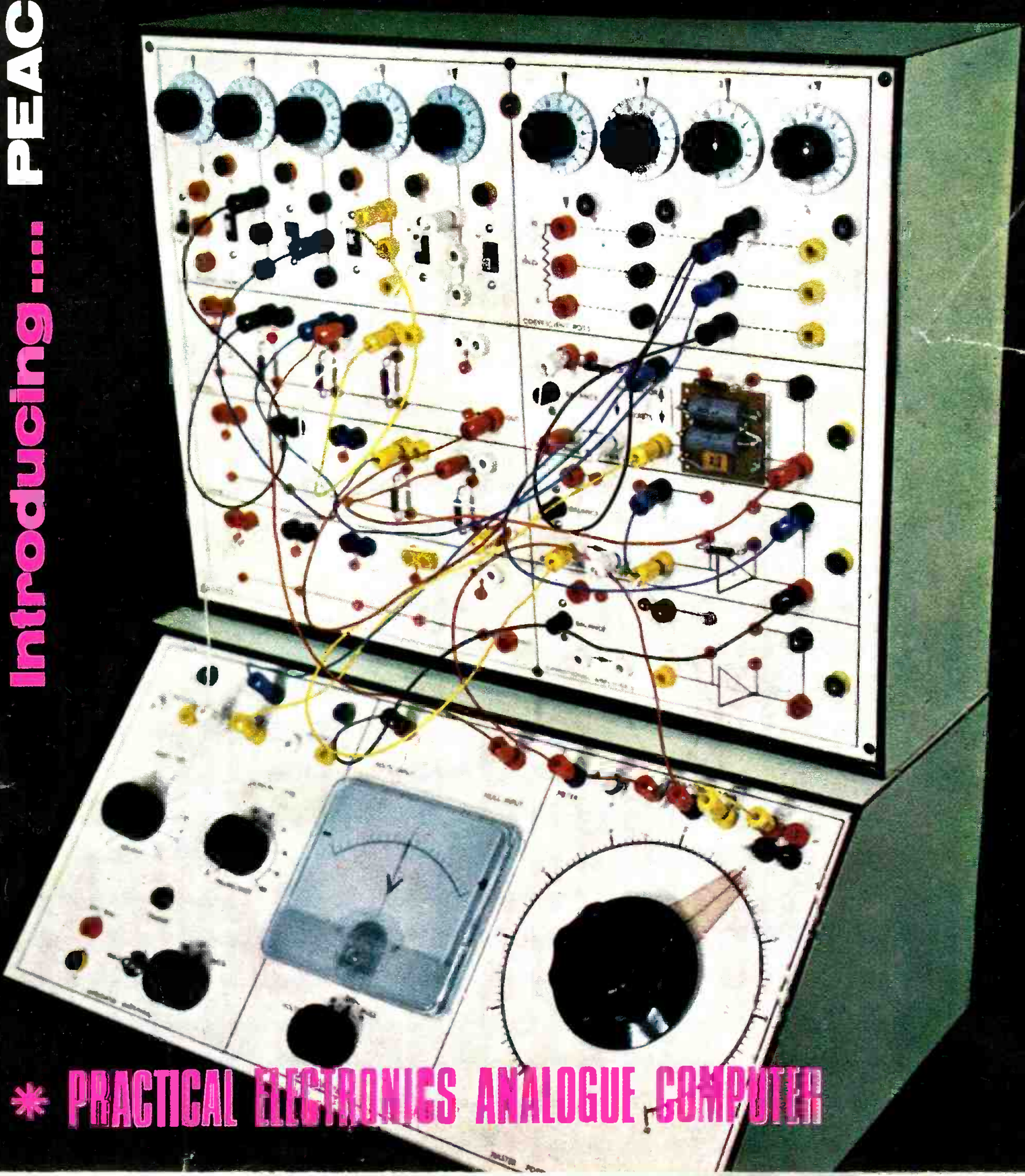
PRACTICAL

ELECTRONICS

JANUARY 1968

PRICE 2/6



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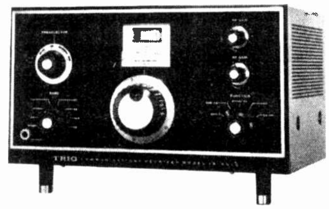
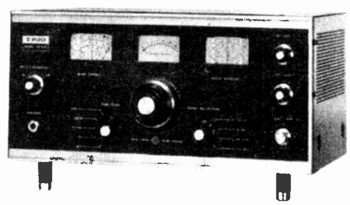


MODEL JR-500SE

This high performance receiver is made especially to cover the amateur bands and utilises a crystal controlled double heterodyne circuit for extra sensitivity and stability. **Brief spec.:** Covers all the amateur bands in 7 separate ranges between 3·5 and 29·7 Mc/s. Circuit uses 7 valves, 2 transistors and 5 diodes plus 8 crystals; output 8 and 500 ohm and 500 ohm phone jack **Special features:** Crystal controlled oscillator ● Variable BFO ● VFO ● AVC ● ANL ● S meter ● SSB-CW ● Stand-by switch ● Special double gear dial drive with direct reading down to 1 kHz ● Remote control socket for connection to a transmitter. Audio output 1 watt. For use on 115/250V a.c. Mains. Superb modern styling and control layout—finished in dark grey. Cabinet size 7 × 13 × 10in. Weight 18lb. Fully guaranteed, complete with instruction manual and service data.

LASKY'S PRICE **£61.19.0** Carriage and Packing 12/6.

MODEL 9R-59DE



Brief spec: 4 band receiver covering 550 Kc/s to 30 Mc/s continuous and electrical band spread on 10, 15, 20, 40 and 80 metres. 8 valve plus 7 diode circuit. 4/8 ohm output and phone jack. **Special features:** SSB-CW ● ANL ● Variable BFO ● S meter ● Sep. band spread dial ● IF frequency 455 Kc/s ● Audio output 1·5W ● Variable RF and AF gain controls. For use on 115/250V a.c. Mains. Beautifully designed control layout finished in light grey with dark grey case, size: 7 × 15 × 10in. Weight 19 lb. Fully guaranteed, complete with instruction manual and service data.

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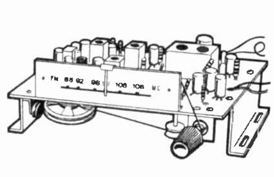

Fully tunable—range 88 to 108 Mc/s. Completely wired on printed circuit. 10·3 Mc/s. IF. 6 transistors and 3 diodes. Slow motion tuning drive. Size 6½ × 4 × 2½in. Operates from any 9V d.c. source. Full data and circuit supplied.

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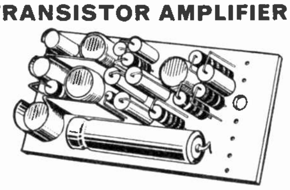

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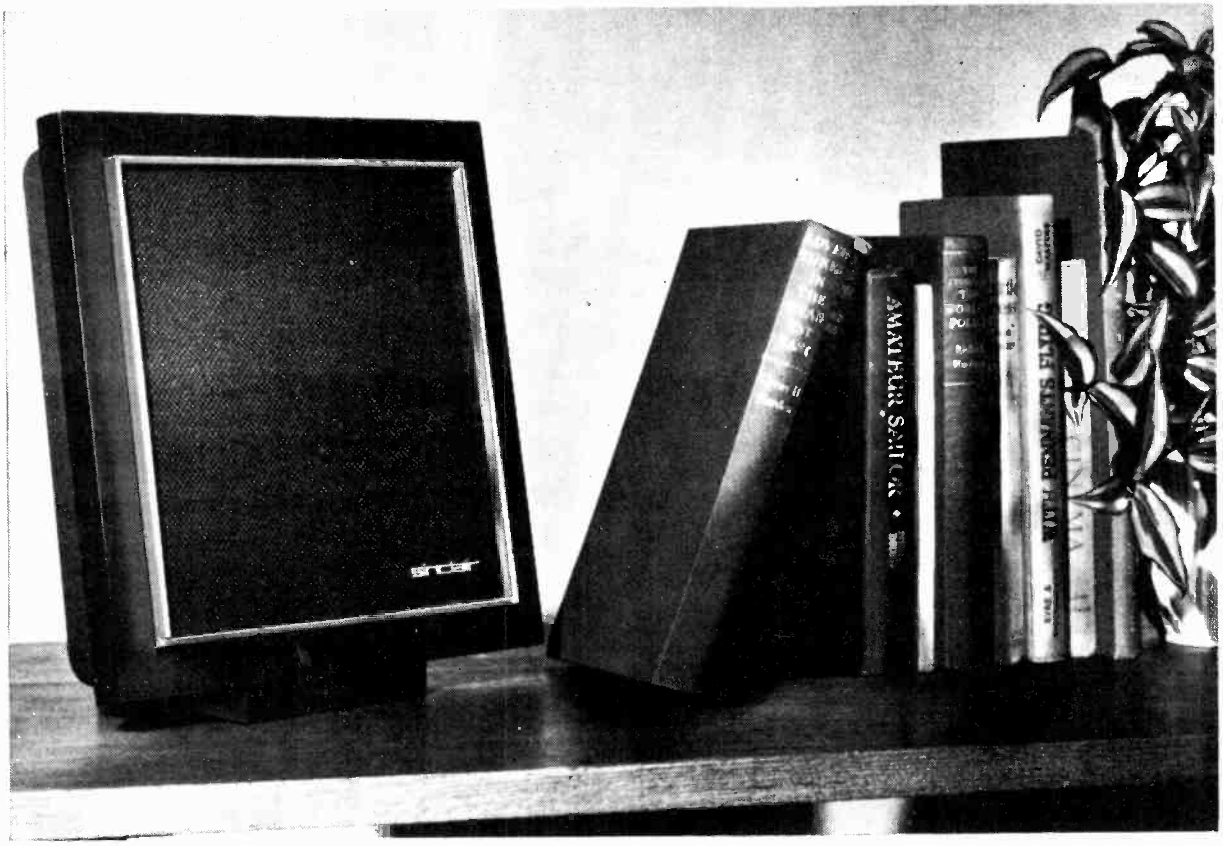
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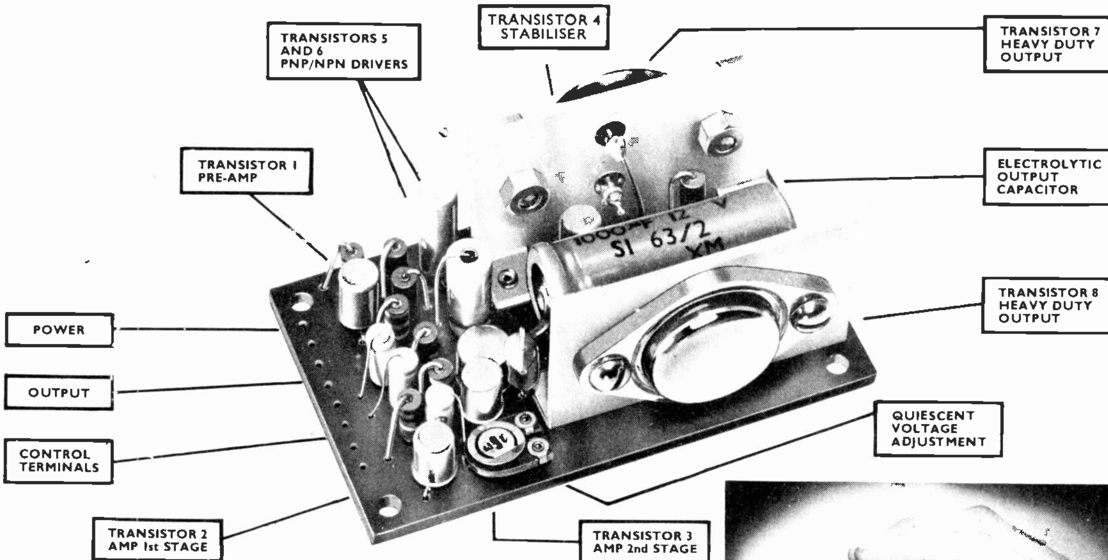

