tone Switch. Connect a plain link between 21a and 20b. Bolt L_3 pot core and bobbin in place (see Fig. 3). The pot core and bobbin are assembled in the following manner. Fit the bobbin in the pot core halves and secure the assembly to the Veroboard using a single 6BA screw and nut fitted with shake-proof washers. Coat the nut and screw end with

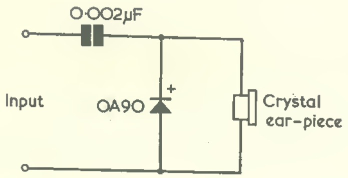


Fig. 2. The demodulator probe used for circuit testing during assembly

varnish. Solder coil wires to holes 25a and 25e. Wire sleeved links between 27f and 20p, 18a and 25f, 20d and 22g, 17c and 18g. Solder in place C_{18}, R_{29}, R_{28}, C_{21}, R_{30}, TR_8, TR_7, C_{20}, R_{31}, D_4, and (see notes below on "Using The Unit") C_{19a} and C_{19b}. Connect actuator lead (green) to hole 27h. Connect a 9 volt battery and check that the no-signal current is approximately 4.8mA; operate the transmitter, and check that this current rises to approximately 24mA. If a good increase in current is not obtained, check that the operating frequencies of the tone switch and the transmitter modulator are correctly matched by adjusting the preset tone control in the SCT/T1 transmitter. If correct operation is still not obtained, reduce the value of R_{28}. When satisfactory, connect a 6V 100mA bulb between the actuator lead and the negative supply lead, and check that the bulb can be turned on and off via the transmitter. With the transmitter antenna completely removed, it should be possible to obtain satisfactory operation over a range of several yards when the cores of L_1 and L_2 are correctly adjusted. After completion of this test, the bulb should be removed from the circuit. The receiver is now complete and ready for use.

Using The Unit

The receiver should be connected to an actuator or escapement, with its own battery supply, using the connections shown in Fig. 4. The receiver output transistor can handle currents up to 0.5 amp for very brief periods, or 300mA for moderately long periods, or 100mA for indefinite periods. The prototype receiver is used with an Elmic "Conquest" escapement driven from a 4.5 volt battery.

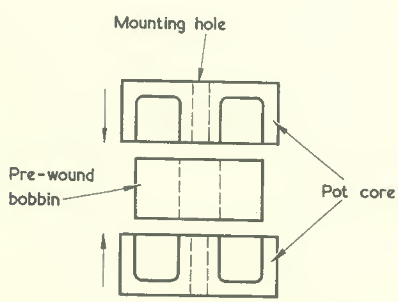


Fig. 3. How the pot core and bobbin are assembled. They are secured to the Veroboard by a 6BA screw and nut as described in the text

The carrier channel of the radio control system can be selected via the matched plug-in crystals in the SCT/T1 transmitter and the SCT/RS1 receiver. At the same time, the operating frequency of the tone switch can be adjusted by means of C_{19a} and C_{19b}, the operating frequency being approximately 1.5 kc/s with the values shown. The operating frequency can be increased by reducing the values of these two components, and *vice versa*. The operating frequency of the receiver tone switch must be matched to that of the transmitter. In the transmitter the values of C_9 and C_{10}, which are of equal value, can be changed to give a coarse control of frequency, while R_7 and R_8 can be varied between the limits 10kΩ to 33kΩ to give a fine control of frequency, final adjustment being given by RV_1.

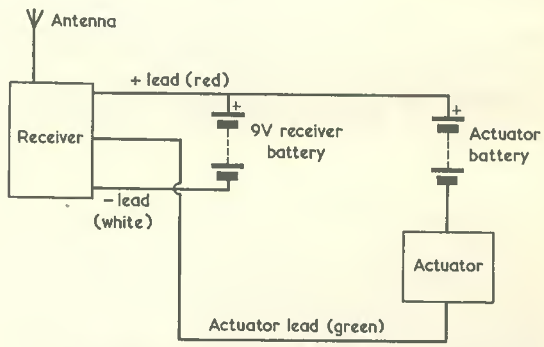


Fig. 4. Connections between the receiver and the actuator. The prototype uses an Elmic "Conquest" escapement and a 4.5 volt actuator battery

Once the crystals have been selected and the tone frequency set, the system should be given a final pre-flight check in the following manner. With the transmitter antenna removed, check that the receiver operates at close range, then move it away from the transmitter and adjust the cores of L_1 and L_2 for maximum range. Check that the tone frequency is correctly adjusted (by way of RV_1 in the transmitter) for maximum range. Now return to the transmitter, fit and fully erect the transmitter antenna, and adjust its iron dust core for maximum output (i.e. maximum reading on field strength meter). Next take the receiver, with actuator and batteries in position, and walk away from the transmitter to carry out a range check, until the actuator ceases to operate. With a fresh 9 volt receiver battery fitted a ground-to-ground range of over 1,000 yards should be obtained, the core of L_1 being adjusted for maximum sensitivity. The system is now complete and ready for use in a model.

Editor's Note

It should be appreciated that the escapement coil operated by the output transistor is intended to be

(*Continued on p. 100*)

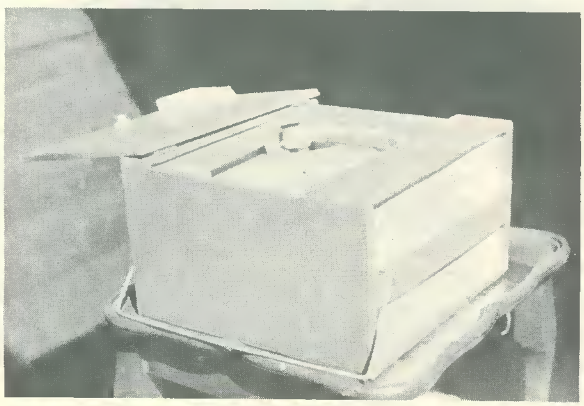
The "Junior" Radiogram

by Sir Douglas Hall, K.C.M.G., M.A. (Oxon.)

Running entirely from its own internal 9-volt battery, which supplies both the electronics and the gram motor, this self-contained portable radiogram offers local station reception on the medium wave band together with reproduction of 45 r.p.m. records. Ingenious circuitry enables the controls to offer alternative functions on radio and gram, and the design employs one valve and one transistor only. An added bonus is that the valve filament is heated at virtually no cost, since it acts as the stabilising emitter resistor for the transistor

Although it is quite possible to design a simple radiogram, it is in many ways an easier task if a fairly elaborate superhet circuit is used instead of a t.r.f. design. With a simple t.r.f. circuit it will be necessary to use reaction if portability is required, and even then the a.f. signal produced on radio will probably be much smaller than that given with the pick-up. A separate audio frequency volume control may be needed for gram, and a larger degree of negative feedback will be desirable when playing records. The design would also have to take into account that more treble cut is required on records than on radio, where there will probably already be some treble cut due to the use of reaction. It will, further be necessary to arrange switching to convert the first stage from a detector to an a.f. amplifier. Thus, the t.r.f. design can become complicated by a multiplicity of controls and multi-contact switches.

Nevertheless, the present design employs a t.r.f. radio section, and the author has attempted to tackle the problems just discussed by arranging for the controls to serve different purposes on radio and on gram. He has also found it possible to cause several other components to perform dual functions and to change over from radio to pick-up, from detector to amplifier and from single to double negative feedback networks, using only two on-off switches ganged to a potentiometer.



A view of the completed radiogram from the loudspeaker end

The "Junior Radiogram" is completely portable, and the prototype measures about 10 by $9\frac{1}{2}$ by $5\frac{1}{2}$in. It will receive local stations on the medium wave band and play 7in records. It employs a comparatively large speaker, 8 x 5in, and has room for two large capacity 4.5 volt batteries for economical use. These batteries also provide power for the turntable motor. On radio—the design must be regarded as strictly "local station"—but it requires no aerial or earth and receives the local stations with quite good quality and adequate volume for normal use. Variable tone control by negative feedback is used on both gram and radio; and on gram, where there is more than enough amplification available, there is an additional degree of fixed feedback.

The Circuit

Let us first examine the circuit given in Fig. 1. $S_{1(a)}$ and $S_{1(b)}$ are ganged to VR_2, and when this control is turned clockwise to close the switches, the circuit is arranged for receiving radio. V_1 acts as a leaky grid detector, C_2 being the grid capacitor. R_4, the grid leak, is connected to give positive bias to the grid of V_1. Signals are passed to V_1 from the tuned ferrite rod aerial, and sensitivity is enhanced by reaction, which is controlled by VR_2 in conjunction with C_4 and L_2. It will also be seen that as VR_2 approaches the zero position it damps the aerial coil and therefore acts as a true volume control.

T_1 is a transformer with a large primary winding which offers a very large inductance with the small current passing through it. It has a step-down ratio of 30:1 so that its secondary matches well to the input of TR_1, an n.p.n. transistor acting as a power amplifier. VR_3, a preset control, is adjusted once and for all so that TR_1 passes an emitter current of 25mA. Half the primary of a push-pull output transformer acts as the collector load for TR_1. A negative feedback loop from output to input of V_1 is provided by R_2, C_1, VR_1, R_3 and C_3. Because of the resistance in the circuit this loop is effective at audio frequencies only; and since C_3 is comparatively small, it is more effective at the higher audio frequencies. VR_1 acts as a tone control on radio, giving treble cut as the slider is moved towards R_3, (i.e. clockwise with the wiring layout shown in Fig. 2.) It should be

COMPONENTS

Resistors
(All fixed resistors ½ watt 10%)
R_1 10MΩ
R_2 470kΩ
R_3 10kΩ
R_4 2.2MΩ
VR_1 1MΩ potentiometer, log track, with switch (S_2)
VR_2 10kΩ potentiometer, linear track, with 2-pole switch ($S_{1(a)}$, (b))
VR_3 2.5kΩ or 3kΩ potentiometer, linear track, preset

Capacitors
C_1 0.005μF paper
C_2 300pF silver mica or ceramic
C_3 300pF silver mica or ceramic
C_4 0.0015μF paper
C_5 1,000μF electrolytic, 3V wkg.
C_6 100μF electrolytic, 6V wkg.
C_7 1,000μF electrolytic, 12V wkg.
VC_1 300pF variable, Dilecon (Jackson Bros.)

Inductors
$L_{1,2}$ See text
T_1 Transformer type QX1P (Osmor)
T_2 Transformer type TT5 (Repanco)

Valve
V_1 DL96

Transistor
TR_1 AC127

Loudspeaker
3Ω Loudspeaker, 8 x 5in

Batteries
2 4.5-volt batteries type 126 (Ever Ready)

Record Deck
Starr Single Speed 45 r.p.m. gram deck (Henry's Radio Ltd.)
Tagboard 10-way, list No. C125—Bulgin (Cat. No. C125—Home Radio Ltd.)
Ferrite rod, 8 x ⅜in dia.
B7G valveholder
3 knobs
Materials for cabinet, wire, etc.

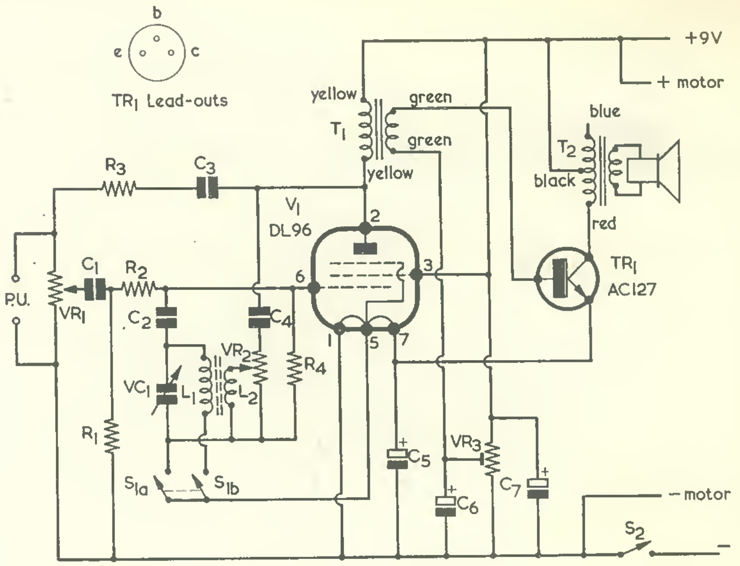


Fig. 1. The complete circuit of the Junior Radiogram. Switch S_2 is ganged with with VR_1, and switches $S_{1(a)}$ and $S_{1(b)}$ are ganged with VR_2

mentioned that the presence of the pick-up in the circuit is an important part of the negative feedback arrangement. Without the capacitance to the negative supply line offered by the pick-up, the negative feedback passed by C_3 would be excessive as VR_1 was turned towards the fully clockwise position. As it is, the presence of the pick-up allows smooth control to be obtained without excessive treble cut.

For playing records, VR_2 is turned fully anti-clockwise so that switches $S_{1(a)}$ and $S_{1(b)}$ are opened. It will be seen that L_1 and L_2 are now isolated from the filament of V_1 but that a second negative feedback loop has been introduced consisting of C_4, the track of VR_2 and R_4, and that the tuning capacitor, VC_1, in series with the grid capacitor C_2, is in parallel with R_4. Thus, a variable degree of negative feedback of the higher audio frequencies can be added to the fixed feedback provided by the network, by using the control VC_1. In other words, when playing records VC_1 becomes a tone control giving treble cut when turned in a clockwise direction. VR_1, the tone control on radio, becomes the volume control on gram, and the existing negative feedback of the higher audio frequencies offered by the loop of which VR_1 is a part, remains. On gram, therefore, there is a fixed degree of feedback of most audio frequencies, tailing off at extreme bass owing to the impedance of C_4 at such frequencies; a variable tone control by VC_1; and a further degree of treble cut which increases at high volume settings. This last effect is useful in preventing shrillness when playing records at maximum undistorted output.

Let us reiterate the use of the controls. On radio, tuning is carried out by VC_1, volume control by VR_2 and tone by VR_1. The unit is switched to gram by turning VR_2 fully anti-clockwise, whereupon VR_1 becomes the volume control and VC_1 the tone control. The battery is, of course, switched on and off by S_2, ganged to VR_1. It might be mentioned that although no radio signals will be heard when VR_2 is switched to gram, it is possible to play records with $S_{1(a)}$ and $S_{1(b)}$ closed in the radio position. Volume will be high, and only a small part of the movement of VR_1 will be usable, as the extra negative feedback designed for use with records will be inoperative. Also, the grid of V_1 will be positive via the grid leak. Quality on records will be considerably inferior to that obtainable with $S_{1(a)}$ and $S_{1(b)}$ correctly open.

Some constructors may have wondered, at this point, why a valve is used for the first stage instead of a transistor, and why there is no filament battery. The answer to the first question is that a valve is more convenient to use with a crystal pick-up than a transistor, owing to its extremely high input impedance. If a transistor (or transistors) were

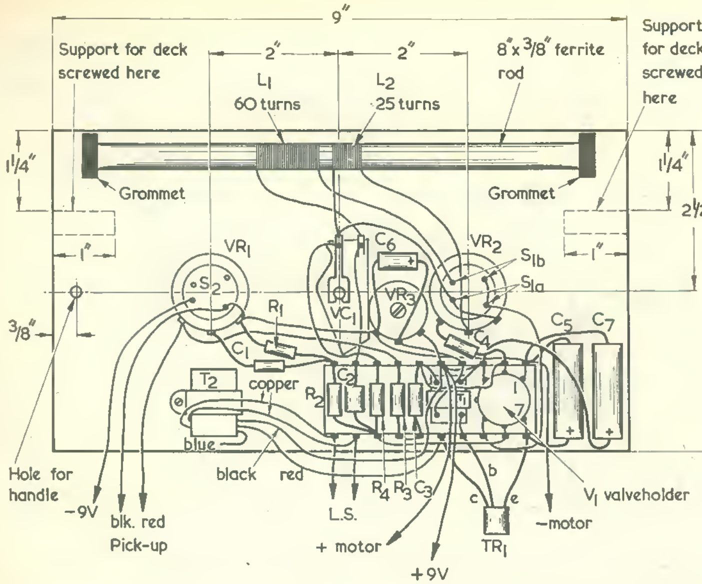
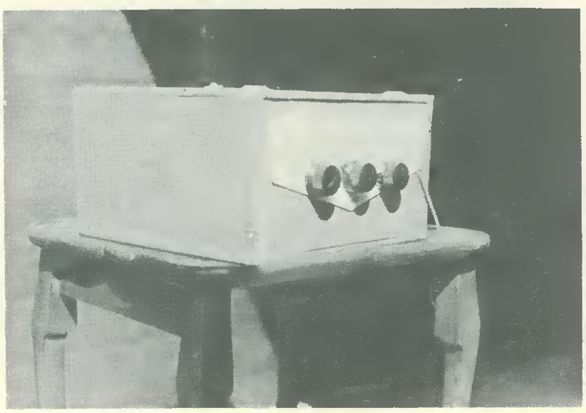


Fig. 2. Wiring up the component panel. The yellow leads of T_1 are towards the panel centre. T_2 is mounted on end with one foot bent through 90°. Note that the blue lead of T_2 is not connected into circuit. V_1 valveholder is observed here from the top, and not from the underside. The potentiometer switch tags shown for $S_{1(a)}$, $S_{1(b)}$ and S_2 may not coincide in position for all components, and the switch tags should be checked through with a continuity meter before wiring

used it would be necessary either to employ two stages connected on the common collector principle in order to obtain an input impedance of about 1MΩ; to use a large series resistor, which throws away all the amplification available and in any case necessitates another stage; or to use a matching transformer. With a valve, none of these devices are necessary. And in this particular circuit the filament of the valve is heated by "waste" current. An emitter resistor is necessary for TR_1 in the interests of thermal stability, and if the filament of V_1 is used for the purpose it can be heated to the right temperature provided the base bias of the transistor is correctly chosen. TR_1 must, of course, be an n.p.n. type with the present arrangement.



Another view, showing the three controls

Construction

The constructional details which follow apply to the prototype. Whilst readers are strongly advised to follow the wiring and component layout given in Fig. 2, they may prefer to use alternative arrangements for the cabinet. It should be noted, nevertheless, that the author's approach towards making the cabinet enables an extremely compact final assembly to be achieved.