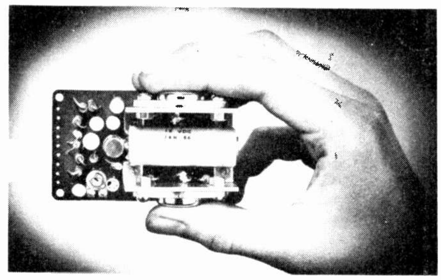

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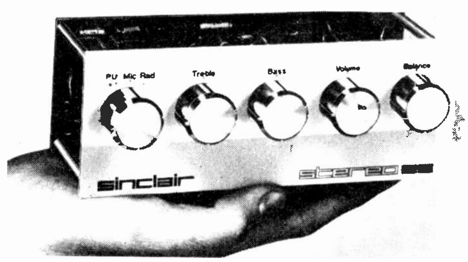

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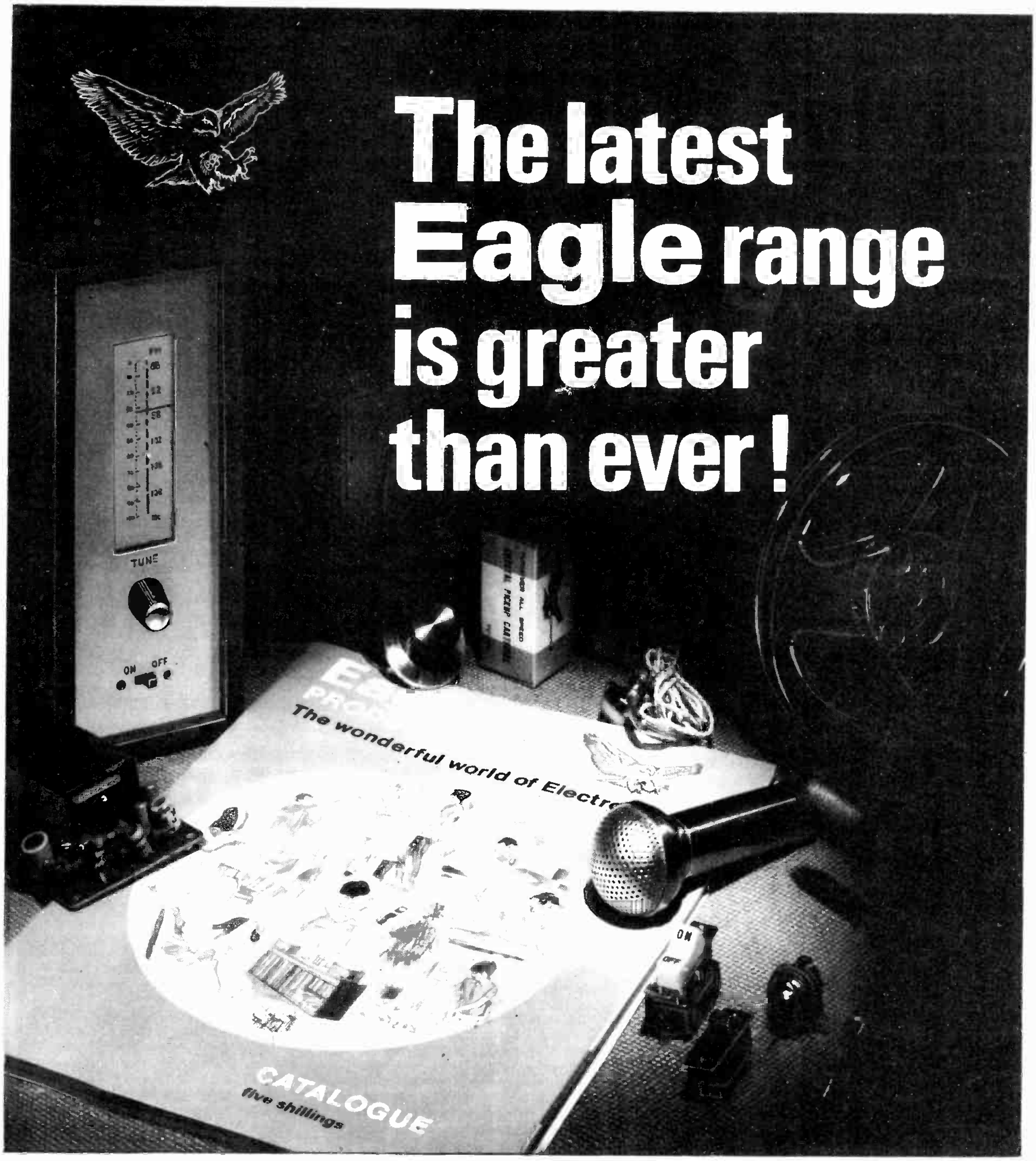

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If *you* find yourself lost in the maze of components required for your next project the surest way to find the way out is to get a copy of that invaluable guide, the *Home Radio Catalogue.* Surprise surprise, although the Catalogue has been enlarged and improved every year, the price remains at **7/6** *plus* **2/-** *postage and packing.* So if you want some interesting Christmas reading send the coupon and p.o. or cheque without delay. *Oh! and by the way,* every catalogue contains **5 vouchers,** each worth **1/-** if used as directed.

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VOL. 4 No. 1
January 1968

PRACTICAL ELECTRONICS

YOURS TO EXPLORE

PARTY time approaches, so here is a simple quiz for you, but don't worry, there are just two questions (and we give the answers too!)

(1) What single piece of equipment or apparatus best typifies the advanced state of the electronic art today?

(2) Name the earliest (and simplest) piece of electronic apparatus of practical value to be put into the hands of the ordinary man.

The first is very easy. Science fiction and James Bond gadgets apart, we think you will plump for the computer.

The second is perhaps a trifle more difficult, and certainly less immediately obvious the younger you are. When you *do* think about it, however, there is no doubt that the "crystal set" radio receiver was the founder member of the great family of electronic apparatus we are familiar with today.

". . . *Tall oaks from little acorns grow*." That early crystal diode or "detector" was a prolific ancestor. A veritable technological forest now exists some 60 years after the first acorn was planted. "Crystal set to computer" just about sums it up.

This "forest" is growing still, and it is becoming rather difficult for the amateur to explore alone: so many different paths each offering rival attractions. Some individuals prefer to keep to the well trodden paths, others are more venturesome and are eager to explore and seek out the less frequented parts of the forest.

We do our best to help, guide, and encourage all in their various pursuits. To this end, gadgets of wide and popular appeal figure prominently in our pages, as do high quality equipments for home entertainment. But in addition, the more serious, scientific minded reader is offered opportunities to exercise his abilities and acquire further knowledge through more advanced and ambitious projects. This is illustrated by our recently introduced series "Nucleonics for the Experimenter" and now by the appearance in this issue of the Practical Electronics Analogue Computer.

Back to that little acorn. As the forester seeds the ground for the future, we likewise have the novice very much in mind. And what is more suitable and appropriate than a crystal set as a very first project? To be honest, we can't say that the beginner of 1968 will have quite as much excitement as his counterpart of the cat's whisker twiddling days, but that's progress for you!

To all readers—whatever their particular interests, whether they participate in electronics for sheer pleasure and relaxation, or primarily for utilitarian or serious experimental purposes—the editorial staff of PRACTICAL ELECTRONICS wish a very happy and constructive new year.

F. E. Bennett—*Editor*

THIS MONTH

CONSTRUCTIONAL PROJECTS

SPECIAL SERIES

GENERAL FEATURES

BEGINNERS

NEWS AND COMMENT

Our February issue will be published on Friday, January 12

All correspondence intended for the Editor should be addressed to: The Editor, PRACTICAL ELECTRONICS, George Newnes Ltd., Tower House, Southampton Street, London, W.C.2. Advertisement Offices: PRACTICAL ELECTRONICS, George Newnes Ltd., 15/17 Long Acre, London, W.C.2. Phone: 01-836 4363. Telegrams: Newnes London. Subscription Rates including postage for one year, to any part of the world, 36s.

INTEGRATED CIRCUIT TAPE RECORDER

A QUALITY TAPE RECORDER IN MODERN BOOKSHELF STYLE USING TWO LINEAR INTEGRATED CIRCUITS IN A SIMPLE CONSTRUCTION

This article describes a mains operated tape recorder using the latest techniques in linear integrated circuits. For ease of wiring and the obvious advantage of being able to monitor the recording from the tape during the recording process, the design has been based upon a three head system. The three-speed tape deck is a readily available unit and may be purchased from many radio dealers. This unit comes complete with two heads (record/replay and erase). A third replay head may be ordered at the same time to fit into the space provided.

The replay characteristics of the final tape recorder follow the recommendations laid down by the C.C.I.R. at all speeds and the reproduction of pre-recorded tapes is of a very high quality. The full output power of 1 watt is more than sufficient to fill a large room and at this level the distortion is held to within less than 4 per cent. The signal/noise ratio, when related to the full output power, is better than 48dB and the hum level better than 52dB down at $7\frac{1}{2}$in/second. Tone correction is available in the form of treble lift and cut using one control only to perform both these functions in the replay condition.

As most recording equipments include a speaker, considerable thought was given to including a speaker in this unit but, due to the inability to maintain a reasonable size and at the same time take full advantage of the sound output quality, it was thought that most readers could use a separate speaker which may be part of an existing hi fi set-up.

The tape recorder was designed as an immobile unit to blend in with the more modern style of furnishing, therefore the addition of a speaker unit as a separate item should present no serious problems. A recommended size for the speaker in question would be in the order of 8 inches and may be housed in an enclosure to suit the reader's taste and pocket.

REPLAY AMPLIFIER

From Fig. 1, it may be seen that the replay amplifier is in no way connected to the recording chain and, for the constructor who may wish to build the unit as a replay device only, can omit the recording amplifier in it's entirety without affecting the replay function.

The pre-amplifier function is performed by the integrated circuit type TAA263 which has been described in the article *IC Gram Amplifier* in the October 1967 issue, so no further description of the internal characteristics of this device is necessary.

The signal from the replay head X1 is fed directly to the input of the integrated circuit, amplified and fed out to the volume control via C2 and R7. The d.c. working point of the pre-amplifier is established by R1, R2, and R3; the a.c. gain is set to the required level by the resistance capacitance network R5 and C4.

In order to promote some of the treble lift required to meet the C.C.I.R. replay specification, further decoupling of the a.c. negative feedback is achieved by the inclusion of R4 and C3 which forms a frequency selective network.

SPECIFICATION

TAPE SPEEDS	$7\frac{1}{2}$, $3\frac{3}{4}$, $1\frac{7}{8}$ inches per second
AMPLIFIERS	Separate record and replay amplifiers
FREQUENCY RESPONSE	Overall, 50Hz to 10kHz $\pm$3dB at $7\frac{1}{2}$in/sec Replay, 50Hz to 12kHz $\pm$3dB at $7\frac{1}{2}$in/sec
POWER OUTPUT (Replay)	1 watt into 15Ω load
DISTORTION	Better than 2·5% total harmonic distortion at 500mW output
SIGNAL-TO-NOISE RATIO	Better than 48dB at peak recording level
RECORDING LEVEL INDICATOR	VU level meter 1mA f.s.d.
INPUTS: Microphone	100–600Ω, 500μV (moving coil type)
Pick-up or Radio	220kΩ, 400mV (crystal or ceramic pick-up)

The more experienced constructor may notice the lack of any form of bass lift in the replay amplifier. This may be readily explained by considering the fact that under open-circuit conditions a tape head will provide a voltage characteristic that falls at the rate of 6dB per octave toward the bass frequencies. However, as the impedance of the head falls in a similar fashion, it can be shown that a constant current output may be obtained, and it is this constant current that is fed into the very low input impedance of the pre-amplifier, which presents a constant voltage output across the output load R18.

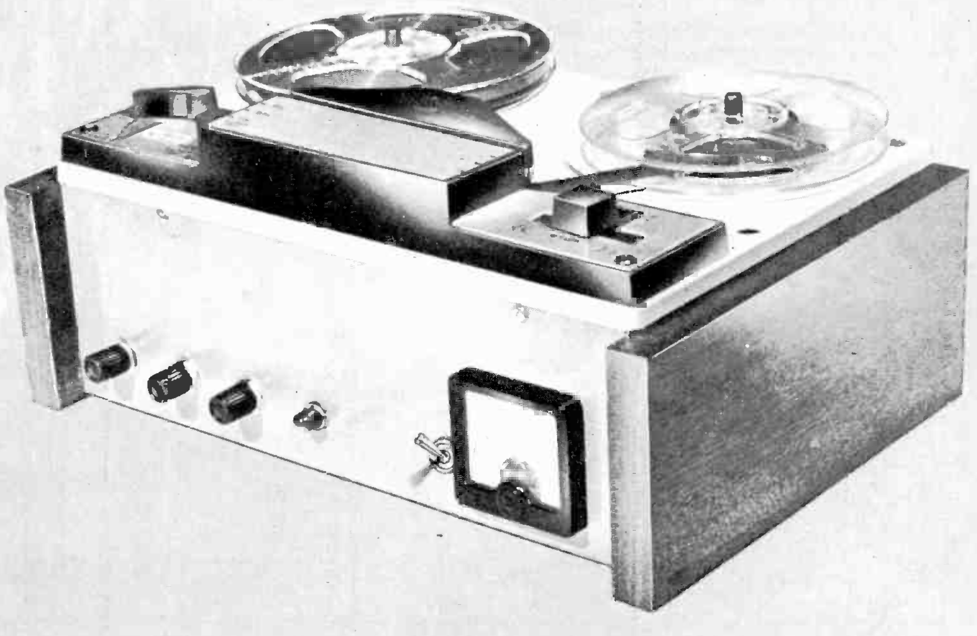
The main amplifier comprises TR1, 2, and 3 connected as a directly coupled configuration thus maintaining excellent stability of the d.c. and a.c. operating points. The stability is brought about by the a.c. and d.c. negative feedback that is applied to the base of TR1 via R9 and VR2.

In order to avoid shorting out some of the negative feedback by the collector load of the previous stage, varying as the volume control slider is moved, R7 has been included in the slider of the potentiometer. D1 and R11 hold down the bases of the output transistors, working in class C operation, to prevent thermal runaway.

The tone control provides both treble lift and cut in the following manner: With the slider of VR1 at the junction of C6, the a.c. negative feedback applied via R9 and VR2 is shorted to the negative rail at the upper frequencies, therefore the amplifier has more gain at any frequency shorted out by C6.

When the slider of VR1 is at the other end of its travel, that is to say at C7, more negative feedback is applied to the base of TR1 by the shunting effect of C7, giving a total variation of 12dB in output at 10kHz. This is quite adequate to compensate for the lack of switched treble equalisation at the three speeds.

By R. HIRST



RECORD AMPLIFIER

Fig. 1 also indicates the record amplifier configuration, where an integrated circuit similar to that contained in the replay amplifier, is used as a pre-amplifier. It is connected in almost identical fashion but the treble lift components have been omitted and the gain is set as before by decoupling the negative feedback applied by R15 and R17.

The output from the pre-amplifier is fed to the record volume control via C11 and R20 and subsequently to the base of TR4. R20 has been included to isolate R18 from the base circuit of TR4, with R21 and C15 forming a treble lift network at the upper frequencies to compensate partially for recording losses. The collector of TR4 is decoupled by C16 so that bias frequency leakage is not superimposed on the collector output signal.

The majority of the treble compensation is achieved by the network C18 and R26 ensuring that the overall response of the system is flat between 50Hz and 10kHz. R27, which is in series with the output to the recording head, helps to prevent bias flowing back into the collector load, which is now effectively a short circuit at bias frequency, thus ensuring an adequate supply of bias for the recording head.

The level of the recording signal is indicated by M1 which is in the collector of TR5. This stage is not biased in the normal manner but relies upon the incoming signal from the record amplifier, via R25 and VR5, being rectified by the base-emitter junction of TR5.

The advantage of this type of circuit lies in the very small range of level that is presented to the meter. The scale from 2 to 8 represents a change in output level of only 6dB. While this condition allows for very accurate setting of levels, some disadvantage may be encountered in the initial use of such a system due to the relatively small movement of the meter at an average signal level. C20 is included in the base circuit to prevent the meter reading from being affected by any bias leakage.

The action of the pointer may be damped to suit personal preference and the existing damping capacitor C21 gives a rather fast action but a value in the order of 100μF may be more suited for programme material of a wide dynamic range.

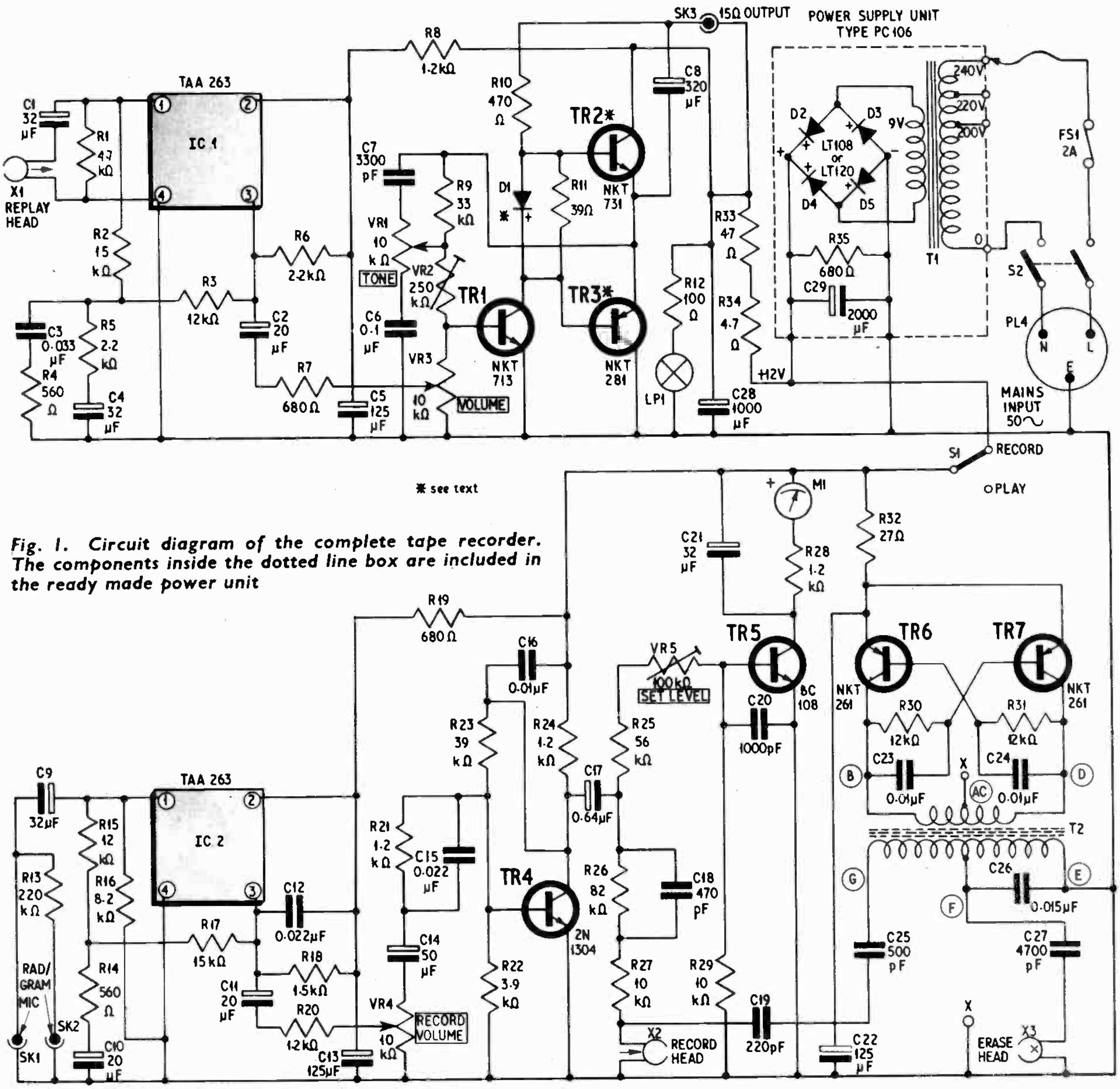


Fig. 1. Circuit diagram of the complete tape recorder. The components inside the dotted line box are included in the ready made power unit

OSCILLATOR

The bias oscillator is of the push-pull variety being biased in class D. The coil is wound on a ferrite core and presents an output of excellent waveshape and symmetry at a frequency of 50kHz. The output winding is tapped to feed the erase head and at this point the coil is tuned to promote the correct operating frequency.

The series capacitor C27 tunes the erase head to minimise the load on the oscillator and a value of 4,700pF matches this particular erase head. Bias for the recording head is fed via C25 and C19 to the junction of R27 and the record head.