All the components, except the speaker, are mounted on a plywood panel, 9 x 5 x about ¼in, using the layout shown in Fig. 2. The spindle of VC_1 is in the exact middle of the panel and VR_1 and VR_2 are 2in apart from VC_1 on either side. The valveholder is fixed to the tagboard by its connecting wires only, and VR_3 is also suspended in the wiring. Fairly heavy gauge single-strand wire should be used for wiring these components in order to hold them firmly. Additional fastening can, of course, be used if desired. T_1 is mounted so that its leads stand away from the panel with the yellow leads towards the middle. The leads are taken to their respective tags and soldered while held fairly tight. This will hold T_1 in position. L_1 and L_2 are wound on paper sleeves fitted over the ferrite rod, using 32 s.w.g. enamelled wire. L_1 consists of 60 turns and L_2 of 25 turns, both wound in the same direction. The coils are close-wound in a single layer. There is some advantage in using separate sleeves so that the distance between the coils can be adjusted for smooth reaction control. About ¼in to ½in spacing between coil ends will be found correct. Coverage should be from about 190 metres to over 600 metres. If the Third programme on 194 metres should be a local station and prove unobtainable it can be brought within range by moving L_1 and L_2 towards one end of the rod. The rod is fitted with rubber grommets at each end and these are tied to the panel with cord, *not* wire, passing through two small holes.

The loudspeaker is mounted on a similar 9 x 5in panel with a suitable hole cut out for it. The two panels are then joined together by two strips of ⅜in wood, each 9in long and 1in wide. One end of each strip is screwed to the control panel in the positions shown in Fig. 2, leaving 1¼in between the top of the strip and the top of the panel. The other ends, screwed to equivalent positions on the speaker panel, will require one corner to be cut away to allow for the speaker frame. If desired, add brackets at all four joints, on the underside, to provide extra rigidity. Both the 9 x 1in

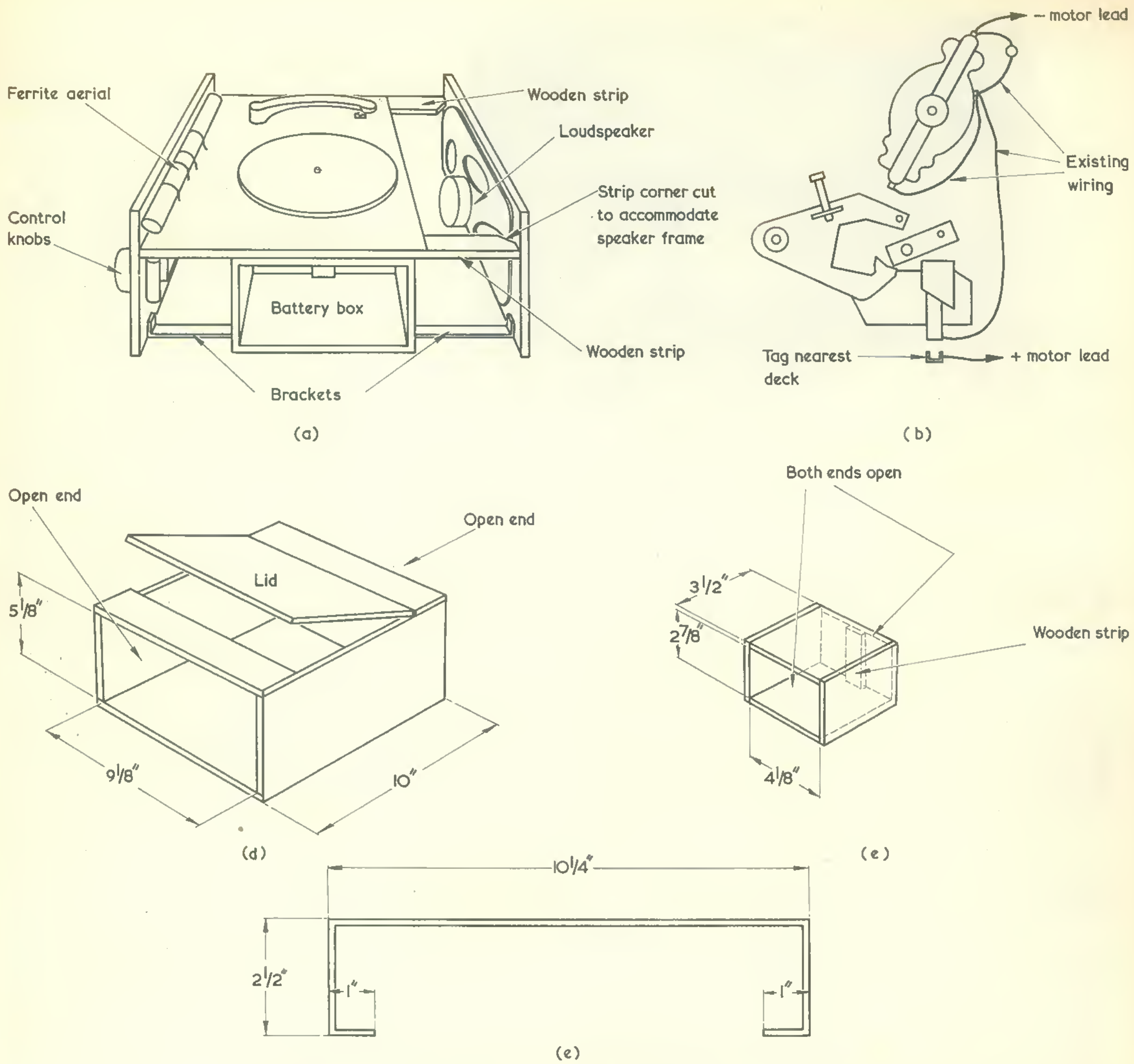
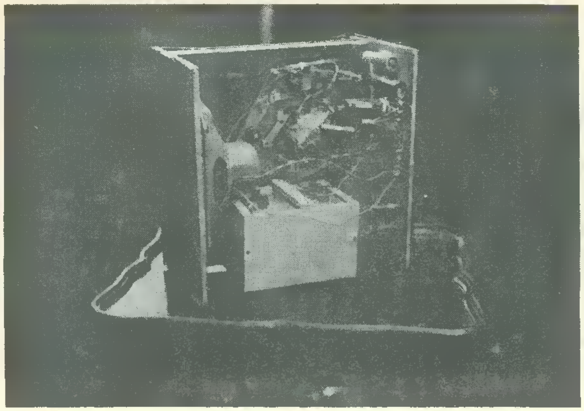


Fig. 3 (a). Assembling the two panels, the battery box and the gram deck
(b). Detail showing the 9 volt connections to the gram motor
(c). The battery box. This takes two Ever-Ready batteries type 126 inserted side by side
(d). The outside section of the cabinet, into which slides the assembly of (a). The internal width and height are shown here as $9\frac{1}{8}$ and $5\frac{1}{8}$in respectively but, to avoid errors, readers may find it preferable to work to the actual cut dimensions of the assembly shown in (a)
(e). The wire carrying handle for the radiogram

strips need their inner sides shaping with a fret saw to allow for various protrusions on the underside of the record deck. These can be found by laying the deck on the strips and marking the strips where they need cutting. The record deck will need to be fixed so as to take up the position shown in Fig. 3 (*a*) and care must be taken to see that neither the pivot end of the pick-up fouls the ferrite rod, nor the underside of the pivot fouls C_6 or any other component. There is plenty of room, but correct positioning is necessary before the deck is screwed to the strips. Note that the ferrite rod is above the gram deck surface and that there is a gap at the speaker end. Thick card or thin plywood, cut to shape and covered with adhesive plastic can be used to surround the deck and cover up open spaces. The ferrite rod, and the top of the speaker can also be covered in this way.

Fig. 3 (*b*) shows how the connections should be made to the motor. It should be noted that the positive lead is taken to the brass tag nearest to the deck and not to the similar tag which already has a manufacturer's lead soldered to it. The deck is being looked at upside down in



Illustrating the underside of the assembly of Fig. 3 (a)

Fig. 3 (*b*). The motor has its own internal switch which is moved to the on position when the pick-up is moved outwards and is turned off at the end of a record. This switch does not of course, control the amplifier, but only the motor.

A battery box is made as shown in Fig. 3 (*c*) using ¼in plywood. It will be seen to have four solid sides, one end open, and the other end open except for a narrow strip of wood across its centre. The box is screwed to the underside of the right hand 9 x 1in strip, looking at the control panel, such that the completely open side of the box is on the outside and flush with the outer edge of the strip. It will be found necessary to cut away a small cylindrical projection on the underside of the deck which would otherwise foul the box.* Batteries are inserted from the outside and are prevented from passing through by the narrow strip on the inside of the box which leaves ample room for the terminals to be accessible. Two metal brackets are screwed to the sides of the battery box and the control panel and speaker panel respectively, as shown in Fig. 3 (*a*). These serve to stiffen up the whole assembly. *At this stage the apparatus should not be switched on unless VR*$_3$ *is first turned fully anti-clockwise* (*i.e. slider at the negative supply line end of the track*).

* This projection is one of four. It consists of plastic and is part of the underside of the deck. Each of the four projections are drilled to take a 4BA tap or similar and are presumably intended to mount a commercially-made amplifier which may be used with the deck. The projection which has to be cut away can be readily located and need only be cut sufficiently to clear the battery box. It serves no useful function in the present application.

A suitable outside case can be made, following the style of the outer cover of a match box. This has two open ends, and a lid in the top, as in Fig. 3 (*d*). The assembly is pushed into the case so that the speaker panel appears at one open end and the control panel at the other. A stiff wire carrying handle (a cheap coat hanger will provide suitable material) is bent and cut to shape shown in Fig. 3 (*e*). One end is passed through the hole in the control panel shown in Fig. 2, and the other end into a similarly positioned hole in the speaker panel, or in an additional strip of wood screwed to it, as will be described shortly. The handle will serve to hold the assembly in the box. The case may be covered with adhesive backed plastic. A piece of thick card or thin ply covered with plastic, can be cut to cover the control panel. A suitable tuning scale can cover an appropriate part of the control panel.

Small hinges and a catch should be fitted to the lid and a small piece of plastic sponge should be cemented to the inside of it to hold the pick-up steady when it is not in use. Finally, a strip of plywood, 9 x 1 x ¼in, covered with plastic, can be screwed across the middle of the speaker fret, which may be of expanded metal. This strip can have a suitable hole drilled in it for the carrying handle, as was mentioned earlier.

Setting up

Before the apparatus is used, VR$_3$ must be adjusted, once and for all. This control should first be set with its slider at the negative supply line end of its track (fully anti-clockwise). A voltmeter, with a sensitivity not less than 1000Ω per volt is switched so that it will give a clear reading of 2.8 volts and its leads are connected across C$_5$ using the polarity indicated by that component. The set may then be switched on, either to radio or gram. The voltmeter should give a very small reading, if any. V$_3$ should then be turned *slowly* in a clockwise direction, whereupon the needle of the meter will rise. When 2.8 volts is registered VR$_3$ should be left as it is but the meter should be watched for 20 minutes or so. At first it may be seen that there is a tendency for the needle to rise very slightly, and this should be checked by turning VR$_3$ slightly anti-clockwise until 2.8 volts is again registered. After a short time the needle will remain steady though, by the end of the 20 minutes it may have fallen very slightly, owing to a small drop in voltage of the battery. This first small drop takes place quickly under load. If necessary adjust VR$_3$ again to give a reading of exactly 2.8 volts. VR$_3$ can then be forgotten and the apparatus is ready for use. *It is important that new batteries be used when adjusting VR*$_3$. If partly used batteries are employed a false setting will result, which could result in damage to V$_1$ when new batteries are later fitted.

Current consumption is about 30mA on radio and about 48mA on gram. Dissipation by TR$_1$ is such that an ambient temperature of 40°C (104°F) is permissible with a brand new battery, and 45°C (113°F) after the battery has been in use for a short time and the voltage has dropped to 1.4V per cell. As these temperatures are unlikely to be achieved in this country no undue precautions need be taken. If it is anticipated that temperatures approaching these just mentioned may be encountered for short periods, TR$_1$ may be provided with a cooling fin.

Baby Alarm

John G. Dew, B.Sc.

Our contributor describes a baby alarm circuit which requires no a.f. wiring between the microphone and loudspeaker. The original tuner section at the loudspeaker end was fitted to a home-built mains/battery receiver, but it can be employed equally successfully with any standard transistor radio

Having recently been blessed with a baby daughter, the author found that a lot of time was spent in "going to see if she was all right". Consequently a one-way intercom system, sensitive enough to pick up a baby's breathing, was required.

The simplest solution would have been a microphone, amplifier and loudspeaker connected by yards of twinflex draped between rooms; but loose wire has a strange affinity for high heels, dogs and vacuum cleaners, and so another method was sought.

All rooms in a house are interconnected by the 200–250 volt mains wiring; and although it would be very difficult to use this wiring to carry audio as well, it *is* possible to transmit r.f. signals along mains cables. The propagation characteristics will depend a great deal on the type and length of wire, and on the distance from a sub-station, but there will usually be sufficient signal strength over a reasonably sized house.

The Transmitter

Valves were chosen in preference to transistors for the following reasons:

(*a*) the unit would be connected to the mains, so battery operation would be pointless. Hence the relatively high power consumption of valves would be no disadvantage.

(*b*) the r.f. output must be coupled into the mains supply, so there is a possibility of transients from the mains finding their way back into the transmitter. From this point of view valves are far less easily damaged than transistors.

(*c*) the cheapest and most sensitive form of microphone is the crystal type, which matches the input impedance of a valve much more readily than that of a transistor stage.

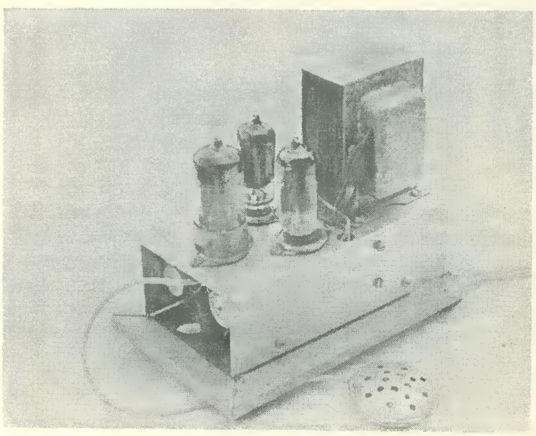
Referring to the circuit diagram of the transmitter shown in Fig. 1, the signal from the microphone is amplified by an EF86 (V_1) and passed to the modulator, V_2. (A volume control could be incorporated at the grid of V_2, but this was omitted in the prototype for simplicity of operation.) Normally, an a.f. choke would be used in the anode circuit of V_2, but inductors of the required value (around 10H) are large and heavy, so a 10kΩ resistor is used instead. Using a resistor severely restricts the amount of modulating power available, but this is of little consequence since the r.f. power output is also very small itself.

V_3 is the anode-modulated r.f. oscillator, operating at about 1 Mc/s. A triode-connected pentode is used simply because the EF91 shown was available; almost any low power valve is suitable for this position. The output from the oscillator is connected to the mains socket via a low value capacitor, C_{11}, which passes r.f. but blocks 50 c/s. This capacitor should have as high a voltage rating as possible, with 750 volts as the lower limit. The prototype used a 6kV type normally employed in the line output stage of a TV set.

Note that the r.f. output is applied to the "phase" (or "live") side of the mains supply and that the transmitter chassis is connected to the mains earth. The transmitter should only be connected to the mains via a 3-way plug and socket offering a reliable earth. Do *not* use the transmitter with a 2-way mains socket, which will not provide the requisite earth connection. If an on-off switch is required, this may be inserted in series with the "phase" input lead.

The Receiver

It is quite possible to use a domestic radio as a receiver, but the disadvantage is that its sensitivity will be far too great. This may result in interference from broadcast stations, as it is quite difficult to



Above-chassis view showing, in particular, the position of the mains transformer

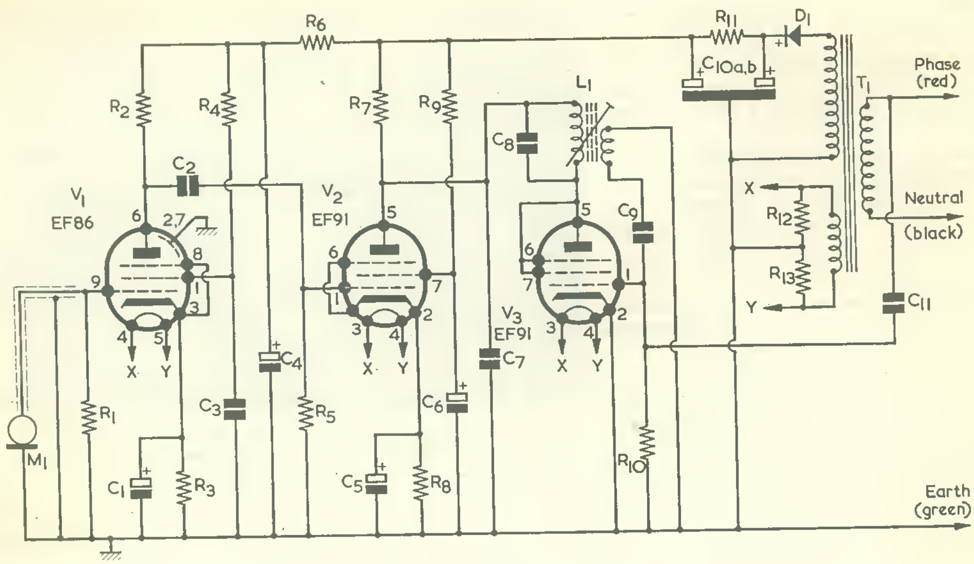


Fig. 1. The circuit of the transmitter unit

COMPONENTS

(Figs. 1 and 2)

Resistors
(All ¼ watt 10% unless otherwise stated)

R_1 1.5MΩ
R_2 220kΩ
R_3 2.7kΩ
R_4 1MΩ
R_5 1MΩ
R_6 33kΩ
R_7 10kΩ, 1 watt
R_8 180Ω
R_9 10kΩ
R_{10} 47kΩ
R_{11} 1kΩ, 1 watt (see text)
R_{12} 100Ω
R_{13} 100Ω
R_{14} 2.2kΩ
R_{15} 68kΩ
R_{16} 10kΩ
R_{17} 2.7kΩ
R_{18} 470Ω

Capacitors
(See text concerning working voltages)

C_1 100μF, electrolytic, 6V wkg.
C_2 0.01μF, 250V wkg.
C_3 0.1μF, 250V wkg.
C_4 16μF, electrolytic, 250V wkg.
C_5 100μF, electrolytic, 6V wkg.
C_6 8μF, electrolytic, 250V wkg.
C_7 1,000pF, 250V wkg.
C_8 220pF, silver-mica, 5%
C_9 100pF, silver-mica
$C_{10(a)(b)}$ 32+32μF, electrolytic, 250V wkg.
C_{11} 100pF, ceramic, 750V wkg. or greater
C_{12} 100pF, ceramic, 750V wkg. or greater
C_{13} 220pF, silver-mica, 5%
C_{14} 1,000pF
C_{15} 1,000pF
C_{16} 0.04μF
C_{17} 0.01μF

Inductors

L_1,L_2 Medium wave oscillator coil (see text)
T_1 Mains transformer. Secondaries: 150V at 20mA, 6.3V at 0.8A (see text)

Valves

V_1 EF86
V_2 EF91
V_3 EF91

Semiconductors

TR_1 OC44
D_1 250V rectifier (e.g. E250C50 or BY100)
D_2 OA81
D_3 OA81

Microphone

M_1 Crystal microphone or crystal microphone insert

Miscellaneous

2 B7G valveholders
1 B9A valveholder
Chassis and board material for transmitter and tuner
Screened wire, etc.

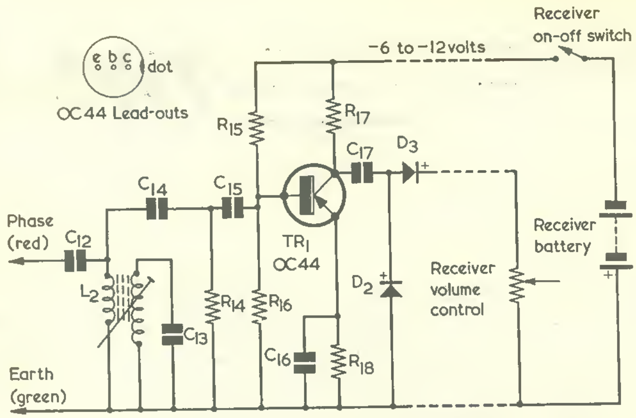


Fig. 2. The receiver tuner. This couples into the volume control circuit of a standard transistor radio

find a quiet spot in the medium waveband. On the other hand, a simple diode detector is loaded too heavily by a transistor audio amplifier, and the combination is too insensitive. (A diode followed by a valve audio amplifier worked well, but it was desired to build the receiver around a mains/portable transistor radio.) The final design employed by the author uses a single transistor tuner followed by the audio stages of the transistor radio just referred to. Since an a.c. power-pack was employed, no extra mains lead was required for the r.f. connection.