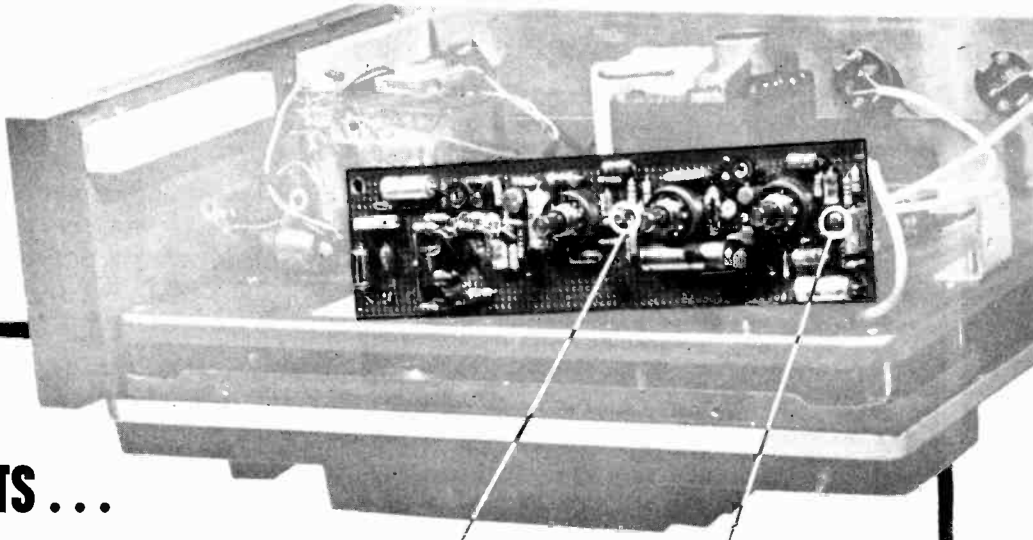
The value of C19 is such as to ensure that 220μA of bias flows through the record head. Some slight delay in the decay time of the oscillator is brought about by the inclusion of R32 and C22, thus reducing the risk of saturating the record head due to sudden spikes when discontinuing the supply by reverting to the replay condition.

The recorder is changed from the replay position to record by virtue of a switch S1 mechanically linked to the function lever on the tape deck. Recording cannot commence until this switch is operated, so there is no risk of the bias frequency partly erasing a pre-recorded tape. To simplify construction only one set of contacts on the switch wafer has been used and these remove the positive supply from the record amplifier and the oscillator.

POWER SUPPLY

The tape recorder was designed to function from a 15 volt source of supply capable of delivering at least 400mA without the voltage falling to less than 12 volts. A ready made unit available on the market was used at a very modest cost, but alternative components can be used.

The only addition to the power supply unit was in the form of a series resistor and capacitor to smooth any remaining ripple. Two 4·7 ohm resistors were



COMPONENTS . . .

Resistors

R1	4·7kΩ	R14	560Ω	R27	10kΩ
R2	15kΩ	R15	12kΩ	R28	1·2kΩ
R3	12kΩ	R16	8·2kΩ	R29	10kΩ
R4	560Ω	R17	15kΩ	R30	12kΩ
R5	2·2kΩ	R18	1·5kΩ	R31	12kΩ
R6	2·2kΩ	R19	680Ω	R32	27Ω
R7	680Ω	R20	1·2kΩ	*R33	4·7Ω
R8	1·2kΩ	R21	1·2kΩ	*R34	4·7Ω
R9	33kΩ	R22	3·9kΩ	*R35	680Ω or as supplied in power unit (see below)
R10	470Ω	R23	39kΩ		
R11	39Ω	R24	1·2kΩ		
*R12	100Ω	R25	56kΩ		
R13	220kΩ	R26	82kΩ		

All 10%, ¼W high stab. carbon except that *R12 is 10%, ½W. R33, R34, R35 are 5%, ½W.

Potentiometers

VR1 10kΩ log. carbon miniature
VR2 250kΩ linear preset sub-miniature skeleton
VR3 10kΩ log. carbon miniature
VR4 10kΩ log. carbon miniature
VR5 100kΩ log. preset sub-miniature skeleton
VR1, VR3, VR4 to have tags on rear (Iskra type P6) (Obtainable through retailers only from Guest Electronics, Nicholas House, Brigstock Road, Thornton Heath, Surrey)

Capacitors

C1	32μF elect. 4V	C17	0·64μF elect. 64V
C2	20μF elect. 16V	*C18	470pF poly. 125V
C3	0·033μF poly. 160V	C19	270pF poly.
C4	32μF elect. 4V	C20	1,000pF disc ceramic
C5	125μF elect. 10V	C21	32μF elect. V4
C6	0·1μF poly. 160V	C22	125μF elect. 10V
C7	3,300pF poly. 160V	C23	0·01μF poly. 160V
C8	320μF elect.	C24	0·01μF poly. 160V
C9	32μF elect. 4V	C25	500pF poly.
C10	20μF elect. 16V	C26	0·015μF poly. 160V
C11	20μF elect. 16V	C27	4,700pF poly.
C12	0·022μF poly. 160V	C28	1,000μF elect. 12V
C13	125μF elect. 10V	C29	2,500μF elect. 25V or as supplied in power unit (see below)
C14	50μF elect. 6·4V		
*C15	0·022μF poly. 160V		
C16	0·01μF poly. 160V		

* See text for alternative values at other tape speeds

Transformers

T1 Mains transformer: Pri. 0–200, 220, 240V; sec. 0–8, 13V 400mA (type PS12/4) *or* transformer supplied in power unit (see below)
T2 Oscillator coil wound on ferrite pot core assembly type LA2103 (see text) (Mullard)

Transistors

TR1 NKT713
TR2 NKT731 } Matched to include D1
TR3 NKT281 }
TR4 2N1304
TR5 BC108
TR6 NKT261
TR7 NKT261

Integrated Circuits

IC1, IC2 TAA263 (Mullard) (2 off)

Diodes

D1 Matched to TR2 and 3 (Newmarket)
D2–5 LT108 *or* LT120 12V 1A selenium bridge rectifier *or* rectifier supplied in power unit (see below)

Power Supply Unit (optional)

PC106 (Newmarket)
Ready made unit incorporates R35, C29, D2–5, and T1

Meter

M1 0–1mA f.s.d. scaled VU Meter *or* scaled 0–10 (type MR2P)

Sockets with Plugs

SK1–3 Phono socket (3 off)
SK4 Mains chassis mounting miniature plug type P360

Tape Heads

X1 Replay head (extra head type MN155 with spring and screw) (B.S.R.)
X2 Record head } Supplied with tape deck
X3 Erase head }

Miscellaneous

Tape deck, 3-speed, type TD10 (B.S.R.)
Perforated s.r.b.p., 0·1in matrix 7¾in × 2in
Aluminium sheet. 18 s.w.g. 12in × 4in (2 off)
Veneered chipboard 9in × 4in (2 off), *or* as required for case
FS1 Fuse and fuseholder 2A
LP1 10V or 12V bulb with wire ends (Hivac)
S1 Single-pole, on/off, wafer (see text)
S2 Double-pole, on/off, toggle

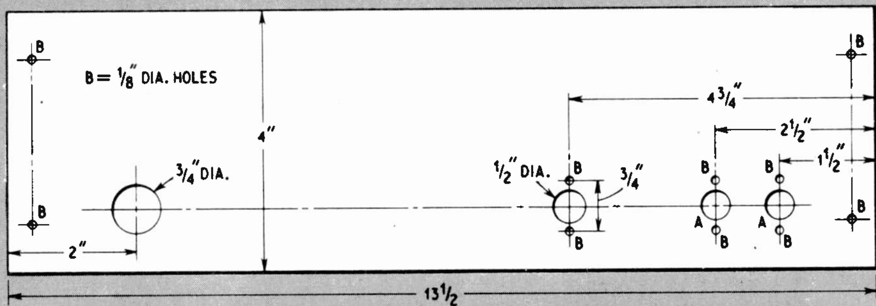


Fig. 3a. Back panel drilling details; 18 s.w.g. aluminium sheet is used

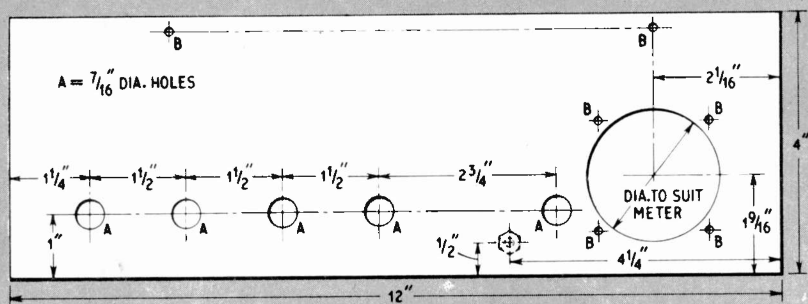


Fig. 3b. Front panel drilling details also in aluminium sheet. Do not cut the holes for the meter until this component has been obtained as the sizes will depend on the item chosen

chosen as they were easier to obtain than one of 9·4 ohms. The mains supply is connected to the transformer at the appropriate mains tap; the resultant d.c. voltage is visually indicated by LP1 which is a 10 volt "pea" bulb taking something in the order of 40mA. Resistor R12 is included to reduce the supply voltage to this level. The bulb rating is not critical; any type can be used provided that R12 is adjusted to suit the voltage rating of it. Current rating should be as low as possible.

OSCILLATOR COIL

The oscillator coil is simple to wind by making a suitable nut and bolt arrangement to fit into an ordinary hand drill. The former is clamped between a nut and the face of the chuck of the drill and two washers will assist in establishing an even fitting. The primary is wound in a bifilar fashion (i.e. both halves wound together to achieve perfect matching). The preparation of the wire is shown in Fig. 2a; the method of winding is also indicated.

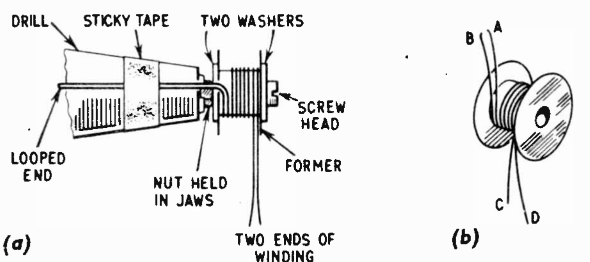


Fig. 2. Primary winding of the oscillator coil. Both halves are wound together

Primary: 6 + 6 turns of 24 s.w.g. enamelled copper wire, bifilar wound (see Fig. 3)

Secondary: 42 turns of 36 s.w.g. plus 48 turns of 40 s.w.g. enamelled copper wire, layer wound

Once the primary has been wound, which incidentally forms one layer only, a single layer of thin plastics tape may be used to hold it in position. When the coil is finally assembled the looped end is cut to form two terminations A and B. One of these cut ends is checked to see which of the other wires C or D at the further end of the coil forms a complete circuit when measured on an ohmmeter.

When this is established A and D should form one circuit and B and C the other. Now twist A and C together which will form the centre tap of the coil and B and D will go to the respective collectors of TR6 and TR7. This operation is shown in detail in Fig. 2b and it is important to observe the correct connections.

The secondary winding of the coil is wound in the more normal manner of layer or pile winding; that is to say, the whole of this winding is wound in the same direction and the tap is brought out to form a connection. The layers are wound on top of each other until the required number of turns has been made. Fit thin plastics sleeving on all lead-out wires. The finished bobbin should be covered with another layer of insulating material before being assembled in the outer ferrite core.