The "front end" is shown in Fig. 2. The r.f. signal is filtered from the 50 c/s mains frequency by the tuned circuit and the high-pass filters consisting of C_{14}, R_{14}, and C_{15}, R_{16}. The output from the collector of TR_1 is demodulated by D_2 and D_3, and applied to the non-earthy end of the volume control in the radio set. C_{12} in Fig. 2 should be a capacitor having a high working voltage, similar to C_{11} in the transmitter.

If the transmitter is not in operation, D_2 and D_3 are zero- or reverse-biased by the voltage across the volume control and do not affect the operation of the radio. When the transmitter is on, D_2 and D_3 rectify the carrier and the resulting d.c. voltage is applied to the volume control. This reverse-biases the detector in the radio, so cutting out broadcast reception. If a very strong station over-rides the bias, it is necessary to detune the radio.

Coils

Both L_1 and L_2 may be normal medium wave oscillator coils intended for valve receivers. With L_1, the tuned winding is in the anode circuit of V_3, and the coupling winding connects to C_9 and chassis. With L_2 the tuned winding connects to C_{13} and the coupling winding to C_{12}. Alternatively, the two coils may be home-wound on a standard Aladdin-type 7mm former fitted with a dust core. The tuned winding would then consist of 100 turns of wire scramble-wound in one or two pies, as convenient, and the coupling winding of 20 turns in a single pie positioned close to the tuned winding (at the earthy end if two pies are used). The wire may be 32 s.w.g. d.s.c. copper, or similar.[1]

Construction

Although no special attempt at miniaturisation was made, the transmitter was kept as compact as reasonably possible. The aluminium chassis was 5in long, 2½in wide and 1½in deep. The width was chosen so that the 32+32μF h.t. smoothing electrolytic capacitor could be fitted across the chassis; the 2½in width also accommodated the mains transformer.

A contact-cooled selenium rectifier, supplying the h.t., was bolted to the side of the chassis; although at the 15mA consumed by the circuit, cooling is scarcely required. Of course, a silicon diode could be used in place of the older selenium type.

Most of the soldered connections were made to the various valveholder tags. Exceptions included:

(*a*) a 3-way tagstrip used to terminate the 3-core mains lead,

(*b*) a single insulated terminal used for the main h.t. connection,

(*c*) the positive lead of the decoupling capacitor C_4 was cut short, and served as the junction for R_2, R_4 and R_6,

(*d*) the junction of C_9 and C_{11} was self-supporting.

These details are given to offer a general guide to the points likely to be encountered by the constructor. If components other than those employed by the author are used, the chassis dimensions should be modified accordingly. The under-chassis

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[1] A suitable ready-made coil would be the Osmor coil type QO8. In Fig. 1, pin 4 of the QO8 connects to V_2 anode, pin 3 to R_7, pin 1 to C_9 and pin 2 to chassis. Reduce the value of C_9 if squegging occurs. In Fig. 2, pin 4 connects to the upper plate of C_{13}, pin 1 to C_{12} and pins 2 and 3 to the earth line.—Editor.

(*Continued on p. 99*)

Cover Feature

TWO-BAND REFL

By S. Sho

This neat miniaturised receiver, case measuring only 2 x 2 x $\frac{3}{4}$in, ob by reflexing two r.f. transistors fixed regeneration circuit whic frequencies. It gives full cover together with switched reception on 200 kc/

IN CONSIDERING THE DESIGN OF VERY small transistorised reflex receivers many factors must be taken into account, and the result is always a compromise depending on the requirements of the constructor and user. In the design discussed here the most important requirement, after obtaining adequate sensitivity and selectivity on medium waves, was that the instrument should be capable of receiving the Light Programme on 200 kc/s. Normally, adding a long wave band to this type of receiver adds substantially to the size and complexity, but the method used here solves the problem in a simple manner and results are good.

Other important aspects of the design were that the circuit should be simple and reliable, using only easily obtained components. Also, to keep down size and weight and to improve stability, chokes and transformers were precluded.

Circuit Analysis

The circuit finally evolved is shown at Fig. 1. The tuned r.f. signal is amplified by TR_1 and TR_2, developed across R_5 and passed via C_4 to the diode detector, which is loaded by R_2. After demodulation the audio signal is fed back to the base of TR_1 via L_2, decoupled by C_3 and amplified again by TR_1 and TR_2. The audio signal developed across R_6 is fed direct to the base of the n.p.n. transistor TR_3. Use of an n.p.n. transistor in this position enables one to dispense with the normal coupling and bias components that would be required if a p.n.p. type were used. This effects a useful saving in cost, as well as improving stability and efficiency. It will be noted from the circuit that, with the exception of C_4 the receiver is entirely direct coupled. R_7 is used to bias TR_3 and, since it is not decoupled, generates a small amount of negative feedback. Further

COMPONENTS

Resistors
(All resistors $\frac{1}{4}$ or $-\frac{1}{8}$ watt 10%)

R_1	1.8kΩ
R_2	4.7kΩ
R_3	1kΩ
R_4	470Ω
R_5	1kΩ
R_6	1kΩ
R_7	22Ω (see text)

Capacitors
(N.B. The Radiospares trimmer may only be obtained through retail sources)

C_1	250pF, single compression trimmer (Radiospares)
C_2	1,000pF silver mica
C_3	0.1μF paper
C_4	220pF silver mica
C_5	50μF electrolytic, 3V wkg.
C_6	0.1μF paper
C_7	0.02μF ceramic disc

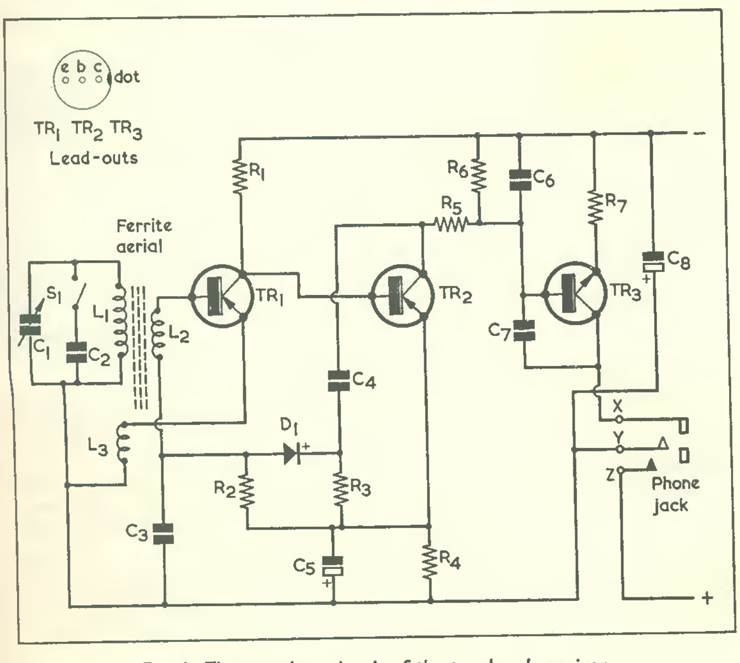


Fig. 1. The complete circuit of the two-band receiver

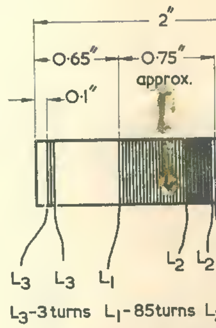


Fig. 2. How the coils on the ferrite slab. end of L_1 is wour The position of L_3 adjusted for optimu

LEX RECEIVER

ort

, which can be fitted in a obtains a high performance s and by incorporating a hich is operative at all erage of medium waves, on of the Light Programme kc/s

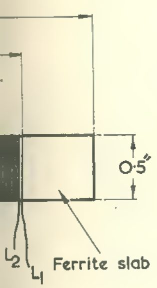
C_8 50µF electrolytic, 3V wkg.

Inductors
$L_{1,2,3}$ Aerial assembly on ferrite slab (see text)

Semiconductors
TR_1 OC44
TR_2 OC44
TR_3 OC139 or OC140
D_1 OA70 or OA81

Switch
S_1 s.p.s.t. wavechange switch

Miscellaneous
Earphone with jack plug (see text)
Jack socket, modified (see text)
3-volt battery, type as required
Veroboard 0.15in matrix, 1 x 1¾in (see Fig. 3)



s L_2-7turns

oils are wound ab. The earthy ound over L_2. L_3 should be imum reaction

negative feedback is introduced by C_7. This reduces transistor hiss, which may otherwise be rather annoying due to the very high gain of the circuit, and improves the bass response.

For best results it is essential that the diode be connected with the polarity shown. If incorrectly wired in there will be a marked loss of gain. It may be necessary to reverse the connections to L_2 for maximum signal; the best way will be immediately obvious in terms of gain.

Long wave reception is obtained by switching in an additional capacitor across L_1 and the values shown enable the Light Programme to be received in about the middle of the swing of the tuning capacitor. The L/C ratio is not the optimum and the Q suffers somewhat, but nevertheless output is similar to that from a local medium wave station

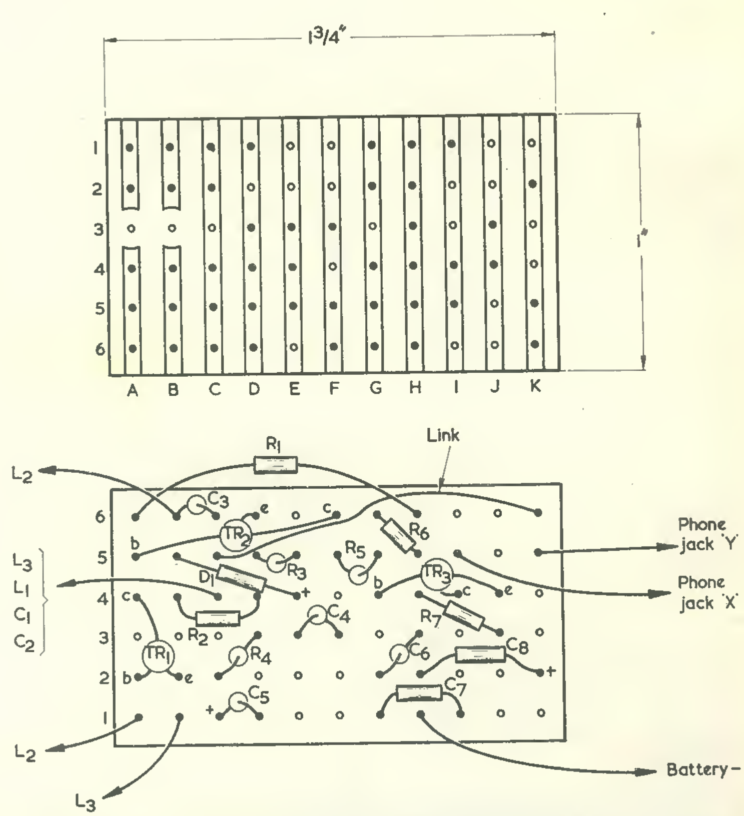
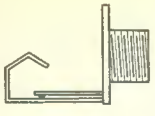
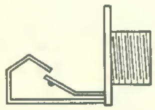


Fig. 3. The copper and component sides of the Veroboard used by the author. Note that one lead of C_3 and one lead of L_2 share the same hole. Components are not drawn to scale and some of those shown flat here may need to be mounted vertically. The wires designated X and Y connect to the similarly lettered contacts of the phone jack illustrated in Fig. 1. Contact Z of the jack connects to the positive terminal of the battery. The circuit around S_1 is external to the board



(a)



(b)

Fig. 4 (a). Showing, in simplified form, the phone jack before modification. The contacts are normally closed, opening when the jack plug is inserted
(b). The jack is modified by bending the centre contact upwards. Inserting the plug then pushes the top contact down on to the upper surface of the centre contact

and selectivity is adequate. The use of this method greatly simplifies aerial design. On a small ferrite slab interaction between coils for different wavebands is a problem, and a switched-out long wave coil can cause damping and dead spots on the medium wave band.

The aerial coils were wound on a ferrite slab measuring 2 x $\frac{1}{2}$ x $\frac{3}{32}$in and, to achieve maximum signal transfer whilst retaining reasonable selectivity, the turns ratio between primary and secondary was made about 12:1. The actual turns were 7 close-wound for the secondary (L_2) and 85 close-wound for the primary (L_1). The latter was wound in a single layer so that the earthy end of the winding covered the secondary. The gauge of wire is not important and 30 to 32 s.w.g. enamelled single rayon covered was found convenient. This winding gave full medium wave coverage with the 250pF trimmer used in the C_1 position. Approximate dimensions are given in Fig. 2. The reaction winding, L_3, is discussed in the next section.

Reaction

With small receivers of this type it is advantageous to introduce some form of reaction to improve sensitivity and selectivity. Any surplus gain can be used up by negative feedback in the audio stages to improve quality. Capacitive coupling was tried between collector and base of TR_1 by connecting short lengths of insulated wire to the collector and the "hot" end of L_1, and these were twisted together forming a small variable capacitance. This was not very satisfactory as, being frequency dependent, different capacitances were required to produce reaction on each medium wave station for optimum gain and no significant gain was produced on long waves.

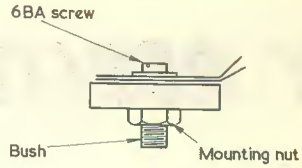
The best results were obtained by winding a coil of two or three turns round the ferrite slab and inserting it in series with the emitter of TR_1. By sliding the coil up and down the slab an optimum position could be found and the coil fixed. This coil is shown as L_3 in Figs. 1 and 2, and it will be noted that it appears at the non-earthy end of L_1. The type of reaction employed here was virtually independent of frequency and provided substantial gain on both bands as well as improving station separation on medium waves. Ensure that the regeneration winding is connected into circuit right way round; the incorrect way will, of course, result in no reaction being obtained. In the author's model three turns were used, positioned as shown in Fig. 2. This positioning is intended purely as a guide to what is to be expected in practice, and constructors should adjust the position of L_3 for optimum reaction in their own receivers. In some cases, it may be necessary to use only two turns for L_3. It may use the same wire as L_1 and L_2.

The receiver proved to be very stable in operation, giving good reception over all the medium wave band and on long waves around 200 kc/s. Good results were obtained on local stations using a 1.5 volt supply, but increasing to 3 volts livened up the performance considerably on the medium wave band, enabling many Continental stations to be received including Luxembourg. No adjustment to component values was necessitated by this voltage increase. Current consumption at 3 volts was 11mA (using an OC140 in the TR_3 position). This may seem rather high but it gives a reasonable earphone output with good quality. As an economy measure, and if the constructor is prepared to accept a lower output, R_7 could be replaced by a resistor of 56Ω. Consumption at 3 volts is then 5mA.

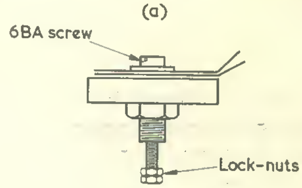
Mechanical Detail

The layout was not critical, the components being mounted on Veroboard of 0.15in matrix, and details are shown in Fig. 3.

The earphone used was a magnetic type having a resistance of approximately 100Ω. However, the set functioned satisfactorily with earphones having resistances varying from 30 to 250Ω. A crystal earpiece could be used by connecting a resistor of suitable value between TR_3 collector and the positive supply rail with the earpiece in parallel.



(a)



(b)

Fig. 5 (a). The Radiospares trimmer before modification
(b). The trimmer after modification. A longer 6BA screw is fitted, this projecting beyond the mounting bush. Lock nuts are then fixed on this to make a hand control

The set is switched on by inserting the earphone plug in the jack. Most miniature phone jacks have contacts which open when the plug is inserted, but it is a simple matter to modify them so that the contacts close on insertion and open when the plug is withdrawn. See Fig. 4. A 2mm plug and socket were used.

The tuning capacitor is a Radiospares trimmer modified by removing the adjusting screw and replacing with a longer screw which protrudes beyond the ceramic base of the trimmer. Lock nuts were then fitted which formed a "knob" for hand adjustment. The modification is shown in Fig. 5.

The case used by the author was a plastic box measuring approximately 2 x 2 x $\frac{3}{4}$in, but other suitable arrangements could be used to fit any box of convenient dimensions. As may be seen from the photograph, C_1 and wavechange switch S_1 were mounted on one side of the case, the switch being a small slide type. The author's receiver is powered by two U16 cells, connected in series.

Baby Alarm

(*Continued from p. 95*)

layout of the major components in the prototype is shown in Fig. 3.[2]

Precautions should be taken to minimise hum pick-up at the grid of V_1. The microphone connects to the amplifier via screened cable, and the length of unscreened wire at V_1 grid must be kept as short as possible. Also, the body of R_1 should be very close to the valveholder tags. If the microphone has a metal case, this must be earthed. The hum-dinger given by R_{12} and R_{13} assisted in reducing hum. R_{12} and R_{13} may, however, be dispensed with if a 6.3 volt winding with a centre-tap is available on the transformer, the centre-tap then being connected to chassis.

The prototype transmitter was housed in a $\frac{3}{16}$in plywood case covered in leather-cloth, measuring 6 x $3\frac{1}{2}$in, and $4\frac{3}{4}$in high. Although the total heat dissipation is less than 10 watts, this heat must be allowed to escape. Initially, the prototype was fully enclosed, but it was switched off hurriedly after half an hour when the transformer started dripping wax! Consequently the case was modified by replacing the top and part of the sides with expanded metal as shown in the photograph, and by drilling ten $\frac{5}{8}$in holes in the base. Rubber feet were used to provide space underneath for air flow.

The microphone may be separate from the transmitter housing, being connected to it by way of its screened cable. In the author's version, however, it was glued behind a $1\frac{1}{2}$in hole at one end of the case.

The Receiver

The tuner was constructed on a printed circuit board measuring $2\frac{1}{4}$ x $1\frac{1}{4}$in, and since the unit was quite small it was mounted on the side of the mains power pack inside the radio. The radio was home-built and space had purposely been left inside the case for the printed board. With many commercially-made transistor receivers this is not the situation and the tuner would then have to remain separate.

Since the volume control usually carries the receiver on-off switch, whereupon a negative supply point becomes available at this component, the three leads from the tuner to the receiver can be taken to the volume control as shown in Fig. 2. Should the on-off switch be in the positive supply line only, or if no switch is fitted to the volume control, an alternative negative supply point has to be found.

The r.f. input connections are taken from the mains, also as illustrated in Fig. 2, and it is once again *essential* that the connection to the mains supply be via a 3-way plug and socket offering a reliable earth connection.

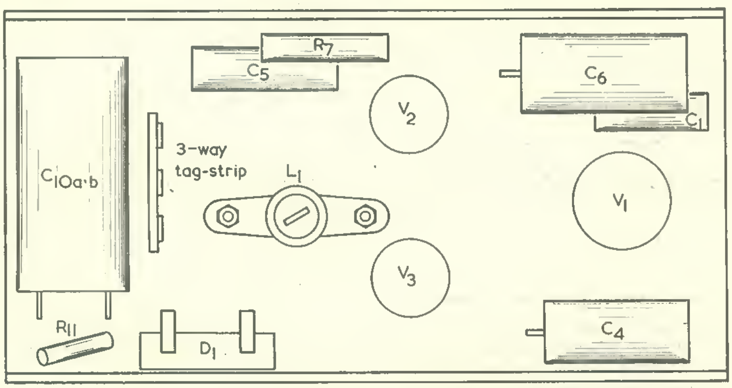
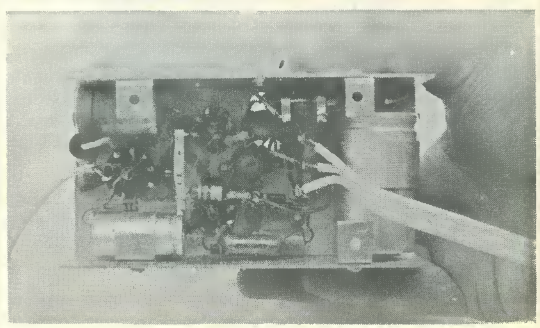
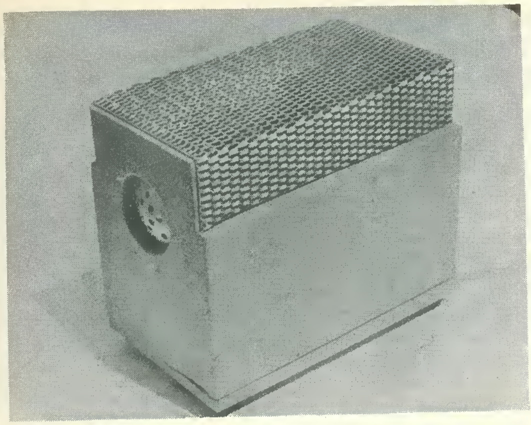


Fig. 3. Underchassis layout of the larger components in the prototype transmitter. Small variations in layout may be required to accommodate components having different dimensions to those used by the author



Below-chassis view of the prototype transmitter

[2] The mains transformer used by the writer has a 150 volt h.t. secondary and is not readily available through the usual postal retail channels. A near-alternative, which may be used in its place, is the mains transformer type P2 available from Henry's Radio Ltd., which has an h.t. secondary of 220 volts at 30mA. If this transformer is used, capacitors with a rating of 350V wkg. should be employed in place of those rated at 250V wkg. in the Components List, and R_{11} should be increased to 3.3kΩ 2 watts.—EDITOR.



In the author's version, the transmitter unit is housed in a case complete with microphone

Operation

Plug the transmitter in, and find a source of continuous noise for a signal (a TV set or radio is useful here). Adjust the core of L_1 to its mid-position. Plug in the receiver, in another room, and adjust the core of L_2 for maximum signal. Different mains wiring can affect the resonant frequencies of both L_1 and L_2, so if no signal is heard try L_1 at its extremes, and tune L_2 through its whole range.

If whistles or interference are heard, change the frequency by a small amount. The background noise should be kept very low, as even the faintest whistle can be a nuisance in an otherwise quiet room.

When the unit is working correctly the ticking of a clock in the same room as the transmitter should be clearly audible, and a baby's breathing will be picked up within the range of a few feet.

Editor's Note

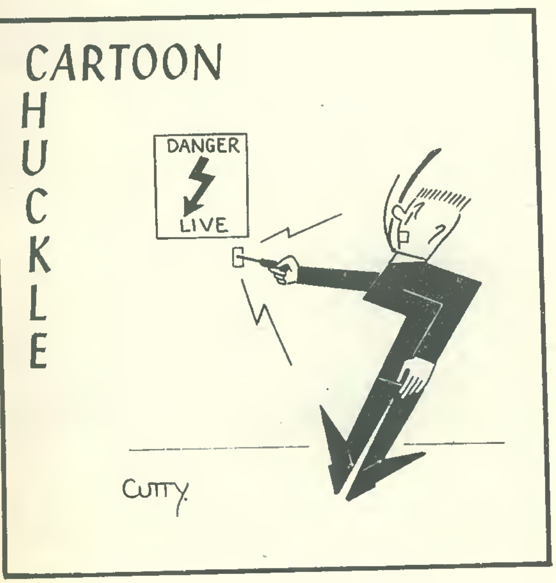
If hum in the transmitted output should prove troublesome, it may be reduced by connecting C_{11} to the upper plate of C_9 (see Fig. 1) instead of to the lower plate.

SCT/RS1 Superhet Receiver

(*Continued from p. 87*)

energised for brief periods in normal use, as is standard practice in single channel work. A light escapement will draw a current of some 300mA when energised. This current must *not* be allowed to flow for other than intermittent periods or the output transistor will become damaged, and it is important to bear this in mind when testing and setting up. If the output transistor is allowed to pass a current of some 300mA for several seconds, then it should be allowed to cool for several seconds before being made to pass current again. A restriction of this nature is common with relayless miniature control receivers.

If short pulse currents of between 300 and 600mA are to be handled, the output transistor could be replaced by two 2G381 or two NKT218 transistors in parallel, i.e. connected emitter to emitter, base to base and collector to collector. This will result in only a small increase in the overall size of the unit.



SOURCE OF EASILY MODULATED INFRA-RED RADIATION

Two new gallium arsenide diodes now available from Mullard emit near infra-red radiation when subjected to a voltage of about 1.5V. The radiation from the diodes, type CAY12 and 101CAY, is coherent and can be easily modulated simply by varying the diode current.

Maximum radiation from the diodes occurs at a wavelength of 0.9μm which is also near the peak of the response curve of the phototransistor type BPX25. Hence, one of the diodes and the phototransistor can be used in a very simple compact communications system, (Gallium arsenide diode–lens–lens–phototransistor). A range of 100 ft. can be easily achieved and this can be extended by improving the lens system.

This communication system could be used on noisy building sites to form a link between the cabins of tall cranes and the ground. The equipment could also be useful in crowded places where rapid, secret communication free of interference is needed between two points.

The high-frequency performance and high switching speed of these diodes make them suitable for use in a.m. or pulsed communication links. Because the emitted radiation is coherent, the diodes can also be used to start laser actions in other devices.

Courses of Instruction

Southall College of Technology
Beaconsfield Road, Southall, Middx.

This College provides classes at all levels for (a) Radio & Television Servicing, including Colour TV (b) Electronics Servicing, covering computer devices, automatic control etc. These courses are intended for technicians, amateur constructors, experimenters, either as a route to formal qualifications or for interest only.

Courses are as follows:—

(a) Part time day or evening classes in Radio and Television Servicing,
(b) Part time day or evening classes in Electronics Servicing (Covering Computers, Automatic Control, etc.).
(c) Part time day courses in Colour Television Receiver Servicing.

Isleworth Polytechnic
Department of Science and Engineering,
St. John's Road, Isleworth.

Electronic Servicing Technician's Course (FE.1 and FE.2)

The course is for prospective entrants into the Electronics or Radio and Television industries. Students attend College full time for *two years* and take external examinations for the City and Guild's Intermediate Electronics Servicing Certificate (or the Radio and Television Servicing Certificate) and the Intermediate Electrical Technicians Certificate.

Suitable students will have the opportunity of taking external examinations for the General Certificate of Education at 'O' level.

Applicants should have a genuine interest in Radio or Electronics and have attained a reasonable standard of education in English and Calculations.

Admission to the second year of the course can be arranged for candidates having suitable experience.

Subjects taken are listed below:—

Electronic

Principles, Techniques, Electronics Laboratory and Electronics Workshop Projects.

General

Mathematics, Physics, Engineering Drawing and English.

Liberal Activities

Students' preference, selected from Visual Arts, Music, Dramatics, Sport, etc.

Fees

Free to students under eighteen years of age.
Minimum age for entry: 16 years.
Application forms for course FE from the Principal.

Beckenham Evening Education Centre
28 Beckenham Road, Beckenham, Kent.

Classes to be held for the Radio Amateurs Examination at the Evening Education Centre, 28 Beckenham Road, Beckenham, Kent; on Thursdays from 7 to 9. Fees are graded according to age: maximum 40s.

Enrolment at the first class, September 28.

Further details, if required, from M. D. Bass B.Sc., (G3OJE) 42 Clevedon Road, London, S.E.20.

Ilford Literary Institute
Cranbrook Road, Ilford, Essex.

Enrolment September 4th to 7th (7 to 8.30 p.m.), courses commence on 20th September.
Fees (Adult) RAE 40/–, Morse tuition 32/–, (Under 21) 25/– and 20/– respectively.
Apply for reservation to G8JM, W. G. Hall, 48 Hawkdene Road, Chingford, London, E.4. (SAE please.)

West Kent College
88 Grosvenor Road, Tunbridge Wells, Kent.

From September 1967 until July 1968 the College will be running full time Radio and Television Servicing and Electronics Servicing courses to intermediate City and Guilds/R.T.E.B. certificate level.

Applications can be considered from prospective students residing outside Kent.

Western Road Evening School, Sheffield, 10.

Radio Amateur Examination Course will commence on Wednesday, September 20th at 7 p.m.
Further particulars may be obtained from J. Bell, G3JON, 25 Edale Road, Sheffield, 11.

Corbridge County School, Corbridge, Northumberland.

A course for the RAE will be held commencing in September. Contact V. Allison, G3TNX, 14 Silverdale Drive Winlaton, Co. Durham.

Sampling V.H.F.

Some Notes and Notions for Newcomers

Wallace Studley

Many keen short wave listeners tend to avoid the 2 metre (144–146 Mc/s) and 4 metre (70.2–70.4 Mc/s) bands, because their receiving equipment is intended for reception of the lower frequency bands only. If a good short wave receiver is already available, however, it is a fairly simple matter to construct a v.h.f. converter having fixed oscillator tuning, the resultant "intermediate frequency" band being fed to the aerial input of the short wave receiver. Individual signals are then tuned on the short wave receiver. Our contributor describes several practical circuits which may be employed for v.h.f. converters of this type. It is assumed that the reader has experience of short wave construction together with access to the test equipment referred to in the article

A GREAT DEAL OF ENJOYMENT CAN BE OBTAINED from experimenting with v.h.f. circuitry —although, unless one has access to reasonably accurate measuring and test equipment, the first results obtained may be somewhat problematical in value!

On the 2 and 4 metre v.h.f. amateur bands, a great deal of interesting signals are transmitted. These v.h.f. bands lie outside the tunable range of most communications-type receivers, however, and it is common practice to make use of a converter, feeding its output to the aerial socket of the receiver to be used.

The simplest converter would seem to consist of no more than a conventional frequency changer circuit arranged around a single valve, the signal grid being fed with, say, 144 Mc/s r.f. from an aerial and the oscillator section running at a frequency higher, or lower, than the signal frequency by the amount required as a first intermediate frequency. The latter could be around 10 Mc/s, which could then be tuned on the associated receiver. Unfortunately, such simplification is rarely practical.

Converters used for v.h.f. working fall mainly into two classes: (1) tunable types; and (2) crystal controlled types.

In the case of type (1) the associated receiver tuning is pre-set and the converter is made manually tunable over the required v.h.f. band. In the case of type (2) the converter signal frequency tuning (normally made wide enough to cover the whole band) is pre-set, the associated receiver being manually tuned over the band of frequencies appearing at the converter output.

In general, the crystal controlled type of converter has much in its favour, and it is moderately easy to get going.

Experiments recently carried out by the writer resulted in the constructional set-up described in this article. the final converter consisting of two separate sections. These were the signal frequency stages and the oscillator section.

Signal-Mixer Stages

The circuit for the r.f. and mixer stages, as used by the writer, is shown in Fig. 1. The input from a dipole aerial is applied to SKT_1, coil L_1 being tuned to the middle of the v.h.f. band to be received. Valve V_1 functions as a normal r.f. amplifier, the tuned circuit, L_2C_4, in its anode circuit being set up to mid-band frequency. L_3 is inductively coupled to L_2 and is also tuned to mid-band frequency by means of C_9. L_3C_9 feed the grid of the mixer. Locally generated crystal controlled oscillations are fed to point "Y" and permit mixing to occur in V_2, the difference frequency being selected by suitably tuning L_4C_{11} in the anode circuit. The output is taken from L_5 and passed to socket SKT_2, after which it may be fed to the aerial socket of the associated receiver or, alternatively, to a "head amplifier". The latter is merely another stage of r.f. amplification at the output frequency of the converter. Coil L_4 should not be sharply peaked since a bandwidth of up to 2 Mc/s is required if the 2 metre band is to be received. This bandwidth is obtained, at the expense of a little gain, by including resistor R_7 as a damper.

Miniature v.h.f. pentodes type 6AK5 are used for both V_1 and V_2 though for 2 metres the use of triodes is, perhaps, more common. According to the Brimar handbook, however, the 6AK5 is "useful as an amplifier up to 400 Mc/s", and they should know! The 6AK5 valve is also satisfactory as a mixer provided the appropriate screen resistor (R_9) is made reasonably large in value.

A Crystal-Controlled Oscillator

The local oscillator frequency in a v.h.f. converter must of necessity be fairly high; of the order of 130 Mc/s for the 2 metre band. To obtain local oscillations inexpensively at such high frequencies it is common practice to multiply the harmonic output generated by a relatively low frequency crystal. A typical oscillator and multiplier circuit of this kind is shown in Fig. 2. Here, V_1 and its

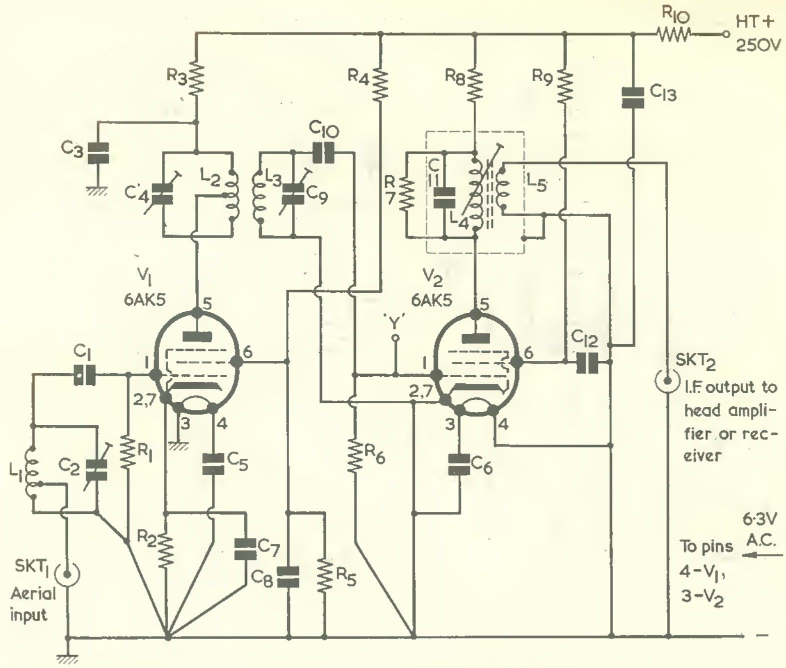


Fig. 1. The circuit of the signal frequency and mixer stages

COMPONENTS

(Fig. 1)

Resistors
(All ¼ watt 10%)

R_1 470kΩ
R_2 220Ω
R_3 10kΩ
R_4 22kΩ
R_5 47kΩ
R_6 1MΩ
R_7 15kΩ
R_8 47kΩ
R_9 470kΩ
R_{10} 4.7kΩ

Capacitors

C_1 1,000pF ceramic
C_2 25pF trimmer, air-spaced
C_3 2,000pF ceramic
C_4 25pF trimmer, air-spaced
C_5 1,000pF ceramic
C_6 1,000pF ceramic
C_7 2,000pF ceramic
C_8 2,000pF ceramic
C_9 25pF trimmer, air-spaced
C_{10} 10pF silver mica
C_{11} 50pF silver mica (see text)
C_{12} 2,000pF ceramic
C_{13} 5,000pF ceramic

Inductors

$L_{1,2,3}$ Shown in Table
$L_{4,5}$ See text

Valves

$V_{1,2}$ 6AK5

Sockets

SKT_1 Coaxial sockets

Miscellaneous

2 B7G ceramic valveholders with skirts and screening cans
Screening can for L_4L_5

associated circuitry functions as the oscillator proper, the frequency being governed by crystal X_1. If the crystal circuit resonates at a fundamental frequency of f kc/s, oscillations at f, 2f, 3f, 4f, etc., kc/s will be found at the anode of the valve. If L_1 is tuned to, say, 3f this new frequency may be fed to $V_{2(a)}$ and amplified. Here again harmonics will be found at the anode, and higher harmonics may be taken off by means of L_2 and C_8, and so on. Using a crystal of fundamental frequency 7333 kc/s would, for instance, enable us to extract 22 Mc/s from V_1, 66 Mc/s from $V_{2(a)}$ and 132 Mc/s from $V_{2(b)}$, which could be fed via a small value capacitor to the mixer circuit. The anode of $V_{2(b)}$ must, of course, be close to the mixer grid to enable the coupling capacitor, C_{13}, to have short leads. With