The two halves of the core were stuck together with a resin adhesive such as Araldite and held to the component board similarly. Care must be taken to ensure that the ends of the wires are tinned and cleaned well so as to make good soldered joints. This is not a difficult item to make as long as the instructions are followed exactly. Care must be taken not to damage the enamel insulation on the wire and not to chip the core.

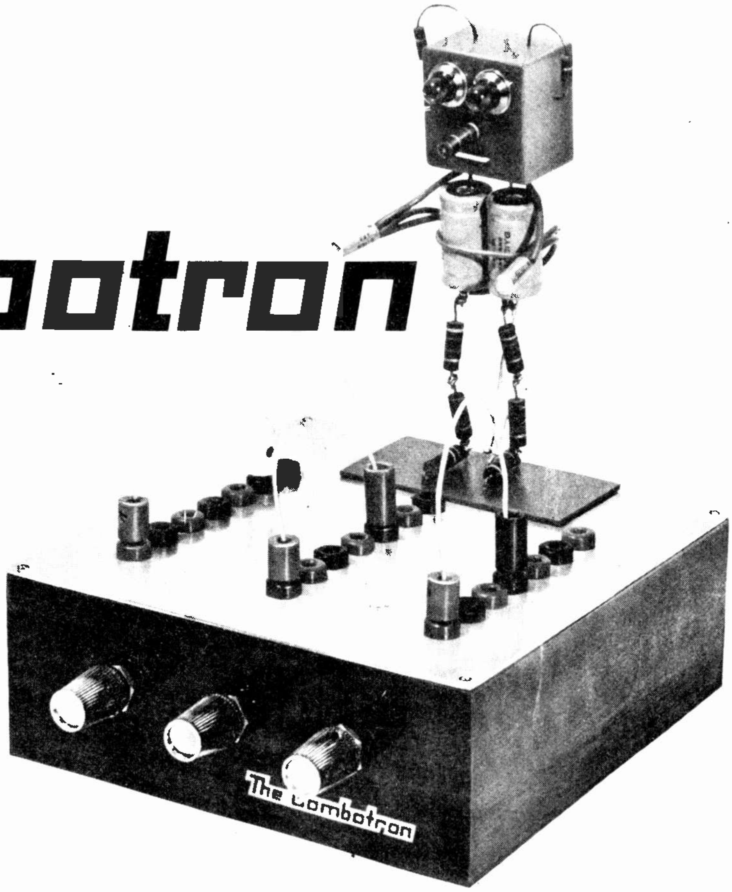
The pot core assembly can be obtained through retailers who distribute Mullard components.

Next month the constructional and wiring details and setting-up procedure will be given

Amuse your friends or family with this fascinating party novelty

You can construct the robot or the game — either way it's fun!

The Combotron



Crack the combination and his eyes respond

THIS is not a game where mental agility or high I.Q. may be demonstrated, but one of chance (with mathematical undertones) where boffin or dullard may compete on level terms.

The object of the game is to crack the circuit completing combination by random insertion of three jumper plugs. Each plug must be inserted into one of the line of sockets running vertically from its fixed termination point, i.e. "A", "B", and "C". If the circuit is successfully completed this winning combination will be indicated by the robot's eyes flashing.

Since many readers might only be interested in constructing the robot as a desk-top or sideboard novelty, its construction will be described separately but with simple add-on instructions if it is to be included in the game.

NUMEROUS COMBINATIONS

Examination of the circuit will show that random switching of S2, S3, and S4 presents a completely different set of plug combinations for each game and if the wiring of sockets to switch tags is equally random in the construction of the unit it should be virtually impossible to memorise winning combinations.

Since there are six sockets available to each jumper jack plug there are six possible inserts at each column of sockets to successfully complete the robot's supply line. It can be seen then that there are 6^3 combinations available by switch settings, or to generalise a formula, $c = x^n$ where c is the total number of combinations, x the number of switch ways and n the number of switches. This indicates that with more switch ways and sockets the game increases rapidly in complexity, and if you don't want to exhaust the patience of your friends or family you should restrict the game to the modest limits set out here.

BUILDING THE ROBOT

The robot is in essence a simple free running "multi", with its working parts contained entirely in its physical make up. The body and legs make up the timing components and the switching transistors the arms. The simplest order of construction was found to be from the head and progressively working downwards.

The head can be any small plastic box of sufficient size to house the small indicator lamps, but not too large to appear ungainly on the body. If the components are obtained first it is a simple matter to proportion the choice of box with the torso capacitors.

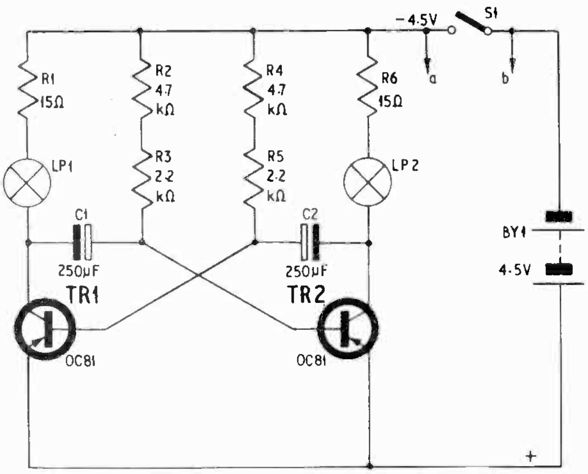


Fig. 1. The robot circuit. This is a free running multi-vibrator

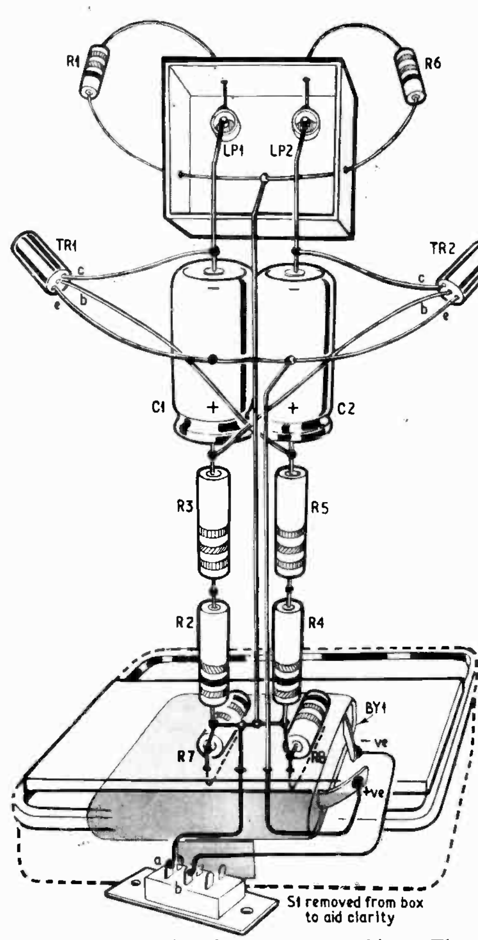


Fig. 2. The completed robot assembly. The "feet" resistors R7 and R8 have no circuit function. A rectangular piece of laminated plastics provides a plinth for the robot, and is mounted on the top of a 2oz tobacco tin

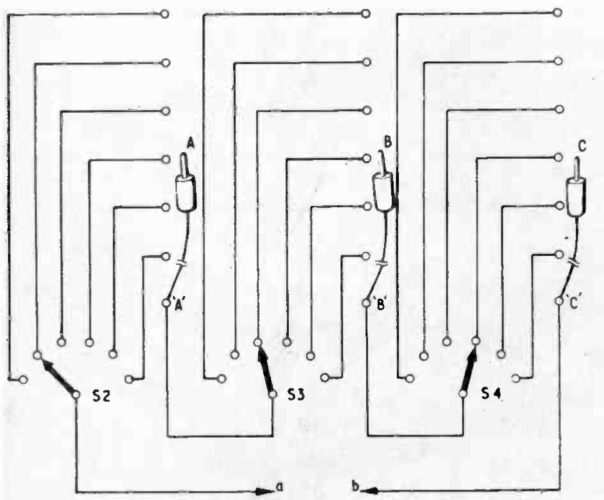


Fig. 3. The game circuitry.

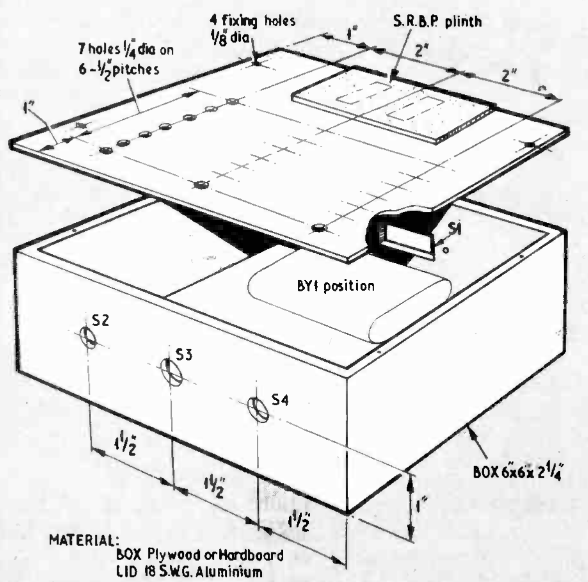


Fig. 4. Constructional details of box for the Combotron

COMPONENTS . . .

Resistors

R1	15Ω ½W	R5	2·2kΩ 1W
R2	4·7kΩ 1W	R6	15Ω ½W
R3	2·2kΩ 1W	R7	any value
R4	4·7kΩ 1W	R8	1W

Capacitors

C1, 2 250μF elect. 15V subminiature tubular (Radiospares) (2 off)

Transistors

TR1, 2 OC81 (Mullard) (2 off)

Lamps

LP1, 2 1·5V 0·16W subminiature 5mm tubular L.E.S. (Vitality Bulbs Ltd.)

Switches

S1 Slide switch s.p.s.t. (see text)

S2–4 Rotary switch, s.p. 8 way (Henry's Radio) (3 off)

Miscellaneous

21 4mm panel sockets; 6 plugs to suit (G. W. Smith)

Aluminium sheet 6in × 6in. Plywood for case. 4·5V flat battery

Holes should be drilled for the lamps LP1 and LP2 and these positioned. Using these as references, holes for the ear resistor leads, nose resistor, and mouth capacitor leads should be made with a No. 60 diameter drill.

A 1 watt resistor of any value, or a piece of sleeved wire, should be inserted at the nose position. One lead of the resistor is cut short with the other protruding into the box by approximately a $\frac{1}{2}$ inch. The ear resistors are then inserted, with one lead being soldered to their respective lamps and the other leads being wrapped round the projecting nose wire. For the mouth a small length of sleeved wire was inserted and retained on the other side of the box by twisting together the free ends with long nosed pliers.

The capacitor negative leads can now be fed through into the box and soldered at the unconnected lamp tags. The head construction is completed by joining a 5 inch length of sleeved wire to the three wires at the nose position and soldering this junction.