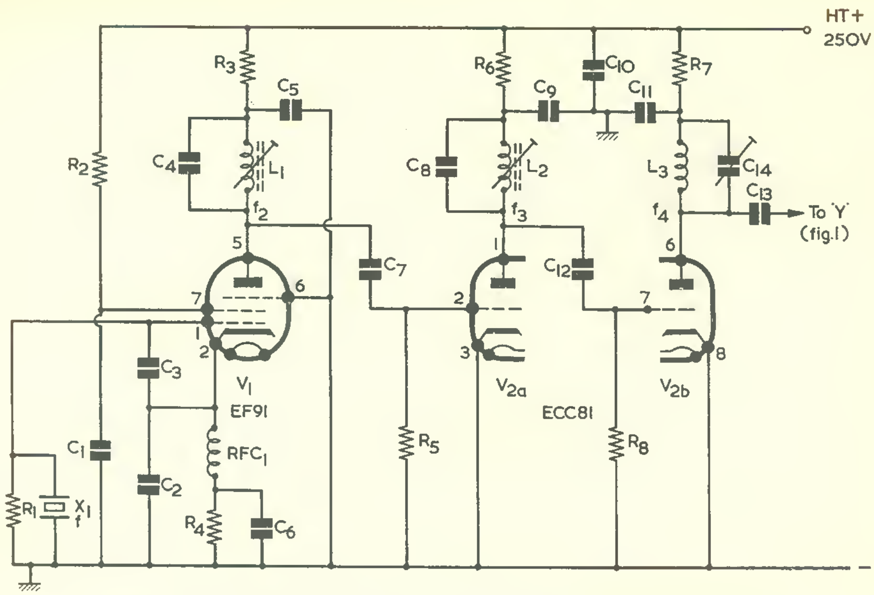


Fig. 2. A simple crystal controlled oscillator and frequency multiplying chain

COMPONENTS

(Fig. 2)

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

R_1	47kΩ
R_2	47kΩ $\frac{1}{2}$ watt
R_3	1kΩ
R_4	220Ω
R_5	56kΩ
R_6	1kΩ
R_7	1kΩ
R_8	56kΩ

Capacitors

C_1	500pF silver mica
C_2	75pF silver mica
C_3	25pF silver mica
C_4	10pF silver mica
C_5	2,000pF ceramic
C_6	2,000pF ceramic
C_7	100pF silver mica
C_8	8pF silver mica
C_9	2,000pF ceramic
C_{10}	2,000pF ceramic
C_{11}	2,000pF ceramic
C_{12}	25pF ceramic
C_{13}	8pF silver mica
C_{14}	25pF trimmer, air-spaced

Inductors

$L_{1,2,3}$	Depend on frequencies required (see text)
RFC_1	R.F. Choke, 1.5mH

Valves

V_1	EF91
V_2	ECC81

Crystal

X_1	FT243 crystal (see text)

Miscellaneous
1 B7G ceramic valveholder with skirt and screening can
1 B9A ceramic valveholder with skirt and screening can
1 Crystal holder

the example just mentioned, the 2 metre band would be tunable on a receiver over its range of 12 to 14 Mc/s (144−132=12, and 146−132=14). Alternatively, for the 4 metre amateur band $V_{2(b)}$ circuitry could be omitted, and the oscillator output taken from L_2 at 66 Mc/s.

Coil details are not given for Fig. 2 (which is intended to demonstrate a simple approach to obtaining the required oscillator frequency) since these will depend on the frequency of the crystal chosen. A grid-dip oscillator will be required to initially bring the coils close to the desired frequency, after which final adjustments may be made by means of dust cores in the case of L_1 and L_2 and trimmer C_{14} in the case of L_3. The final setting of C_{14} should insert only a low capacitance into the tuned circuit. After initially setting up L_1 with the grid-dip oscillator, insert a 0–1mA meter between the lower end of R_5 and chassis and adjust L_1 for maximum current indication. Repeat with L_2, inserting the

TABLE

Coil details for Fig. 1

Coil	144 Mc/s	70 Mc/s
L_1	5 turns, tapped 2 turns from chassis	7 turns, tapped 3 turns from chassis
L_2	4 turns, tapped 1 turn from anode	6 turns, tapped 2 turns from anode
L_3	4 turns, untapped	6 turns, untapped

Coils are wound on a ¼in diameter former and allowed to spring off, using 20 s.w.g. tinned copper wire with turns spaced wire thickness.

milliammeter between the lower end of R_8 and chassis. L_3 is finally set up by inserting the milliammeter between the lower end of R_6 (Fig. 1) and chassis. The crystal used in the circuit of Fig. 2 may conveniently be a type FT243.

The final local oscillator frequency may be either above or below the signal frequency. By using the lower frequency, forward tuning of the receiver results (i.e. an increase in receiver tuning frequency corresponds to an increase in v.h.f. signal frequency) and this is usually more convenient. As may be seen, various combinations are possible and this is fortunate since advantage can be taken of crystals available cheaply or already to hand. It is of course

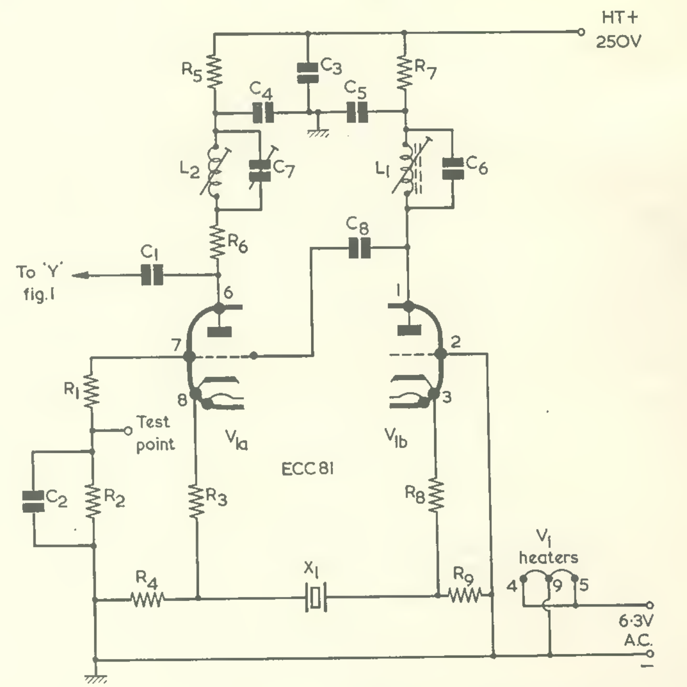


Fig. 3. A practical Butler crystal controlled oscillator and harmonic generator

COMPONENTS (Fig. 3)

Resistors
(All ¼ watt 10%)

- R_1 56kΩ
- R_2 3.9kΩ
- R_3 10Ω
- R_4 270Ω
- R_5 2.2kΩ
- R_6 10Ω
- R_7 2.2kΩ
- R_8 10Ω
- R_9 270Ω

Capacitors

- C_1 8pF silver mica
- C_2 1,000pF ceramic
- C_3 2,000pF ceramic
- C_4 2,000pF ceramic
- C_5 2,000pF ceramic
- C_6 25pF silver mica
- C_7 25pF trimmer, air-spaced
- C_8 100pF silver mica

Inductors

- $L_{1,2}$ See text

Valve

- V_1 ECC81

Crystal

- X_1 Fundamental or Overtone crystal (see text)

Miscellaneous

- 1 B9A ceramic valveholder with skirt and screening can
- 1 Coil former, 0.3in diameter, with dust core
- 1 Crystal holder

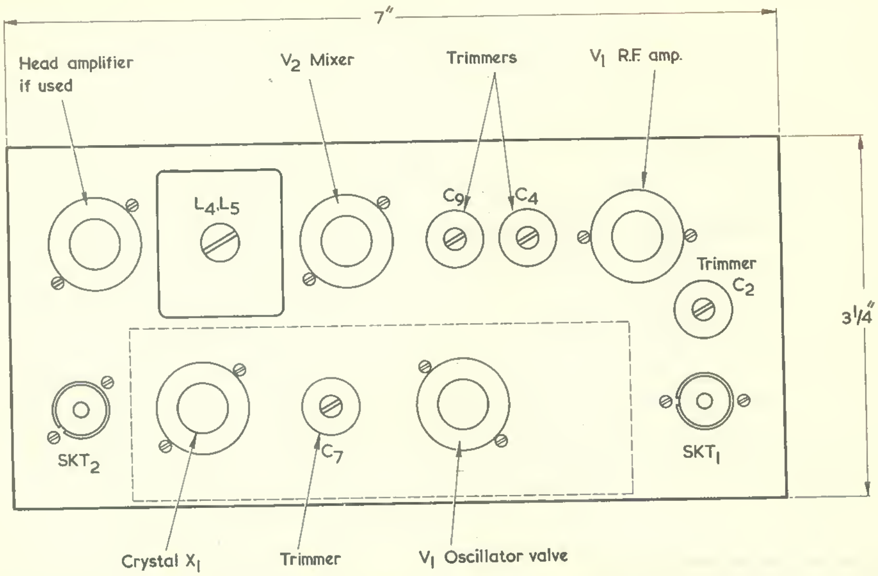


Fig. 4. Above-chassis layout of a v.h.f. converter using the circuits of Figs. 1 and 3. The dashed line encloses the components of Fig. 3 and does not indicate a screen. Chassis depth may conveniently be 2in

necessary to consider exactly what ranges are available on the receiver to be used. Whilst a converter output tunable over, say 12 to 14 Mc/s might be suitable for one receiver it might not be so with another without bandchanging. The first step, therefore, is to select a suitable receiver range and one in which no spurious signals are likely to break through, thereafter selecting a crystal frequency after doing a few simple sums along the lines already described. The final result can usually be varied a little to suit crystals already to hand although care is required to ensure that no frequencies are likely to be generated by the oscillator that can cause harmonics to fall directly in the band tuned over by the receiver.

The coil used for L_4L_5 in Fig. 1 will also require consideration in relation to the output frequency; normally a dust-cored aerial-type short wave coil can be utilised. Screening is essential to prevent unwanted self pick-up at the coil itself. As a guide to suitable coil types, the Osmor coil type QA3 may be used for converter output frequencies of the order of 10 to 13 Mc/s, the Osmor QA2 for output frequencies of the order of 16 to 20 Mc/s and the Osmor QA1 for output frequencies of the order of 23 to 30 Mc/s. The tuned winding (L_4) of these coils connects to tags 3 and 4 and the coupling winding (L_5) to tags 1 and 2. The coil would need to be fitted in a screening can for the present application and a wide adjustment of the dust core may be needed. The value of C_{11} can, of course, be varied up to a maximum of 100pF to obtain a specific tuned circuit frequency.

An Alternative Crystal-controlled Oscillator

The preferred extended Butler-type oscillator is shown in Fig. 3 and this is somewhat easier to get going since fewer stages are needed in order to secure the end-product frequency. In the test model made up by the writer crystal X_1 was a B7G-based item of frequency f_1=10873.3 kc/s, coupled between the cathodes of triodes $V_{1(a)}$ and $V_{1(b)}$, which are sections of an ECC81 valve. Harmonics of the fundamental frequency were tuned at the anode, coil L_1 being adjusted to f_2=43.5 Mc/s (f_1x4) and L_2 to f_3=130.5 Mc/s (f_2x3). The band 144–146 Mc/s is thus tunable on the associated receiver in the range of 13.5–15.5 Mc/s and forward tuning is secured. Alternatively—and where an Overtone type of crystal is to be used—L_1 may be tuned to the overtone frequency and L_2 to the desired multiple thereof with a similar result. Thus, an Overtone crystal marked at a frequency around 44 Mc/s could be multiplied up to around 132 Mc/s. Some variation in the value of R_6 in Fig. 3 may be needed for best results with some crystals.

The Butler oscillator may be checked by connecting a testmeter, set to read 0–1mA, between the Test Point and chassis, tuning the anode coils for maximum indication then temporarily short-circuiting either R_4 or R_9 to chassis, whereupon the meter reading should fall sharply to zero. Thereafter L_1 and L_2 are trimmed to their correct operating frequencies using a wavemeter, or grid-dip oscillator, in conjunction with the testmeter for checking. Each coil is peaked for maximum indication, but remember that successive indications are given as the various harmonics are tuned through; the correct one is found with the wavemeter or grid-dip oscillator.

Coils used by the author for Fig. 3 were as follows. L_1 consisted of 8 turns of 20 s.w.g. enamelled

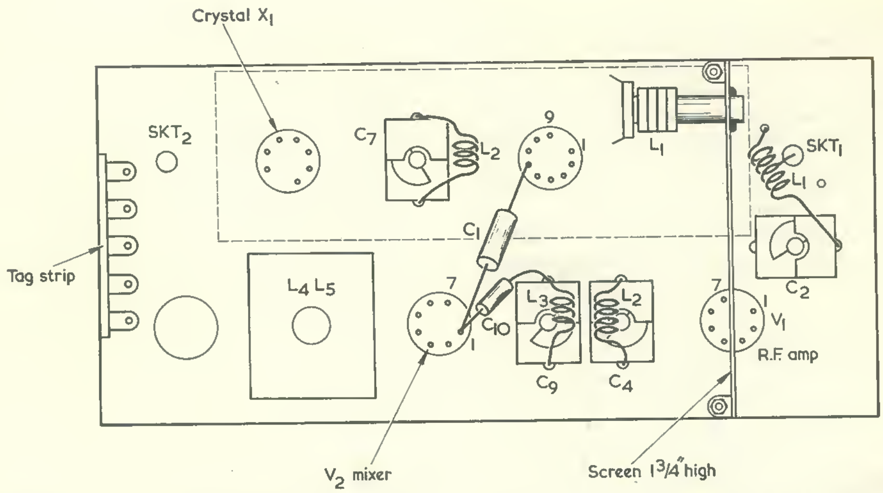


Fig. 5. Below-chassis view of the converter. The oscillator section of Fig. 3 again appears between the dashed lines

copper wire, turns slightly spaced, wound on a 0.3in diameter former fitted with a dust core. L_2 was 4 turns of 20 s.w.g. enamelled copper wire, turns spaced by wire thickness, wound on a ¼in diameter former and allowed to spring off. Some adjustment to coils may be required, and this point is dealt with later. The final setting of C_7 should be such that only a small capacitance appears across L_2. Fundamental B7G-based or HC6/U Overtone crystals may be used.

Layout

A convenient layout for the circuits of Figs. 1 and 3, and as used in the author's test model, is shown in Figs. 4 and 5, and it is doubtful if this can be much improved upon! All wiring at v.h.f. frequencies must, of course, be kept extremely short indeed. The trimmers, which should be kept near their minimum settings, are accessible from the chassis upper surface whilst oscillator injection into the mixer grid circuit is conveniently direct. Note the manner in which L_2 and L_3 of Fig. 1 are coupled together and, also, that the trimmers are the air-spaced type with rotary moving vanes.

Setting Up

Normally, the oscillator section is set up first as outlined earlier, after which attention is given to the signal frequency circuits. With socket SKT_2 connected to the aerial socket of the associated receiver via screened lead, the core of L_4 (Fig. 1) may be adjusted for maximum noise level, the receiver being tuned to the centre of the band to be used (in the writer's case, 14.5 Mc/s). No aerial is used for the present; if signals are heard, spurious break-through is occurring and screening, or probably the receiver itself, is at fault. No v.h.f. signals are likely to be heard at this stage!

Attention is next given to aerial and mixer coils whereupon the use of a signal generator or grid-dip oscillator set at the mid-band v.h.f. signal is required. Some "cut, squeeze and try" is inevitable in order to get these coils adjusted correctly but the operation, although sometimes a little tedious, is quite painless! It is usually most convenient to commence with too many turns per coil, removing half a turn at a time until coverage is correct. Trimmers assist considerably here but should not be allowed to introduce excessive capacitances. Squeezing turns more closely together increases the inductance and lowers frequency slightly, and *vice versa.* The effect of varying the spacing between L_2 and L_3 should also be checked. Optimum mixing efficiency is indicated when a 0–1mA meter inserted between the lower end of R_6 (Fig. 1) and chassis gives a maximum reading. This indicates maximum oscillator input.

The h.t. current drawn by the author's test model incorporating the circuits of Figs. 1 and 3 was 22mA at 250 volts. This current drain increases, of course, if the oscillator stages do not function.

Final slight adjustments are made using transmitted signals, received via a horizontally oriented dipole aerial connected to socket SKT_1. The length of a half-wave dipole aerial, cut centrally and coupled to the receiver via coaxial cable of 75Ω nominal impedance, may be calculated from the simple formula:

$$L=\frac{5616}{f}$$

where L is the total dipole length in inches and f the desired operating frequency in Mc/s. For 144 Mc/s the length is thus 39 inches.

UNDERSTANDING RADIO

Beam Tetrodes and Pentodes

$f = \frac{1}{2\pi\sqrt{LC}}$

by W. G. Morley

In last month's issue we completed our examination of the various classes of operation in which a valve may be employed. These were Class A, B and C, together with the intermediate Class AB. In all cases a subscript figure may be added after the letter indicating the class, this figure being 1 when no grid current flows during the input cycle, and 2 if grid current flows during the more positive parts of the input cycle.

We now turn our attention to the various valves which may be employed in an a.f. output stage.

Output Valves

In the circuits illustrating output stage operation used in these articles up to now, we have shown triode valves in order to render explanation more simple. A.F. output stages may alternatively, however, employ pentode valves or beam tetrode valves instead of triodes. Both the latter types provide a higher output for the same h.t. power consumption than does a triode output valve of comparable type. Also, they are both more sensitive than the triode and require a lower input signal for the same output power. As a result of these two advantages, pentodes and beam tetrodes are almost invariably employed instead of triodes in practical valve a.f. output stages.

We have previously discussed (in the last February and March issues) the use of pentode and tetrode valves as voltage amplifiers, but we have not yet dealt with pentode output valves, nor with beam-tetrode valves. This we shall next proceed to do.

Readers of the earlier issues will recall that the I_aV_a characteristic curves of a tetrode voltage amplifier valve have the appearance illustrated in Fig. 1 (*a*). As may be seen, there is a "kink" in the curves over the range of anode voltages from slightly above zero to somewhat in excess of screen-grid voltage, after which the curves become linear. As was explained in the previous articles the "kink" is the result of secondary electrons from the anode (released by electrons arriving from the cathode) being attracted towards the screen-grid. Indeed, over the section of the characteristic curves where anode current decreases as anode voltage increases, secondary electrons are leaving the anode at a greater rate than the rate of electrons arriving from the cathode, and the curves exhibit negative resistance.

As was also discussed previously, the pentode valve has a suppressor grid at cathode potential interposed between the screen-grid and the anode, its function being to repel the secondary electrons emitted from that anode. In consequence, the "kink" in the I_aV_a characteristic of the tetrode disappears and the I_aV_a curves for the pentode have the general appearance shown in Fig. 1 (*b*). At the right, these curves are similar to the linear sections of the I_aV_a curves for the tetrode, but the linearity now carries on over to the left, continuing to well below screen-grid voltage.

An a.f. output pentode is fundamentally the same as a pentode employed for voltage amplification, apart from the fact that it is designed to operate at higher currents and is therefore capable of feeding a higher power to a load in its anode circuit. The I_aV_a curves of an output pentode have the same appearance as those in Fig. 1 (*b*), which are for a pentode voltage amplifier, except that the output pentode curves would represent a wider range of grid voltages, typically from $Vg=0$ to $Vg=-15$. Also, the currents along the I_a axis would typically be in tens or hundreds of milliamps instead of in single milliamps, as would occur with the voltage amplifier pentode.

Beam Tetrode

An a.f. output tetrode whose I_aV_a characteristic exhibited the "kink" illustrated in Fig. 1 (*a*) would be of little use in practice because of the considerable distortion which would be caused if, during the output cycle, the anode voltage approached the screen-grid voltage. With an output pentode, on the other hand, this type of distortion is absent, even when the anode voltage is considerably below the screen-grid voltage. In consequence, the pentode lends itself very well to use as an a.f. output valve.

The beam tetrode is an output valve which overcomes the effects of secondary emission from the anode in a different manner to that given in the pentode. In the beam tetrode the wires which form the

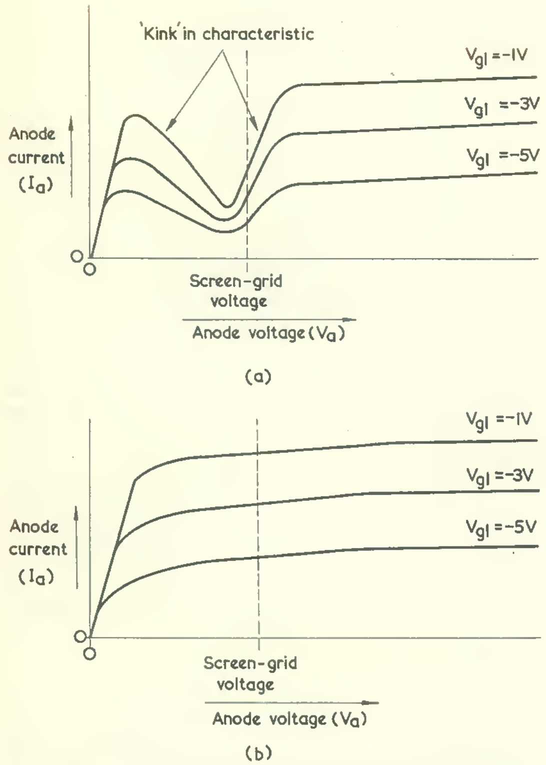


Fig. 1 (a). These I_aV_a characteristic curves for a voltage amplifier tetrode demonstrate the distinctive "kink" given by this type of valve

(b). The "kink" is eradicated in the pentode, due to the presence of the suppressor grid

control grid and screen-grid are in optical alignment. The spacing between wires in both grids is the same and, assuming that the cathode is vertical, are at the same horizontal level. See Fig. 2 (*a*). Also, there is a greater spacing between the screen-grid and the anode than is normal with a pentode.

Looking out from the beam tetrode cathode, the wires of the screen-grid are "shadowed" by the wires of the control grid. Electrons leaving the cathode are forced into horizontal beams by the wires of the control grid, the vertical height of these beams (as shown in Fig. 2 (*a*)) decreasing as the electrons continue towards the anode. If the beam-forming process were perfect, the beams of electrons would pass right through the wires of the screen-grid without striking them, although they would still be subject to the electric field the screen-grid provides. In practice, some of the electrons strike the screen-grid, but the quantity is much lower than with the normal pentode construction. In point of fact, screen-grid current in the beam tetrode is about a third of the screen-grid current in a comparable pentode. After leaving the screen-grid the beams of electrons still continue to converge until, at a vertical plane some distance outside the screen-grid, they achieve maximum electron density per beam. After this the electrons in each beam then fan out vertically and, later, strike the anode. The plane at which maximum electron density occurs can be looked upon as a virtual cathode, and it offers repulsion to secondary electrons released from the anode. So far as the anode is concerned, the virtual cathode is similar to that of a diode, and the same freedom from secondary emission effects is given. Indeed, a feature of the beam tetrode valve is a very rapid rise in anode current as anode voltage is initially increased from zero, this being reminiscent of the performance of a diode with close cathode-anode spacing.

Two *beam forming plates* (also known as *beam confining plates* or, simply, *beam plates*) are fitted around the vertical edges of the screen-grid as shown in Fig. 2 (*b*). These are connected to cathode and cause the horizontal beams of electrons to be confined to the regions where the optical alignment between control grid and screen-grid wires is at its best. Thus, only beams of electrons which are capable of providing the virtual cathode plane are allowed to pass to the anode. (We have referred to a single virtual cathode plane but, as may be seen

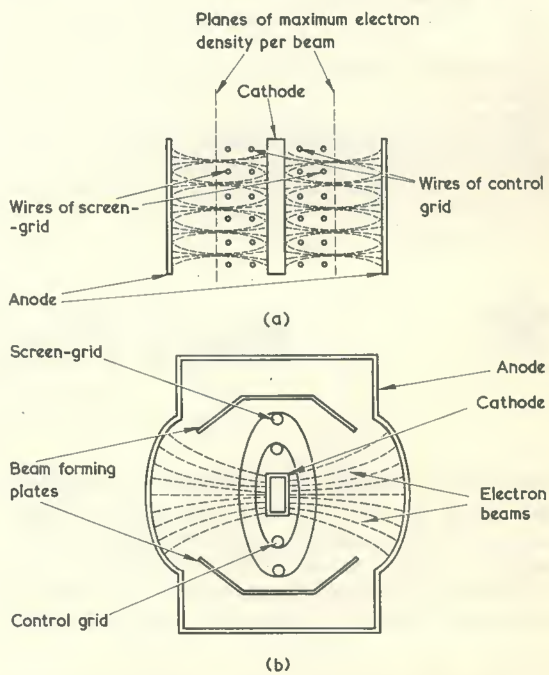


Fig. 2 (a). Cross-sectional side view of a beam tetrode, illustrating how the electron beams tend to converge at two planes of maximum electron density per beam. A practical beam tetrode would have longer electrodes than are illustrated here

(b). Top view, showing how the beam forming plates, which do not appear in (a), restrict the horizontal beams to areas in which the optical alignment between control grid and screen-grid wires has greatest effect

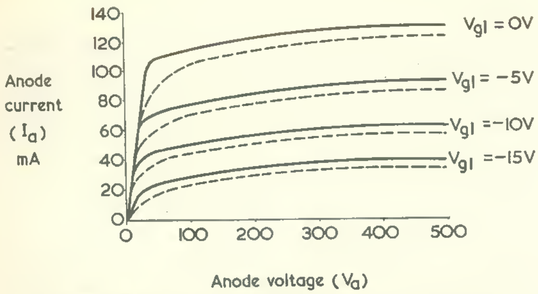


Fig. 3. The solid lines show typical I_aV_a characteristic curve shape for a beam tetrode. The dashed lines represent the I_aV_a characteristic curves of a comparable output pentode

Fig. 4. The circuit symbol for a beam tetrode. The two electrodes between the screen-grid (g_2) and the anode are the beam forming plates. It is common practice to show a connection to one beam forming plate only (as illustrated here) the connection to the other plate being assumed

from inspection of Fig. 2, there are really two similar planes, one on either side of the cathode.)

A typical family of I_aV_a characteristics for a beam tetrode are given in Fig. 3, these being compared with typical output pentode curves, which are shown in dashed line. It will be noted that the linear sections of the beam tetrode curves extend a little farther to the left than occurs with the pentode curves, whose transition from the nearly horizontal condition to the nearly vertical condition is less abrupt. This factor indicates that somewhat more power may be obtained, at an acceptable distortion level, from a beam tetrode than from a comparable pentode.

The circuit symbol for a beam tetrode is shown in Fig. 4. It will be seen that this is similar to that for the pentode except that two symbols to represent the beam forming plates now appear between the screen-grid and the anode in place of the suppressor grid of the pentode. In Fig. 4 the beam forming plates are connected to a separate valve pin, which may be externally connected to cathode (or to chassis). In some beam tetrodes the beam forming plates are connected to the cathode internally.

In the past, beam tetrodes have been described by the term *kinkless tetrode*, the adjective deriving from the absence of a "kink" in the I_aV_a characteristic.

Next Month

In next month's issue we shall briefly examine output pentode and beam tetrode performance, after which we will carry on to the ultra-linear output circuit and, if space permits, the subject of phase-splitters. ✱

★

Micro-Power Amplifier

BY G. SHORT

The low frequency voltage amplifier described in this article has outstanding component economy and operates from a battery input power of a fraction of a milliwatt. Its design illustrates an important difference between silicon and germanium transistors

Looking at conventional germanium transistor circuitry, one is struck by its wastefulness in terms of resistors and capacitors. A typical amplifier stage, as shown in Fig. 1, uses four resistors and three electrolytic capacitors. They are all necessary, of course, to enable the stage to operate properly in the face of temperature and beta variations. The cost of the passive components exceeds the cost of the transistor.

Compare the modern silicon transistor circuit of Fig. 2. This is a three-stage amplifier, but it uses only one more passive component (a resistor) than the single-stage germanium circuit. It is much less noisy than a three-stage germanium amplifier, and provides a voltage gain of about 15,000. The total current consumption is about 0.1mA at 1.5V, or about one-fifth of the consumption of a single typical low-level germanium stage. In terms of power, this high-performance silicon amplifier consumes only 150 microwatts, as against 750 microwatts for the single germanium stage. The total cost of the transistors and components is less than £1.

Direct Coupling

The philosophy behind this design is that the cheapest means of coupling two stages is a piece of wire. If the layout is compact, the piece of wire can be one of the leads of the transistor, so the ultimate in economy is achieved.

The one unusual feature of the design is that the base of one transistor is at the same potential as the *collector* of the previous transistor. To anyone accustomed only to germanium transistor circuitry this looks like a certain recipe for disaster, in the shape of greatly reduced gain, or no gain at all. This is because the working base-emitter voltage (V_{BE}) of a germanium transistor is quite small, usually 0.1 to 0.2V in a low-level a.f. amplifier stage. With direct coupling, as in Fig. 2, this small voltage would be the working *collector*—emitter voltage of TR_1 and TR_2, and 0.2V is not enough. TR_1 and TR_2 would therefore operate with an inadequate collector voltage, and if they worked at all they would provide only a small gain.

Not so with silicon devices, if these are chosen carefully. The working base-emitter voltage for a *silicon* transistor in a low-level amplifier is 0.5–0.7V. There are many silicon transistors nowadays which will work happily with 0.5V on the collector, so it is perfectly in order to use this simple form of direct coupling. It may seem rather surprising that a transistor will work with a collector voltage which is the same as its base voltage, but that is so. Many planar transistors will work with a *smaller* collector voltage than their base voltage!

Stabilisation

Thus, the amplifier of Fig. 2 works quite satisfactorily. Stabilisation of the working points of the various transistors is provided by overall d.c. negative feedback via R_5 and R_1. A.C. feedback is removed by C_2. If C_2 is omitted the circuit will probably oscillate at an ultrasonic frequency, owing to stray phase shifts which turn the negative feedback into positive feedback at some frequency.

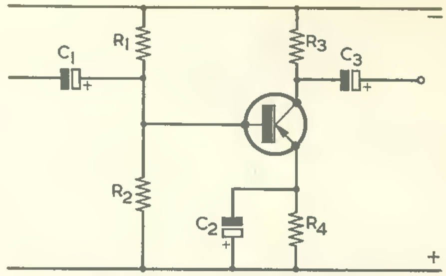
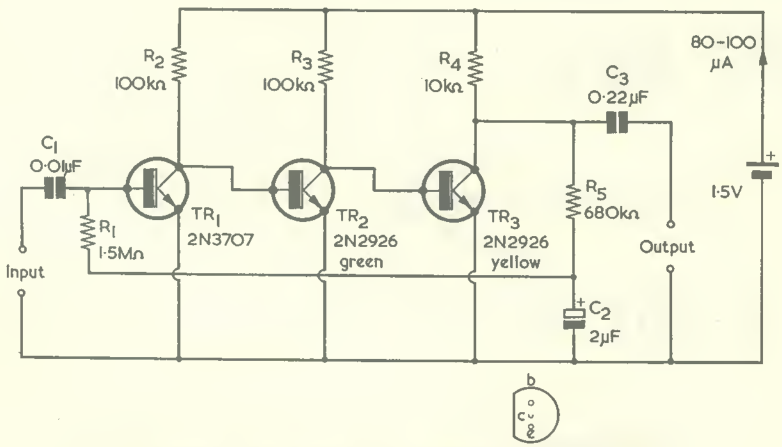


Fig. 1. A typical germanium transistor amplifier stage. The potential divider R_1 and R_2, and the emitter network R_4 and C_2, are necessary for stabilisation but are otherwise wasteful of components

Operation At Other Supply Voltages

At the small expense of substituting a preset potentiometer for R_5, as shown in Fig. 3, the amplifier can be set up to work at voltages above 1.5V, without changing the other components. The current taken from the battery increases in proportion to the voltage. It may also be desirable to use a preset arrangement if there is a wide variation in the current gains of the transistors. Fixed components are, however, satisfactory with the transistors specified here, though the performance will not be optimised for all possible combinations of transistors. (The main result is a slight reduction in maximum output.)



2N3707, 2N2926 lead-outs

Fig. 2. Complete 3-stage micro-power amplifier using silicon planar trqnsistors. Only a few passive components are needed, and the power consumption is very small. (The transistors specified are available from Amatronix Ltd.)

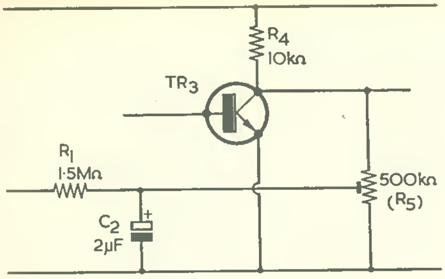


Fig. 3. Method of adapting the circuit of Fig. 2 for use with higher supply voltages

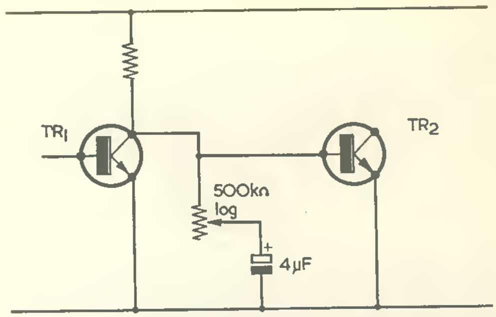


Fig. 4. The best position for a gain control is between the first and second stages. Here the control shunts the input of TR_2

Performance And Applications

The amplifier has a relatively high input impedance (about 200kΩ) because the first transistor has a high gain and operates at a very low collector current.

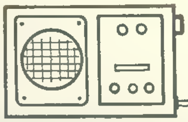
This, coupled with the fact that the whole circuit, including the battery, can be very small, makes the amplifier ideal for use as the output amplifier of a measuring bridge. It may also be used with a crystal microphone to amplify speech signals, and in this case C_1 may be omitted. (If the load is a crystal earpiece, as it may be in bridge work, C_3 may be omitted.)

Selenium or silicon photovoltaic cells ("solar cells") generate about 0.5V, and three of these in series will power the amplifier. A simple "crystal set" using a single diode at the front end then provides a radio receiver. If the r.f. signals are large enough they may be fed straight into the amplifier. The first transistor then acts as a detector.

The frequency response of the amplifier begins to droop at around 3 kc/s, despite the fact that all the transistors have high cut-off frequencies at currents of a few milliamps. This is an inevitable result of using low currents and high collector loads. The peak output voltage is about 0.5V into an infinite load. If a gain control is to be used, it is best placed between the first and second stages. A suitable arrangement is shown in Fig. 4.

The wide-band noise level referred to the input is low, at around 1µV. If the output is filtered by a high-Q tuned circuit, input signals as low as 1µV can be detected. ✱

In your workshop



In last month's issue Smithy passed on to Dick the basic details of integrated thin-film and thick-film circuits. In this episode Smithy completes the integrated circuit story by describing the basic manufacture of semiconductor integrated circuits

"And what," asked Smithy obligingly, "can I do for you, mate?"

The Serviceman brushed the crumbs of his lunch-time sandwiches off his jacket and gazed enquiringly at his assistant.

"Can you," replied Dick promptly, "complete the discussion we've been having on integrated circuits? You'll remember that the last time we had a technical natter together you told me about thin-film and thick-film circuits, after which you said that there was another type of integrated circuit called the semiconductor integrated circuit, and that you'd have to leave this until a later date. And you finally promised to have a bash at it during lunch-break today."

Semiconductor Integrated Circuits

"Did I?" replied Smithy. "Very well then, I won't waste time and I'll get down to it straightaway. If you think back to what I said during our last gen-session together, you'll remember that thin-film and thick-film circuits have a substrate, or bottom supporting layer, which is normally made of ceramic. On to this substrate are deposited, through masks which act as stencils, films of conductive and resistive material. These form a pattern which allows a circuit to be made up on the surface of the substrate. Capacitors may also be made up as an integral part of a thin-film or thick-film circuit, or they can be added in the form of flip-chips. Transistors and diodes can also be added as flip-chips. To finalise on what I said on the previous occasion, you may recall that I told you that the transistor and diode flip-chips were tiny squares of silicon into which the transistor or diode had been formed. O.K.?"

"Yes," replied Dick. "I remember all that."

"Good," said Smithy briskly. "Then, let's now approach the semiconductor integrated circuit. However, it will be better if, instead of tackling this immediately, I first go through an intermediate step by briefly describing how n.p.n. silicon planar transistors are made. This is because the manufacture of silicon planar n.p.n. transistors gives an excellent introduction to the more complex techniques used for semiconductor integrated circuits. As I'll have to sketch out some diagrams to explain what I'm driving at, you'd better come over to my bench."

Obediently, Dick took his stool over to Smithy's side, whilst Smithy selected a clean sheet from his note-pad.

"Silicon planar transistors," commenced Smithy, "are made in large quantities on single circular slices of silicon. Each slice is cut from a pure silicon crystal which has been doped with an n-type impurity, and it may have, typically, a diameter of about three-quarters of an inch or so. The slice is very thin and the idea behind the manufacturing technique is to make hundreds of silicon planar transistors in it."

"Hundreds?"

"That's right," confirmed Smithy. "Hundreds! If the final individual transistors are of a type that's small in size you can get thousands, even. These transistors are obtained, after processing the slice, by breaking it up into tiny squares, or 'chips', one for each transistor. But that happens much later, so let's get down to the first manufacturing process. This consists, after the slice has been polished and cleaned, of forming an oxide layer over it. The oxide layer is given by heating the slice to around 1,000°C in an atmosphere of pure oxygen or steam, and the favourite approach here seems to be to use oxygen. The result of this process is that a hard layer of silicon dioxide—which is a glass—is formed on top of the slice. So, after the first stage of manufacture has been completed, you have a substrate of n-type silicon with silicon dioxide on top."