The 1 watt resistors making up the legs and feet should now be completed making sure that the joints are mechanically strong before soldering so providing a rigid support for the robot. The resistor wires at the feet should be left long at this stage.

The addition of the transistor arms is straightforward if care is taken with soldering. The base leads are extended by soldering a 2 inch piece of wire to their ends after which both are sleeved and joined to the capacitors. The emitters are then made common with a small piece of bare wire. An 8 inch piece of sleeved wire should be connected to its mid point for battery positive.

If it is not intended to incorporate the robot with the game it can be conveniently mounted on a 2oz tobacco tin using the feet wires, through holes drilled in the lid, both for retaining and connection to the slide switch S1 in Fig. 1. For added rigidity Araldite should be applied to bond the resistors and lid.

Finally the sleeved positive lead should be taken through a hole in the lid and connected to the $4\frac{1}{2}$ volt flat battery that will be housed in the tin (Fig. 2).

GAME SECTION

If the robot is to be used as an indicator with the game the game circuitry should be connected to points *a*, *b* in Fig. 1. The game circuitry thus forms a complex on/off, or combination, switch. The switch S1 can be retained as a master control, permitting the robot to be operated continuously for display purposes.

The socket panel used was a piece of 6in $\times$ 6in aluminium sheet. If the vertical rows of sockets are commenced about 1 inch from the panel edge with separation of a $\frac{1}{2}$ inch for sockets there will be ample space for the robot's attachment which will follow the same lines as detailed before.

A box for switch mounting and battery housing of dimension 6in $\times$ 6in $\times$ 2in should be constructed of plywood or hardboard. When drilling the switch holes these should be arranged slightly below the line of centre to offset any possibility of contact with sockets. Wiring of the sockets should be commenced and the leads plaited to their respective switch tags, making sure that the leads protrude by about 3 inches beyond the panel when the bunches are drawn taut.

With the robot attached to the panel wiring, wiring to the switch tags can be completed. This operation should be random for the reasons outlined previously. With battery connections made the game is complete.

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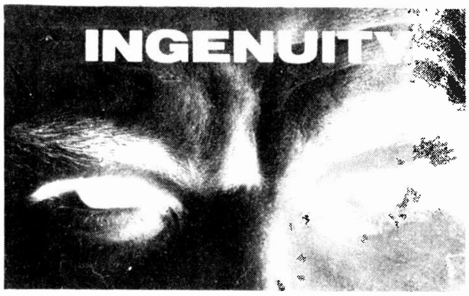


UNLIMITED!

IN THIS feature we hope, from time to time, to be able to publish suggestions submitted by some of our readers on the possible improvement of projects previously described in PRACTICAL ELECTRONICS; short contributions on other subjects may be included. The aim is not to find fault or undermine the abilities or knowledge of our contributors. It may well be that the original article is *par exellence* but it could be improved or adapted to suit individual requirements. The views expressed by readers are not necessarily those of the Editor.

THE "MINI-CLIP"

THE necessity to protect semiconductor devices from overheating when soldering into circuit, needs no further elaboration to the average experimenter.

When making up transistor circuits, it is a fair assumption that the soldering-in process may well be a one-shot, "for all time" job. The usual pliers or crocodile-clip heat shunt, when soldering semiconductors, normally suffices.

However, for the experimenter who designs and builds, his budget may demand that components will be used many times over. After re-soldering many times, bending leads to effect the appropriate temporary connection, a transistor may start to complain. On the other hand, the novice may solder in a transistor with painstaking precautions, and then immediately solder many other components to the same terminal, with no thought for the device rapidly frying to death!

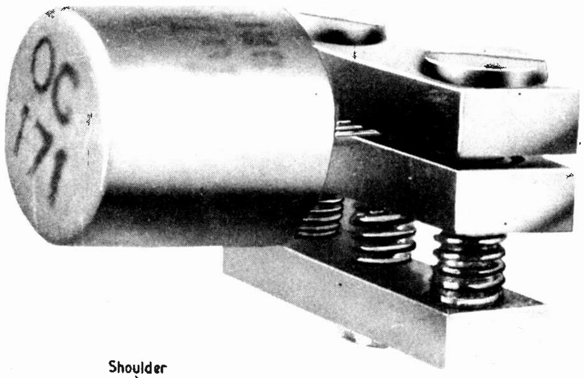
This novel gadget (which may be fitted and removed in seconds) will give threefold protection to semiconductors. It will provide a very good thermal shunt, give mechanical protection of the lead-out wires and seals, and by shorting all the leads together, protect against stray currents from a "leaky" soldering iron.

The Mini-clip is in essence, a miniature screw clip (Fig. 1). The transistor leads are placed between the "jaws" to within 5mm of the encapsulation and the clip screwed up. The leads are then held very firmly. On test, all three leads of a transistor were wrapped around the bit of a 25 watt iron for 3 to 5 minutes with the clip in place without the leads becoming dangerously hot. The leads below the clip may be bent at any angle and even pulled strongly with pliers without disturbing the transistor in any way.

After soldering, the clip is removed by unscrewing the jaws open to only half of the diameter of the encapsulation, the end plate may then be removed and the clip lifted off the transistor. Thus, the Mini-clip may be used in fairly confined spaces.

The dimensions given (Fig. 2) are for the "large size" (as seen in the photograph) which will accommodate the larger four-lead transistors. The dimensions may be considerably reduced for use with the small epoxy encapsulated devices now available. The prototype was made up from a small piece of brass (from a valence rail) about 2mm thick. The three pieces are cut and drilled as shown.

Fit the two 6 B.A. runners through the holes in the pressure plate, and locate their ends in the holes in the shoulder plate. Solder these screws in. Make up the thumb screw as in Fig. 2 and screw into the tapped hole. Fit the base-plate over the guide rails and the unit is then complete. Several of these clips may be constructed in an hour or so.



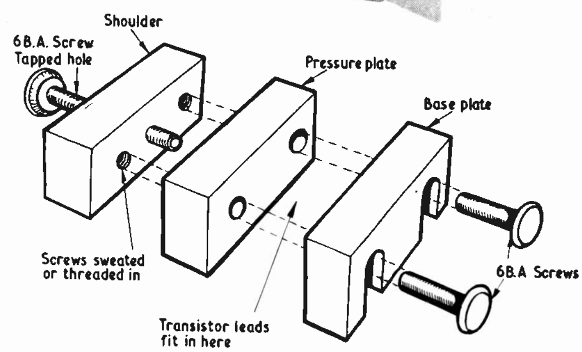


Fig. 1. Exploded view of the Mini-clip

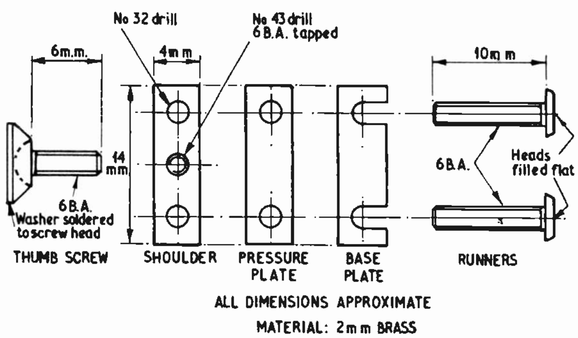


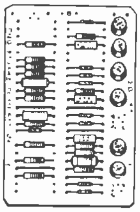
Fig. 2. Dimensions of the Mini-clip parts

It is essential to ensure that the faces of the plates which hold the transistor leads are perfectly flat and parallel, so that even pressure is exerted on all the leads.

Some transistors with tinned leads may have some irregularities on the surface which must be removed before screwing-up.

Don't forget to remove the Mini-clip before switching on for circuit testing!

D. S. Branston,
Birmingham, 14.



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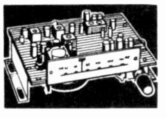

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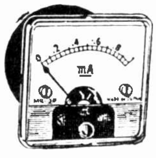

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		10mA	22/6	5A d.c.	22/6	50V a.c.	22/6
		20mA	22/6	3V d.c.	22/6	150V a.c.	22/6
		50mA	22/6	10V d.c.	22/6	300V a.c.	22/6
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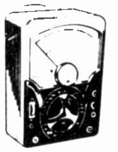

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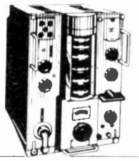

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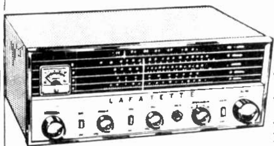

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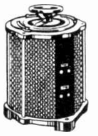

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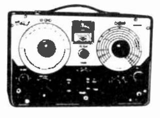

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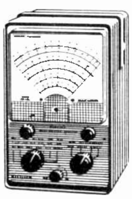

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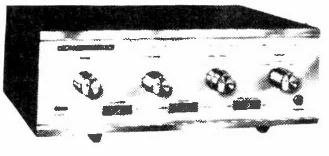

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TAPE STOP FOIL DEVICE

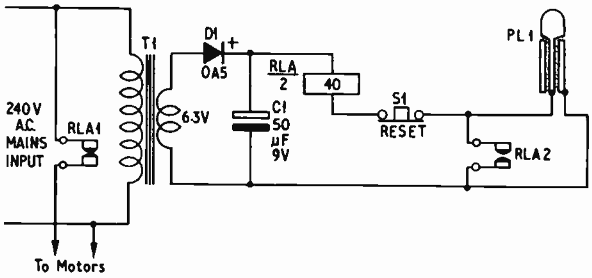
An inexpensive auto-stop for a tape recorder is a useful addition to any machine. The one that appeared in the Tape Recorder Auto-Switch article in the January 1967 issue uses a 12V relay and suggests insulating a spare guide bollard. This is not possible on many tape decks (such as the B.S.R. TD2) and may appear at first sight to be more difficult than fitting a photocell. This is the principle described here that can be made for under £1.

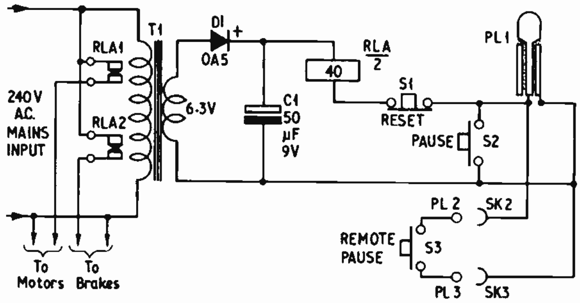
To provide a pillar with two insulated contacts, a 3·5mm jack plug was mounted on the deck. This is arranged to switch a 6V relay which is powered via a rectifier from the 6·3V heater winding of the tape recorder mains transformer.

A latching circuit may be incorporated as shown in Fig. 1. This enables shorter lengths of stop foil to be used. S1 is a "reset" switch, releasing the relay.

If the recorder uses solenoid operated brakes, a latching circuit is not required. Two additional refinements are then worth adding: pause and remote pause. The circuit is given in Fig. 2, S2 being the pause control and S3 a remote start/stop. It is not considered worthwhile adding these extra facilities to a deck in which the brakes would be uncontrolled, due to the time taken for the drive mechanism to slow down.

The diode and smoothing capacitor may be mounted directly on to the tags of the relay. All mains contacts on the relay must be heavy duty types rated at 250V a.c.





5A. The Omron type MK2/40 ohms is available from Keyswitch Relays Ltd., 120 Cricklewood Lane, London, N.W.2.

P. M. Delaney,
Poole,
Dorset.

STOPPING MODEL TRAINS

My model locomotive controller was built in rather a hurry several months ago; however I have since drawn up a complete circuit and included a modification to obtain a more realistic performance. It appears to be usual practice for children to reduce the output voltage from maximum to zero instantaneously as the train approaches a station. A locomotive with magnetised wheels running on steel track comes to an immediate stop.

Speed versus voltage was plotted and found to be a linear function, therefore if the voltage could be made to fall in an exponential manner the above defect would be overcome. A time constant at the input to the compound emitter follower gives the desired results, as shown below.

With the switch in position A the circuit performs as before; this position is used for shunting, etc.

When starting the train a similar set of conditions occurs although the waveform is not as ideal for starting, it is a reasonable compromise. The output voltage is quite often increased from zero to 10 volts instantaneously, causing the train to lurch away from the station. With the switch in position B acceleration is more gradual.

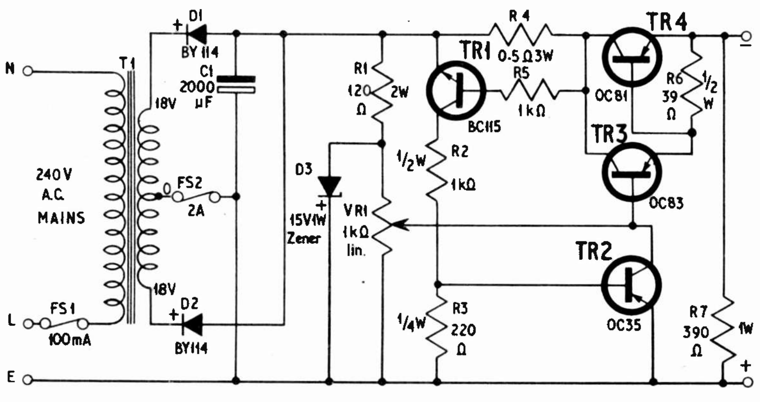
A note regarding construction may be of interest especially when the safety of small children is considered.

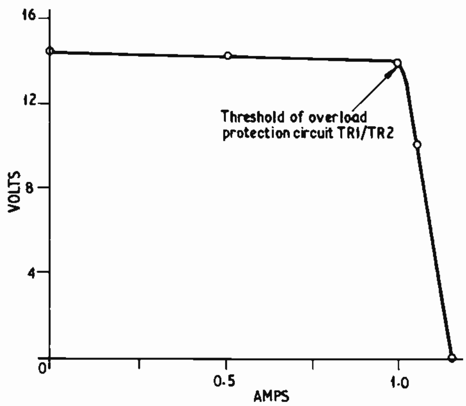
The mains transformer and fuses are housed in a separate unit, this being situated near the mains supply socket. An 8ft length of three core lead connects the 18–0–18V supply to the controller.

One side of the output is connected to earth so that the 100mA fuse in the primary can prevent a dangerous rise in output voltage should the transformer insulation become faulty.

This arrangement eliminates high voltage mains from the train set but also provides a low voltage secondary for the operation of "point" solenoids, etc.

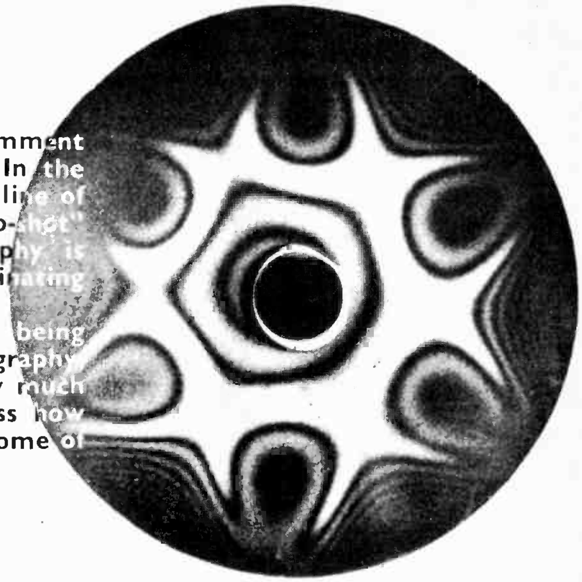
G. H. Baker,
Romford,
Essex.





HOLOGRAPHY has been exciting a great deal of comment in the scientific circles during recent years. In the popular press this comment has tended to take the line of optimistic suggestions about three-dimensional "snap-shot" cameras, cinema, and television. While holography is potentially capable of providing these and other fascinating devices, it is scarcely out of its infancy.

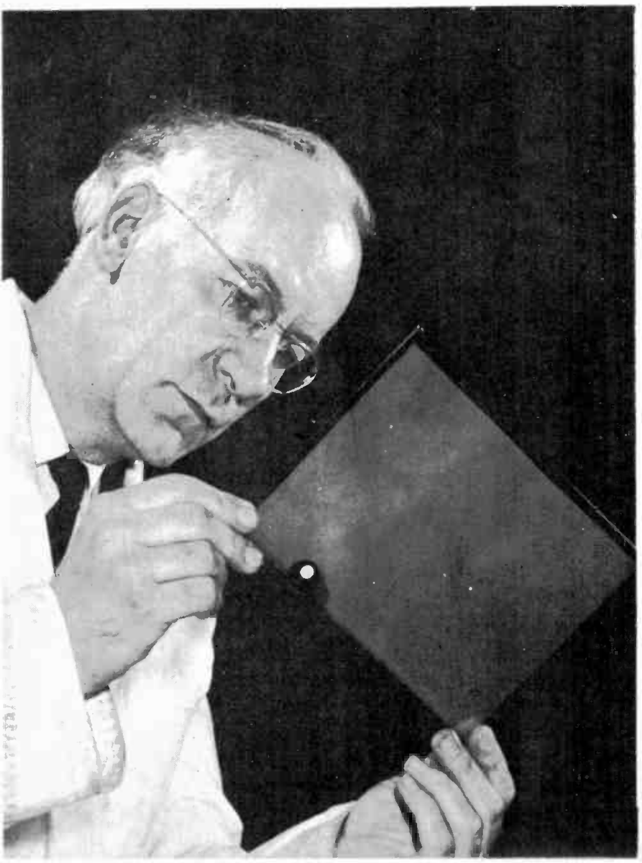
Five years ago the recently invented laser was being described as "a solution in search of a problem". Holography, a thriving offspring of laser research, is today in very much the same situation. In this article we shall discuss how holograms are made, the theory behind them, and some of their applications.



HOLOGRAPHY

By M. R. B. FORSHAW E.M.I. ELECTRONICS LIMITED

Fig. 1. Under the ordinary room lighting the hologram looks like an ordinary photographic plate, with little or no visible detail upon it



When seen in ordinary room lighting, a hologram looks like an unexposed photographic plate, with a uniform layer of grey or "milky" emulsion on it (Fig. 1). No sign of an image, three-dimensional or otherwise, can be seen.

Suppose now that we take a helium–neon gas laser, which emits a continuous pencil beam of red light. If this narrow beam (a few millimetres in diameter) is passed through a lens, the laser light is focused to a point and then diverges. When this diverging cone of light falls on the hologram most of it passes straight through, but a fraction of the light is scattered by the emulsion. The result of this scattered light is a red image which appears to lie behind the surface of the hologram.

Fig. 2 shows how the camera is focused on the image of a toy horse, which lies behind the out-of-focus hologram frame. The hologram becomes a window, through which one can see the impressively substantial scene on the other side. In some way the hologram has recorded information about the distance to the various parts of the scene, which an ordinary two-dimensional photograph fails to do.

Instead of using a laser to illuminate the hologram, suppose that a "point" source of white light is used; a quartz–iodine car headlamp bulb is a convenient approximation to such a point source. The image which results is usually unrecognisable; a spectrally dispersed rainbow of colours is all that results. Putting a red gelatine filter over the white light enables us to recognise the image on the other side of the plate, but the finer details of the scene are blurred or indistinguishable.

The purpose of this second experiment is to show that monochromatic (single frequency) light gives the best reconstruction from a hologram: the helium–neon gas laser is a near-ideal source of such monochromatic light. A tolerable reconstruction can be obtained with a non-laser source (the white light and red filter) if it is nearly monochromatic.

A laser is not only the best source for *viewing* holograms: it is also the most suitable source for making them. One can make holograms with a non-laser source such as a mercury arc (the first ever holograms were made by Professor D. Gabor in 1947 using mercury lamps) but the results are visually unimpressive and nowadays nearly all holograms are made with laser sources. The reason for this is explained later.

MAKING HOLOGRAMS

Making a hologram is a relatively simple progress. Fig. 3 illustrates one holographic "camera" layout which has proved convenient and adaptable. Light from the laser is split into two beams by the beam splitter—a piece of ordinary unsilvered glass. Most of the light passes straight through this glass plate and is reflected from the plane mirror M1. This reflected light passes through the lens L1 which illuminates the object O. The light scattered from the object then falls directly on the hologram.

The rest of the laser beam is reflected from the beam splitter, bounces off mirror M2 and is expanded by lenses L2 and L3 to a wide collimated beam of light which also illuminates the hologram. This second beam is called the "reference" beam, and it is the interaction between the reference beam and the light scattered from the object which affects the photographic plate and produces the hologram. To make the hologram one simply switches the laser on for the required exposure, perhaps ten seconds, and then develops the photographic plate in the normal way.

There are snags, of course. For reasons which will become clear all the apparatus has to be kept stationary to within one-tenth of a wavelength of light during the exposure. This is done by mounting everything on a firm table, with foam rubber under the table to isolate the equipment from shocks.

Very fine grain photographic plates must be used if wide angle scenes are to be recorded. The photographic plates most often used in holography have this extremely fine grain, but only at the expense of film speed. For comparison, an ordinary fine grain film, with a film speed of about 100 ASA, will resolve up to 50 lines per millimetre. The special holographic plates can resolve up to 5,000 lines per millimetre, but their speed is only 0·03 ASA.

After the plate has been developed, processed, and dried, it is then illuminated by the "reference" source by itself (the objects having been removed in the meantime) and the three-dimensional image is seen as in Fig. 2.