Smithy applied his pen to his note-pad. (Fig. 1 (*a*).)

"The next job," continued Smithy, "is to apply a photo-resist liquid all over the top surface of the slice. That is, on top of the silicon dioxide layer. This photo-resist becomes hard when exposed to ultra-violet light. In the process that follows, a photographic mask is interposed between the slice and a source of ultra-violet light. This mask causes a central section on every transistor it is eventually intended to obtain from the slice to be in shadow, whereupon the photo-resist around that central section goes hard, because it is exposed to the ultra-violet light, whilst the photo-resist in shadow at the central section stays soft. The next stage consists of washing the slice in a solvent which removes the unexposed photo-resist, whereupon we have a central section on each transistor where the silicon dioxide layer is exposed, all the rest of the surface being covered with hard photo-resist. The slice is then subjected to etching. The etching fluid contains hydrofluoric acid and it dissolves all the silicon dioxide which is not covered by the photo-resist. Finally, the photo-resist is itself removed, whereupon each transistor section in the slice consists of an n-type substrate covered with silicon dioxide except for a 'window' in the centre where the silicon dioxide has been etched away." (Fig. 1 (*b*).)

"Blimey," remarked Dick. "That's a dickens of a lot of work just to get a hole in the silicon dioxide, isn't it?"

"It is rather," admitted Smithy. "It's a somewhat long-winded business to explain, too, when you do it step-by-step, and I haven't included all the intermediate cleaning processes which may be required. However, that's by the way, and what we have now obtained is a silicon slice on whose surface each embryo transistor has a window at its centre. The slice is then ready

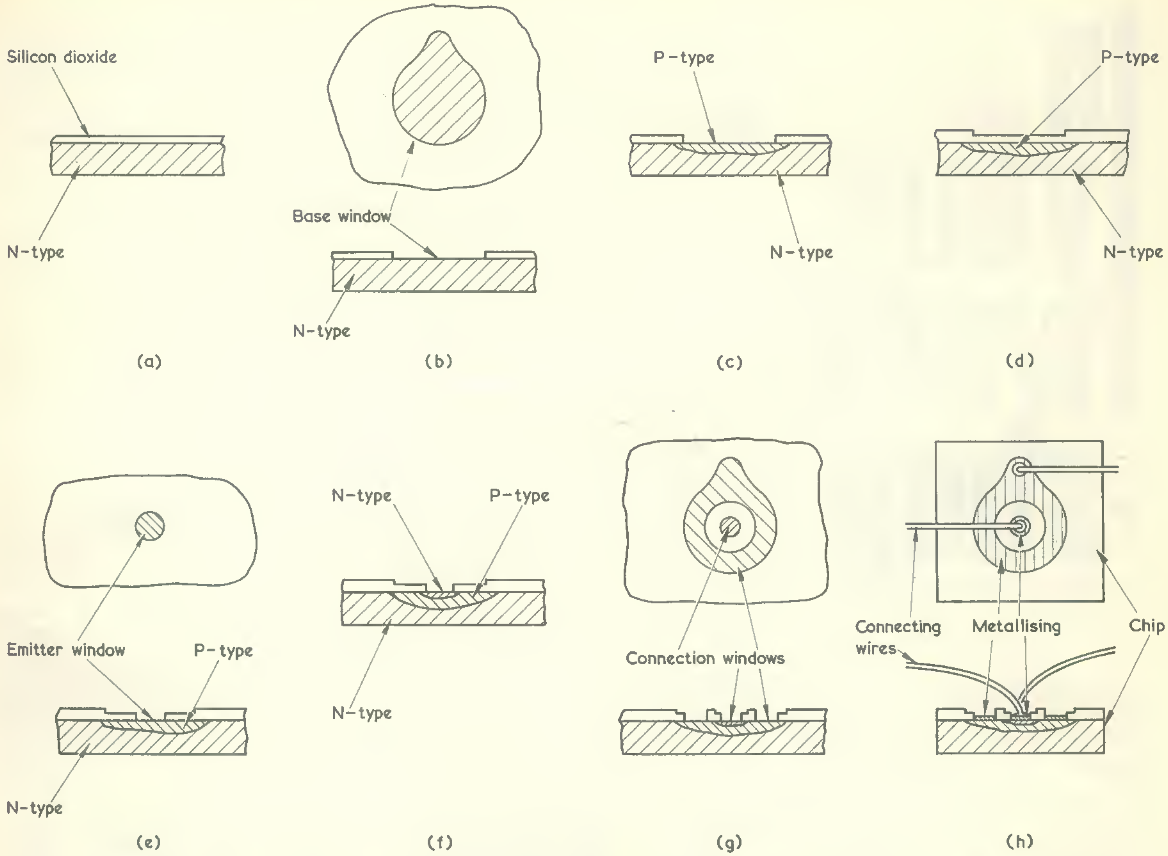


Fig. 1 (a). Part of an n-type silicon slice in which many hundreds of silicon planar transistors are to be made. A silicon dioxide layer is initially formed on its upper surface
(b). Etching the window for the base diffusion. The 'pip' in the window outline accommodates a connecting wire later. (Alternative window shapes are used for some silicon planar transistors)
(c). P-type impurities are diffused through the window to provide the base
(d). A further layer of silicon dioxide is formed on the slice
(e). Etching the window for the emitter diffusion
(f). Diffusing n-type impurities through the window of (e) to form the emitter
(g). Following the emitter diffusion a further layer of silicon dioxide is formed, after which base and emitter connection windows are etched, as shown here
(h). Metallising is deposited in the emitter and base connection windows whilst the transistor is in the slice. Wires are later connected to this metallising after the slice has been broken up and the transistor is in chip form

for what is called the first diffusion."

"First diffusion, eh?" remarked Dick. "That sounds interesting."

"It is," agreed Smithy. "What is more, we're getting on to other processes which are even more interesting. For the first diffusion the slice is heated up again, this time in an atmosphere which contains p-type impurities. The p-type impurities first neutralise and then predominate over the n-type impurities immediately under the windows and diffuse into the silicon, with the result that the substrate is still n-type silicon, but each transistor-to-be has a diffusion of p-type silicon under its centre window. (Fig. 1 (*c*).) There is a neutral plane along which the p-type and n-type impurities balance each other, and this provides a p.n. junction. So what we have done up to now is to create a p.n. diode. Actually, we've created hundreds of p.n. diodes because there were hundreds of windows in the silicon slice, each window appearing at the centre of each future transistor."

Second Diffusion

"This," remarked Dick, "is getting quite fascinating. What happens next?"

"Another layer of silicon dioxide is formed on the surface of the slice," replied Smithy. "This is done by heating the slice in an oxidising atmosphere in the same manner that occurred at the beginning. This heating process can, incidentally, also be the ultimate heating process which causes the first diffusion to finally settle down and establish itself in the substrate. Our silicon slice is now once more covered all over with silicon dioxide. The silicon dioxide over the p-type impurity sections will be thinner than over the rest of the slice, because these parts had no dioxide on them at all before the last oxidising process started. (Fig. 1 (*d*).) But that doesn't matter and is incidental so far as we are concerned here. The slice then undergoes another photo-etch set of operations using a different mask this time which puts in shadow a smaller central section of each transistor. The slice leaves this process with every future transistor having a small central window over the middle of its p-type diffusion. (Fig. 1 (*e*).) The slice then has its second diffusion, this time in an atmosphere which carries n-type impurities. (Fig. 1 (*f*).) The consequence is that there is an n-type diffusion into the first p-type diffusion whereupon, starting from the top centre, we now have n-type silicon, p-type silicon and n-type silicon. In other words we've got an n.p.n. transistor!"

"Gosh," breathed Dick. "That really *is* something."

"It certainly is," agreed Smithy, "especially when you remember that there are hundreds of these transistors in the single slice of silicon. I should add, by the way, that the n-type substrate forms the collector of the transistor and the second n-type diffusion the emitter. After which statement let us proceed to further wonders. The next job consists of heating up the slice in an oxidising atmosphere again so that its surface is once more covered with silicon dioxide. After that there is a photo-etch process which provides windows at the emitter and base for *connections*. In a typical n.p.n. silicon planar transistor, a small central window is provided for the connection to the emitter, and a concentric annular window is provided for the base." (Fig. 1 (*g*).)

"Annular?"

"In the shape of a ring," explained Smithy, "like an American doughnut. Now, our silicon slice has windows in it at all the places where base and emitter connections are needed. The whole surface of the slice is next covered with a thin film of aluminium using techniques similar to those for the thin-film deposits which we discussed during our last technical chin-wag. Another photo-resist and masking process follows, after which all the aluminium is etched away except for that in the emitter and base windows. The slice is then heated again, just sufficiently to cause a good connecting bond to be given between the aluminium deposit and the silicon of the emitter and base. Later on, after the slice has been broken up, connections can be made, with suitable thin wire, to the base and emitter metallising." (Fig. 1 (*h*).)

"How do you connect to the collector?"

"The collector connection," replied Smithy, "is to the back of the slice, and this back has also to be prepared for connection. Silicon is etched away from the back of the slice to reduce its thickness and thereby improve subsequent operation as a transistor and increase heat dissipation from the base-collector junction. The back is then cleaned for later securing to the base plate of the transistor can. This plate is normally gold-plated and gives a good bond to the silicon chip obtained after breaking up the slice when the pair are heated. But, at the moment, our transistors are in the slice stage. We have hundreds of embryo transistors in the slice, and all of these share a common collector material which is, of course, the substrate. Whilst still in this state, the slice is next given an initial electrical test on a piece of equipment which causes fine pointed probes to be applied to each emitter and base combination in turn. If this equipment detects faults in any of the future transistors, these are marked with ink whilst still in the slice. The slice is next scribed with two sets of parallel lines at right angles so that each square so produced contains a transistor. The slice is then broken across these lines into individual chips, each consisting of a transistor. The good ones—that is, the ones which aren't marked with ink—are finally mounted in their cans and connected up, ready for final testing."

Semiconductor Integrated Circuits

"Phew," remarked Dick. "I must say that all this does sound complicated."

"I'll agree that quite a number of processes *are* involved," concurred Smithy, "but the procedure nevertheless lends itself very well for mass-production, because of the large quantity of transistors that can be produced once the production line has been set up. Anyway, that's all we need to know about the silicon planar transistor at this stage. Once you've grasped the basic manner in which this type of transistor is manufactured it becomes a lot easier to carry on to the semiconductor integrated circuit. As you'll soon be able to see, a semiconductor integrated circuit—or silicon integrated circuit, as it's also called—is made by following pretty nearly the same techniques as are used for the silicon planar transistor. For instance, semiconductor integrated circuit manufacture commences with a slice of silicon which is finally broken up into little square chips, just as with the planar transistor. In this case, though, each chip consists of an integrated *circuit*. Now, each chip will have more than one transistor in it, so we can't follow the planar transistor techniques exactly or we'd end up with all the transistors on a chid sharing the same collector, just as occurred with all the planar transistors on the slice before the slice was broken up. To get over this snag there is an additional first step with the integrated circuit which I'll now explain."

Smithy picked up his pen again.

"With integrated circuit manufacture," he continued, "we don't start off with a slice of n-type silicon for the substrate. We start off, instead, with a slice of p-type silicon. (Fig. 2 (*a*).) We then cause an epitaxial layer of n-type silicon to be grown on the surface of this p-type silicon. (Fig. 2 (*b*).) Because of this initial process we obtain a substrate of p-type silicon to provide mechanical strength for

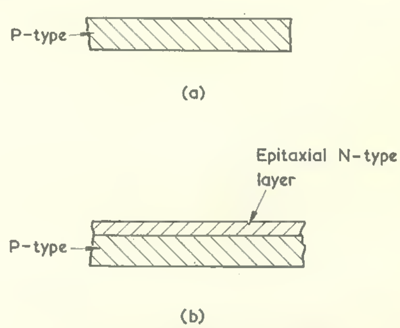


Fig. 2 (a). The semiconductor integrated circuit commences with a p-type silicon slice (b). An epitaxial n-type layer is grown on the p-type slice

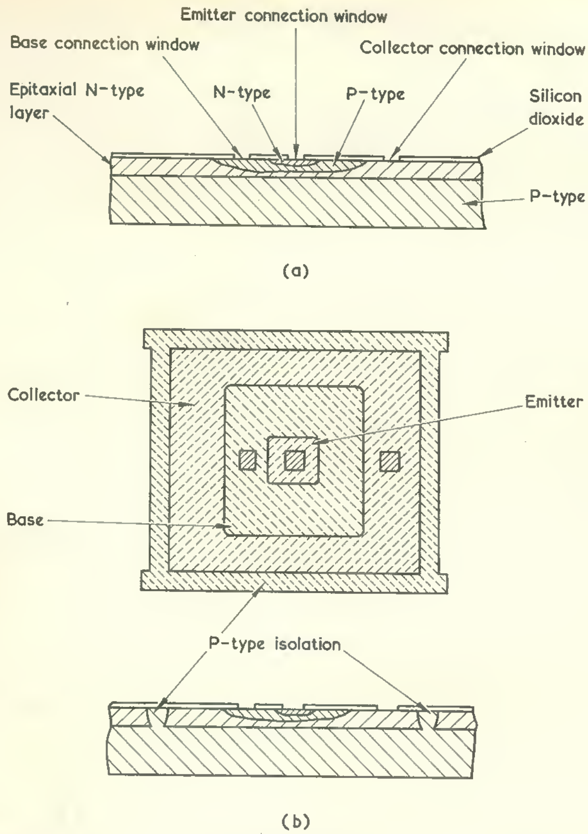


Fig. 3 (a). Diffusing an n.p.n. silicon planar transistor into the epitaxial n-type layer of an integrated circuit slice
(b). The transistor may be isolated from other components by diffusing a p-type isolating wall all round it. Note the tendency, with semiconductor integrated circuits, for diffused elements to be square or rectangular in outline

the slice, together with a layer of n-type silicon on top into which we can diffuse transistors and any other components we want to make up. Hallo, what are *you* making faces about?"

"I'm still stuck," replied Dick, frowning, "at the epitaxial layer bit! What does 'epitaxial' mean?"

"It refers to growing a further layer on an existing crystal surface," explained Smithy, "the further layer taking up the crystalline structure of the initial crystal, so that the whole is still equivalent to a single crystal. To grow the epitaxial layer of n-type silicon on the original p-type slice, for instance, the p-type slice is heated in a mixture of gases containing a compound of silicon and chlorine and a compound which includes an n-type impurity. The silicon in the gases then becomes gradually deposited, together with the n-type impurity, on top of the p-type crystal. As a rough analogy, it's rather like the growing of copper sulphate crystals in a saturated solution of copper sulphate, which you may have done at school. In the present case, the epitaxial process causes a layer of n-type silicon to be formed on the p-type slice, the whole retaining a single-crystalline structure. All right?"

"Yes, I think so," stated Dick.

"I should mention," added Smithy, "that it would be possible to make very simple integrated circuits using, say, a few diodes, without bothering about the epitaxial layer. But the practical integrated circuits we are are now going to talk about all have the epitaxial n-type layer. Let's start off by making an n.p.n. planar transistor in our slice. Or, rather, a large number of n.p.n. planar transistors, of which there'll be more than one in each chip when the slice is eventually broken up. I shan't bother to go into any details concerning the oxidising, photo-etching and diffusion processes, because these follow the same lines as occurred with the silicon planar transistor. We commence with a diffusion which gives up p-type silicon for the base of each transistor, followed by a second diffusion to give n-type silicon for the emitter. (Fig. 3 (*a*).) So we now have what seems to be quite a respectable n.p.n. silicon planar transistor, in which the base is the p-type diffusion, the emitter is the n-type diffusion, and the collector is the n-type silicon which was epitaxially grown on the p-type substrate. Note that the transistor appears in the n-type epitaxial layer only, and is not in contact with the p-type substrate. The epitaxial layer and the substrate form an n.p. diode, but this diode will be reverse-biased if the substrate is made negative of the epitaxial layer. So, if the p-type substrate is always kept negative of the n-type epitaxial layer—and this can be done by, say, returning the substrate to the most negative point in the circuit—the n.p. junction acts as an insulator. Our transistor is, therefore, isolated from the substrate."

"Whoa-up!" protested Dick. "There's a snag here! I can see that all transistors made up in the slice are now isolated from the substrate. But you're now talking about more than one transistor per *chip*. This means that they'll be sharing the *epitaxial layer* as a common collector. They'll be coupled together by this epitaxial layer, and you're back to Square One again!"

Isolation

"You," remarked Smithy, as he beamed fondly at his assistant, "are a very brainy lad and the light of my declining years."

"Gosh," said the startled Dick. "What brought *that* on?"

"Your statement did," replied Smithy, "because it is an extremely pertinent one and demonstrates that you're right on the ball so far as integrated circuit basics are concerned. You are quite correct in what you say and, as things stand at present, all the transistors in a chip *would* share a common collector. We overcome this problem with an additional p-type diffusion which wasn't required with the silicon planar transistor. This diffusion causes a continuous wall of p-type silicon to be diffused all round any transistor which has to be isolated, the diffusion going right on through to the p-type substrate. (Fig. 3 (*b*).) Because of this diffusion each transistor can now be completely isolated from any other transistor, or from any other component which may be diffused elsewhere in the epitaxial layer. It's like a boat in a sea of p-type silicon! This isolation trick can be used for any transistor or component which appears in the integrated circuit."

"That's a neat idea," said Dick, looking closely at Smithy's sketch. "If the p-type substrate is kept negative, so also are the p-type isolating walls that are diffused through to it, whereupon any component surrounded by the p-type silicon becomes completely isolated."

"That's exactly right," confirmed Smithy. "As you can now understand, the idea of working with an epitaxial n-type layer on top of a p-type substrate makes it possible to form really complicated circuits using a lot of components on a single silicon chip. All the components can, where necessary, be isolated from each other by diffusing p-type walls between them right through to the substrate."

"This," remarked Dick, "gets even more fascinating, Smithy."

"Microelectronics," confirmed Smithy, "which is a blanket term to cover all integrated circuit principles, *is* fascinating. But I must next introduce a complication. Whilst the transistor we have produced up to now appears to be quite a reasonable-looking device, a few minor details need altering if it is going to work really well. To start off with, my sketches have not demonstrated the fact that the epitaxial layer on the substrate is very thin indeed. Typically, its thickness would be 0.0004 inch. In terms the micrometer-twiddlers would prefer to use, that's just four-tenths of a 'thou'. The n-type collector of the transistor we have been considering is similarly very thin, and it's even thinner in the area under the base. Unless suitable steps are taken, therefore, this very thin collector will exhibit a high series resistance. The high series resistance effect is overcome in practice by means of a buried diffusion of n+ silicon in the p-type substrate, the buried diffusion appearing under nearly all the area of the collector."

"I *knew* that things were going too easily up to now," stated Dick forlornly. "I *knew* that we'd bump into something really baffling sooner or later! How on earth can you have a buried diffusion under all the stuff that's already on the substrate, and what's n+ silicon anyway?"

"The buried diffusion," replied Smithy, "is quite simple. It's a diffusion that's made, in the required places, *before* the epitaxial n-type layer is formed. And don't worry about the n+ business. An n+ semiconductor is one having a large quantity of donors or, to put it more simply, an n-type semiconductor which has been more heavily doped than usual. The plus sign is added after the 'n' to differentiate it from the normal n-type material. The main reason for using n+ semiconductor is that it has a lower resistance than the n-type stuff. In consequence, by having a buried diffusion of n+ material under the n-type collector of the transistor, and in contact with it, the overall resistance of that collector becomes lowered. Because of the lower resistance of n+ silicon it's also a good idea to diffuse some of it into the n-type material at the window where the connection to the collector is to be made. (Fig. 4.) This ensures that a good low-resistance connection is given at this point. With integrated circuit transistors, the diffused emitter is normally of the n+ type as well, although the problems of resistance are not so difficult here because of its smaller size."

Smithy broke off for a moment.

"Before going farther," he said, "we'd better have a quick recap on the manner in which that integrated circuit transistor has been formed. This is because, to make the explanation easier, I have purposely introduced some of the manufacturing processes in a different order to that used in actually making the transistor up. So, to keep the record straight, I'll now go through the manufacturing steps in their correct order. We commence with our p-type silicon slice and the first thing we do is to make the buried n+ diffusions at the places where the transistor collectors are going to be. We next add the epitaxial layer of n-type silicon. The following step is the diffusion of the p-type isolating walls, right down to the substrate, which are going to isolate the components from each other. This step has to be done at an early stage because a very heavy diffusion is needed here. It is after this that we diffuse the base. We next diffuse the emitter, normally with n+, and for good measure squirt a bit of n+ into the connection window for the collector as well. All these processes will, of course, require different masks and all the paraphernalia of oxidising, photo-etching and so on, which we've already observed for the silicon planar transistor. Whilst the base and emitter we've been considering were being diffused, so also were the bases and emitters of the other transistors in the integrated circuit. Resistors are diffused at the same time as the bases."

"How," asked Dick, "are the resistors done?"

"By diffusing a rectangle of p-type silicon into the n-type epitaxial layer," replied Smithy. "Like the thin-film resistors we talked about last month, you then talk in terms of so many ohms per square, a typical practical figure being of the order of 100 to 200Ω per square. (Fig. 5.) It's difficult to get tolerances of better than plus or minus 20% with this process and this factor has to be taken into account when designing the circuitry of an integrated circuit. The p-type material forming the resistor and the n-type epitaxial layer give a diode, of course, and it's necessary to ensure that the potentials on each of these materials are such that the diode is reverse-biased. If capacitors are required, these can be given by reverse-biased diodes, the capacitance being given by the junction capacitance. Or a capacitor can be formed by diffusing an n+ area in the n-type layer, suitably processing the slice to get a silicon dioxide layer of the

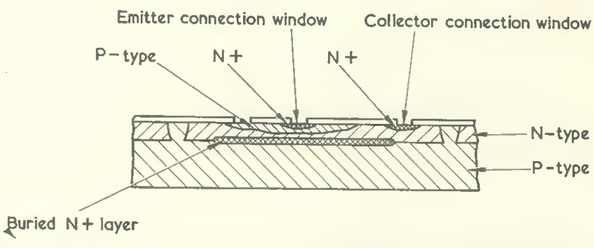


Fig. 4. To reduce the series resistance of the collector a buried diffusion of n+ silicon is made before the epitaxial layer is added. Silicon of the n+ type also appears at the emitter and collector connections

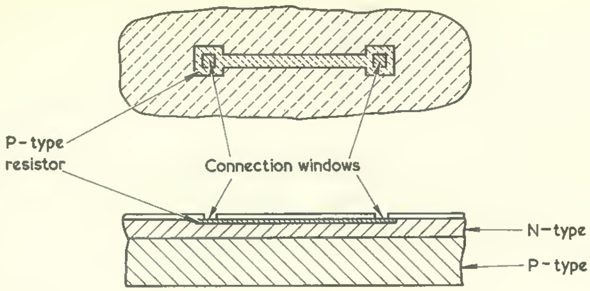


Fig. 5. A resistor is formed by a rectangular diffusion of p-type silicon. The rectangle shown here has a length 12 times as great as its width, giving a resistance equal to 12 squares

required thickness over this area and applying the metallising which is used to finally connect all the parts in the circuit together to form the upper plate of the capacitor. (Fig. 6.) As with thin-film and thick-film circuits, inductors are avoided in the semiconductor integrated circuit."

"How many parts can you get in a completed circuit?"

"That," said Smithy, "is where we come to the almost incredible thing with silicon microelectronics. It is, for instance, quite commonplace to have about twenty transistors and about as many resistors in a chip measuring a millimetre square only. Some manufacturers are, indeed, talking about a component density of 2,000 components per chip in a few years' time. Anyway, before talking about complete circuit design, I'd better finish discussing the final stages of production. These are of the same type as with the silicon planar transistor. After all the components have been diffused into the chip there is a final process in which the interconnections are made, this consisting of applying a layer of metallising and etching away the unwanted bits. There will also be metallised areas on the edges of each circuit, to which external connections can later be made. Each integrated circuit on the slice is then tested by a multi-probe device working on the same basic principles, so far as connections are concerned, as with the silicon planar transistors, any faulty integrated circuits being similarly marked at this stage. The slice is next scribed and broken up into individual chips, each of which consists of a complete integrated circuit. Each chip is then fitted in a housing of some sort and connected up to the lead-out terminations of that housing. A popular housing is a modified TO-5 transistor can. Alternatively, the chip can be fitted in a flat plastic housing with termination lead-outs appearing at the sides."

Integrated Circuit Design

"How," asked Dick, "do the manufacturers set about working out the circuitry for an integrated circuit?"

"That's quite a specialised procedure," replied Smithy, "and it's different to normal electronic circuit design. With semiconductor integrated circuits there are a lot of limitations which have to be allowed for, and these place considerable demands on the ingenuity of the designer. For instance there are parasitic diodes all over the place. The n-type collectors of all transistors form n.p. diodes with the substrate. These diodes are reverse-biased, of course, but they still exhibit a fairly high capacitance, and this has to be borne in mind. If you look closely at the sketch of the transistors in the integrated circuit (Fig. 4) you'll see that there's a parasitic p.n.p. transistor there, too, the last 'p' being given by the substrate. There's even a parasitic n.p.n.p. device which might conceivably act as a silicon controlled rectifier! All these parasitics have to be allowed for in the design. Another point is that all the metallic interconnections on the surface of the chip between components must be capable of being carried out in the same plane, as in a normal printed circuit. You can't have a length of the final interconnecting metallising 'bridging' another length. So far as components are concerned, the most economic ones are the ones which take up least space. Because of this, a transistor is much more economic than a high-value resistor. This is why, whenever you see the circuit of a semiconductor integrated circuit drawn out, it seems to be absolutely bristling with transistors. Since diodes are relatively easy to make, you'll find plenty of these, too, in integrated circuit designs. To give an idea of the philosophy behind integrated circuit design for applications with which we are familiar, as early as last year R.C.A. in America introduced an integrated circuit in some of their TV receivers. This functioned as intercarrier sound amplifier, f.m. sound discriminator and audio pre-amplifier. It even held the circuitry needed to provide regulated supply voltages for some of its own stages, and the only components external to the integrated circuit were two intercarrier frequency transformers and a 0.1μF bypass capacitor. The chip had 12 transistors, 12 diodes and 14 resistors in it. That makes you think, doesn't it?"

Final Points

"I'll say," agreed Dick. "Stap me, if these integrated circuits *do* get into domestic electronic equipment in quantity we'll be more like watch-repairers than radio servicemen!"

"I'd better point out before finishing," stated Smithy cautiously, "that I've only given you a very general background information, and that I haven't covered all the field by any means. Still, what I've told you should help you to under-

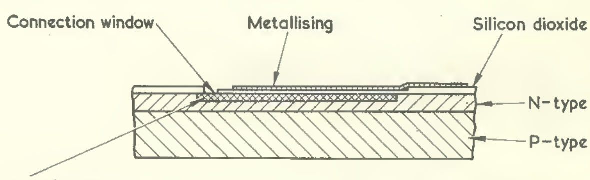


Fig. 6. One method of obtaining an integrated circuit capacitor. One plate is an n+ diffusion, the other plate is the inter-connection metallising, and the dielectric is the silicon dioxide on top of the epitaxial n-type layer

stand what integrated circuits are and how they work. The semiconductor integrated circuit I've been talking about is also called a monolithic integrated circuit, the word 'monolithic' meaning that it's all made out of one single piece of material. You can have hybrid integrated circuits which use a combination of several techniques, say monolithic and thin-film. As I said last time, you can add a flip-chip to a thin-film or thick-film circuit. This then gives you a hybrid integrated circuit. A flip-chip, incidentally, is merely a silicon chip designed for connection to thin-film or thick-film circuits. There are also integrated circuits using field-effect transistors, and I have'nt mentioned these. Another thing I haven't mentioned is that you'll quite often bump into the term 'linear amplifier'. A linear amplifier is an integrated circuit capable of amplifying a signal in the same way as a conventional amplifier, although the actual amplification provided may not necessarily be linear. The term 'linear' is used to differentiate this type of integrated circuit from logic integrated circuits, the latter being flip-flops and similar devices intended for digital processing. Both types are made up in the same way, but their functions are different."

Smithy glanced at the Workshop clock, and started.

"Phew," he remarked. "Once more we've had a gen-session which has extended well into working time. Back to the grind, Dick my lad!"

At which request, Dick, who had been surreptitiously keeping an eye on the clock for at least the last quarter of an hour, returned thoughtfully to his bench without raising any of his usual objections. Indeed, as they worked through the afternoon, dealing with conventional entertainment equipment, both he and the Serviceman found themselves fully preoccupied with thoughts that rested more on the Lilliputian world of the future, than on the jumbo-sized domestic electronics of 1967.

Local T.V. for Middlesex Schools

One of the most ambitious educational television schemes in the country is planned to begin operations early next year at Hillingdon in Middlesex. The television studio will be at the new Brunel University. The audience will be children at schools in the Hillingdon Borough.

Experimental transmissions via coaxial cable to nine local schools will pave the way for a full scale network to the hundred-plus schools and to adult education centres in the Borough. The programmes, which will be carefully selected to augment the normal curriculum, will be originated at the University studio to be equipped by EMI Electronics Limited.

Five of EMI's latest CCTV cameras, including the BC.920, which was specially designed for educational and other small studio installations, and the BC.900 for telecine and caption work will be employed together with full sound and vision mixing/switching facilities. The BC.920 is a semi-professional turret camera incorporating side focusing control, a 4-inch electronic viewfinder, cue light and full communications facilities.

Television will also be used extensively as a visual aid in the University's own teaching programme. Transmissions will be relayed to a suite of six lecture theatres, where a question-and-answer system under the direct control of the lecturer in the studio is also to be installed.

Director of Television Services at Brunel is Mr. G. H. Noordhof, B.Sc., A.R.S.M., an experienced producer of educational television programmes, including "Dawn University" networked by Anglia TV. The Director of Educational Television to the Hillingdon Borough is to be Mr. J. M. Jones, who is at present Senior Lecturer (Television) at Bolton College of Education. Mr. Jones has a wide teaching experience and was formerly Assistant Head of the Information and Research Division of the Centre for Education Television Overseas.

Radio Topics

By Recorder

WELL, WHAT DO YOU THINK about colour TV? Not at all bad, is it?

It will be a little while yet before the Recorder household has its own colour TV receiver and this is one particular sphere of domestic electronics in which I am quite definitely *not* going to attempt to produce a home-designed receiver!

Colour TV Kits

I see, nevertheless, that Heathkit, in U.S.A., have had two colour TV kits available for quite some time now. In their reviews in the technical press, these kits are reported to be easy to put together and to give excellent results. Total assembly and setting-up time is around 25 hours and both models have their own built-in dot generator for convergence and purity adjustments. One kit, offering a viewing area of 295 sq. in, sells at $479.95, and a second, with a viewing area of 180 sq. in, sells at $379.95. Both prices are less cabinets, which are also available. The first screen size is approximately equal to 25in diagonal and the second to 19in diagonal. (I should add that, after recent Federal Trade Commission rulings specifying the manner in which TV screens may be referred to in advertising matter it has become customary, in the U.S.A., to quote viewing area for television receivers.) And the prices are roughly equal to £168 and £133 respectively (working to three dollars to the guinea).

Now, one of *those* kits I wouldn't mind making up! The kits are of course intended for American N.T.S.C. standards. I wonder if, one of these days, we'll see corresponding kits for PAL in the U.K.

The PAL system we are using has its roots in N.T.S.C., but it seems that some British TV receivers are showing slight differences in design approach from those which have become fairly well established in America. I note that one British manufacturer, for instance, is feeding red, blue and green direct to the picture tube cathodes instead of R–Y, B–Y and G–Y to one set of modulating electrodes (say, the grids) and luminance (Y) to the other set (the cathodes). The red, blue and green signals are obtained from three adding circuits following the matrix which extracts G–Y from the R–Y and B–Y signals, the Y signal also being applied to these adding circuits. But these are early days yet and it would be rash, to say the least, to predict the precise form British colour TV circuit design will take up in the years to come.

One thing we must be grateful for is that colour has at last had Governmental blessing and that we are now working with a viable colour system. British TV manufacturers are a little cautious concerning possible sales at the onset, and this approach is, I feel sure, a wise one. Time alone will tell, but I feel quite certain that colour TV will reach a high saturation level (no pun intended) by the end of this decade.

Stereo For Smoochers

One minor little social feature I have observed during recent surveys on the habits of our more smoochy teenagers as they wander around in their couples is that, whilst the skirts get tinier and tinier, the transistor radios which are an essential part of the gear are becoming progressively larger. Several years ago the done thing was to carry very small receivers going full blast, the broadcast programme being just about decipherable if one listened very carefully to the fundamental frequency of the square wave fed to the 2in speaker by the output transistors. But nowadays the youngsters seem to prefer to tote around much bigger transistor radios, some noticeably bulkier, even, than the valve portables which preceded them; and the sound these sets reproduce is at least acceptable. (Making the assumption that one *has* to be forced to listen to other peoples' choice of radio programme.)

This encouraging interest in higher quality sound reproduction evinced by the generation coming up, together with the current stereophonic broadcasts transmitted by the B.B.C., tempts me to predict what the next stage to be adopted by our perambulating youth is going to be. As I see it, both members of a pair will bear a receiver of respectable proportions, the young man walking on the left and carrying a radio reproducing the left-hand stereo channel, and the young lady walking on the right carrying a radio reproducing the right-hand channel. Get the phasing correct, and they'd have an excellent stereo background to their mutual confidences as they promenade together.

As always, undoubtedly, there'll be the types who'll spoil it for everybody else. These will be the ones who will arm themselves with two identical receivers reproducing the normal *mono* programme, but with one speaker out of phase with the other. Passers-by will then receive the full blare of whichever radio is the closer but the pair in the middle will be able to canoodle in blissful silence as the two anti-phase sound signals neatly cancel out around them.

Discovery

Talking of youth reminds me that some of our children around the age of 5 or 6 are also capable of a little ingenuity, although this may not always be as constructive as they fondly imagine. But before I can recount the next story I must first of all provide a little bit of introduction.

If, like me, you like to save the odd penny, you may have occasionally removed the Carr snap fastener terminals from worn-out batteries of the PP9, PP8 or PP1 variety before consigning such batteries to the tender attentions of your local Cleansing Department. These terminals can, of course, be used as battery connectors for radios and the like, the previous positive terminal fitting to the negative terminal of a new battery and vice versa.

It needs the genius of a 6-year-old, however, to take this simple process one stage further. As was realised to his cost by a friend of mine recently when, on returning home from work, he found that his 6-year-old son had invaded his workshop and had carried out some experiments with his stock of half-a-dozen virtually brand-new PP9 batteries. The boy had made the momentous discovery that not only does the positive terminal of one PP9 battery fit into the negative terminal of another PP9 battery but that *one PP9 battery can be plugged into another PP9 battery.*

Try it some time. If, that is, you don't mind losing some seven bobsworth of battery in much less than seven minutes!

Relay Dodge

And, to finish off with, here's a little relay dodge which may be of use to those who like playing around with circuits incorporating these components. The dodge isn't new, but it may well spark off some secondary ideas along the same lines.

To make a relay slow-to-release, simply connect a diode across its coil so that it is reverse-biased when the energising voltage is applied. The operate time is not altered, but when the energising voltage is removed the back-e.m.f. in the coil causes the diode to conduct and the magnetic field in the relay takes longer to die away. The effect varies for different types of relay construction and diode, and for different coil resistances, and a little experiment will be needed to suit particular requirements. A silicon diode is best for relay having resistances lower than 100Ω or so. If the diode gives too long a release delay, insert a variable resistor between the diode and the relay coil and find the resistance which gives the desired delay. A fixed resistor can then be inserted in its place. ✱

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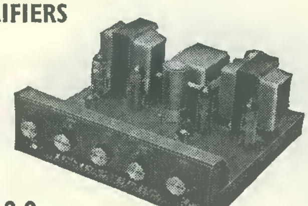

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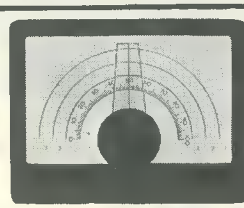

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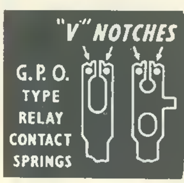

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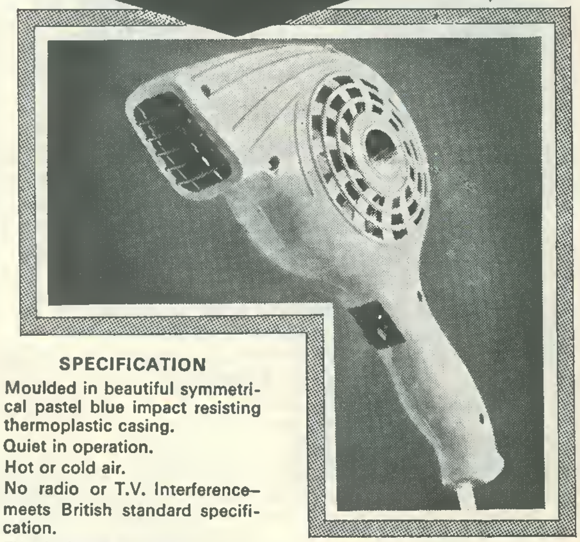

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