PRINCIPLES

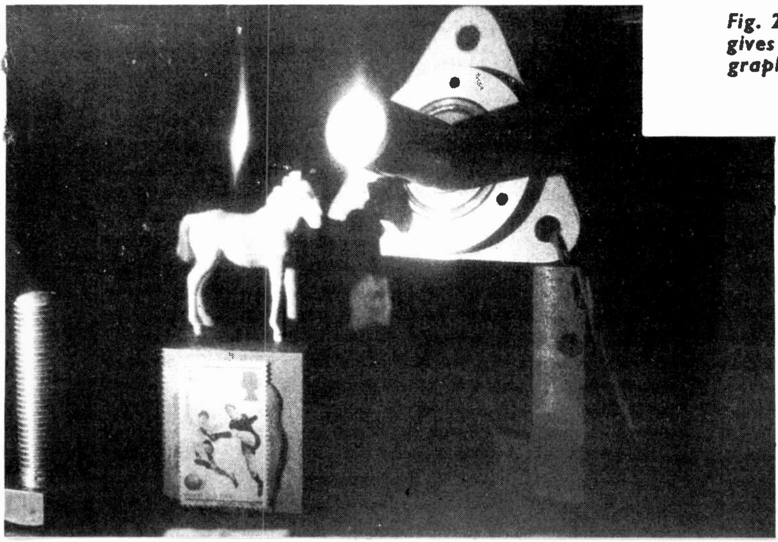
The underlying principle of holography can be expressed quite briefly. Like radiowaves and microwaves, light is an electromagnetic wave phenomenon.

If two waves, A from the object and B from the reference source, have exactly the same wavelength, then they are said to be mutually coherent. They are able to interfere with one another and produce a stationary wave pattern which is recorded by the photographic plate as a detailed fringe structure (see Fig. 4). This photographic plate, with the fringe pattern recorded upon it, is the hologram. If the photographic plate is illuminated by the reference wavefront B, then the recorded fringe pattern behaves like an optical diffraction grating and diffracts (scatters) some of the light. This diffracted light has exactly the same form as wavefront A (the object wave). The reconstructed object thus "appears" once more in its original position.

If the object and reference waves A and B are not monochromatic (i.e. if they contain more than one wavelength) then interference still occurs but each wavelength lays down its own interference pattern and the resulting average fringe structure recorded in the hologram becomes blurred or disappears completely. This is why monochromatic lasers have to be used to make holograms.

It was mentioned earlier that, in order to make a good hologram, all the equipment had to be kept steady to within a fraction of a wavelength. This stationary condition prevents the recorded fringes from being smeared out and lost. This blurring of the recorded fringes can be turned to good use.

As an example, suppose that halfway through the recording of a metal plate (simulating a bridge), we were to load it with a model car (see Fig. 5). The mirror behind the model car provides a plan, as well as a side view of the bridge. The bridge will deflect under the load and some of the interference fringes recorded by the hologram will be blurred. These fringes, once destroyed, cannot reconstruct their



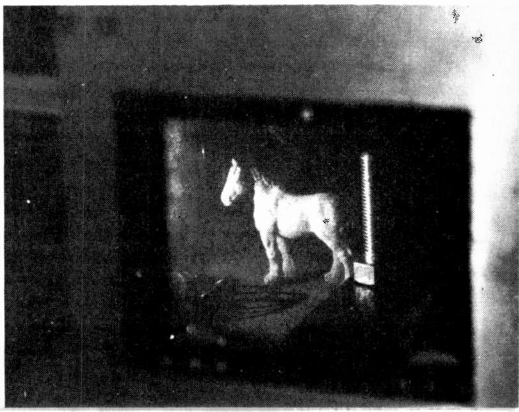
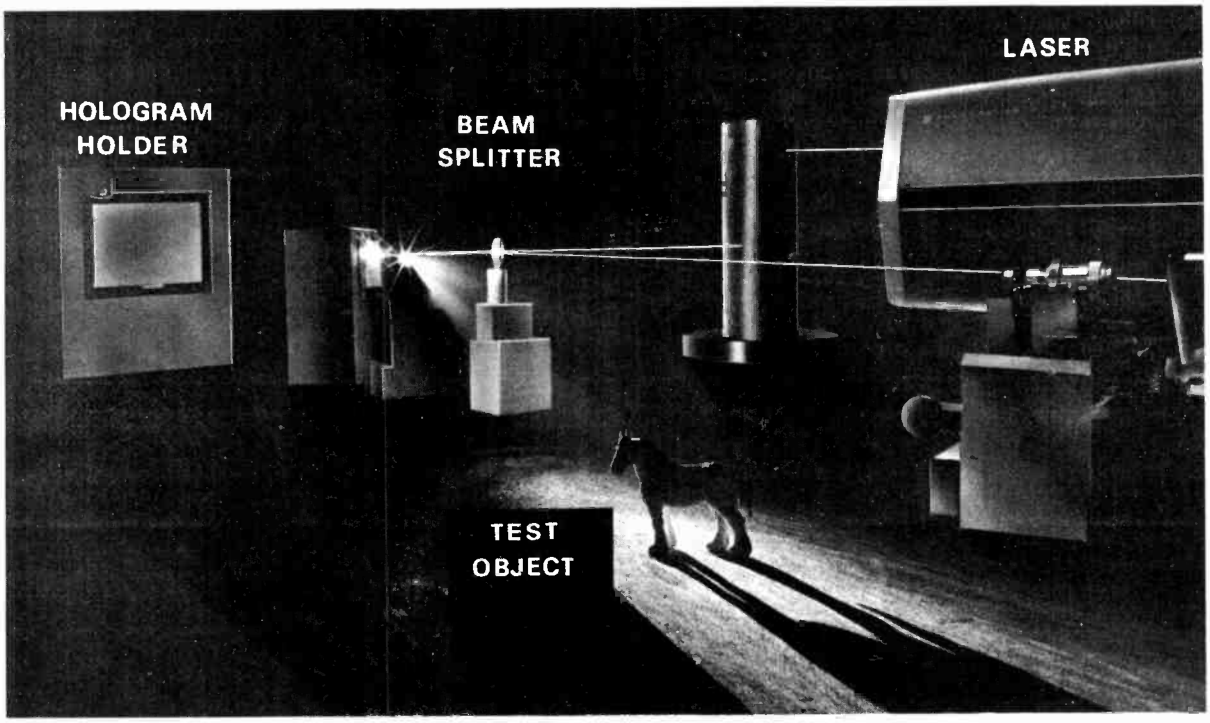


Fig. 2. Illumination of the hologram with red laser light gives a three-dimensional image lying behind the photographic plate



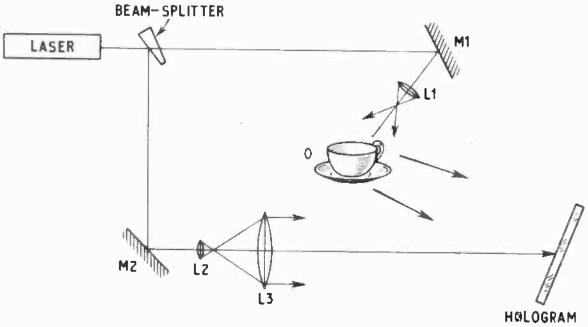


Fig. 3. The apparatus required for making a hologram

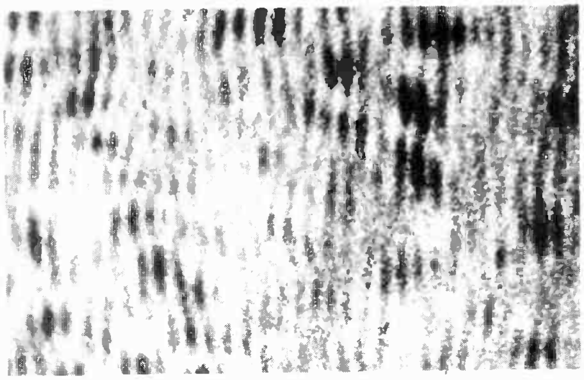


Fig. 4. Enlargement of part of a hologram (about 1,000 lines per millimetre)

corresponding images, and parts of the bridge will be invisible in the reconstructed image. Fig. 6 shows how different parts of the bridge have been deflected by varying amounts. The deflection can be calculated quite readily because each dark ring in the picture represents a deflection of one half wavelength of light.

Almost any sort of small movement or vibration can be detected by this technique which is called holographic interferometry. It is used very successfully in wind tunnels to obtain three dimensional pictures of the air flow patterns round aircraft models. It can be used to measure stress in mechanical structures, to measure thermal expansion or "creep", or to measure the amplitude of vibration of objects such as quartz crystals or loudspeaker cones.

Fig. 7 shows a holographic image of a loudspeaker diaphragm undergoing small periodic oscillations; each dark zone represents about one half of a wavelength of light flexure of the diaphragm. This is a measurement which is readily made using holography. There is no need to touch the object in any way while making the measurement, and so the vibration is unaffected by the measurement.

INTERFERENCE PATTERNS

Another interesting facet of holographic interferometry is the production of "live" interference patterns. Take as an example the bridge shown earlier, but without disturbing the apparatus during the exposure. If the hologram is developed and put back in exactly its original position, then on looking through the hologram we see the original object and its holographic image superimposed. If the object and image are perfectly aligned, nothing unusual is seen, but if the bridge is now loaded by the toy car then "live" interference patterns are seen. These are similar in appearance to those in Fig. 6, but can vary as the car is moved along the bridge. "Real-time" measurements can be made in preference to the "frozen" patterns shown in Fig. 6.

Numerous other applications are being investigated in laboratories throughout the world—three-dimensional microscopy, pattern recognition devices, holograms made with microwaves and ultrasonic waves, and a variety of experiments concerned with the use of holograms in visual display systems. Work on the last item includes the development of a new type of hologram which, depsite the remarks in the opening paragraphs, can be viewed with unfiltered white light sources.

This last type of hologram is called a reflection hologram, or sometimes a "white light" hologram. The "camera" arrangement used to make reflection holograms differs from that shown in Fig. 3. Instead of the object and reference beams converging onto the same side of the photographic plate, as in Fig. 3, they fall on opposite sides of the plate. The resulting interference pattern recorded in the emulsion differs from that in an "ordinary" hologram as Fig. 8 shows. Closely spaced layers of silver, half a wavelength of light apart, are stacked through the thickness of the emulsion. Even though the emulsion is very thin (about $1{\cdot}5 \times 10^{-3}$ cm) several dozen layers can still be registered.

These reflection holograms require a different viewing technique from that used for ordinary "transmission" holograms. Fig. 9 compares the two viewing methods. Ordinary, transmission holograms require a laser, mercury lamp, or other monochromatic source for viewing. Reflection holograms, as their name implies, are viewed by reflection and give a single-colour image with any "point" white light source, such as a car headlamp or torch bulb—even sunlight gives a recognisable image.

There are two main reasons why reflection holograms are not more widely used. First, the reconstructed images are not very bright; second, a colour change occurs between recording and viewing, that is to say a reflection hologram made with *red* laser gives a *green* image.

The explanation of the faintness and colour change of the image is as follows. When we shine white light onto the reflection hologram, most of it passes straight through the thin emulsion, but light which has a wavelength corresponding to the spacing of the silver layers (see Fig. 8) is selectively reflected. The action of the stacked layers is to pick out a narrow band of wavelengths and reflect them towards the viewer, as indicated in Fig. 9. Because the emulsion is so thin, not much of the light is reflected and so the image is very faint.

The change in colour between making and viewing the hologram is due to the leaching of the silver salts from the emulsion during the fixing stage. The emulsion shrinks on drying, and the layers which were originally half the wavelength of red light apart contract to a spacing of half the wavelength of green light—we therefore see a green image. By dampening the emulsion the correct colour can be recovered temporarily before the gelatine dries out once more.

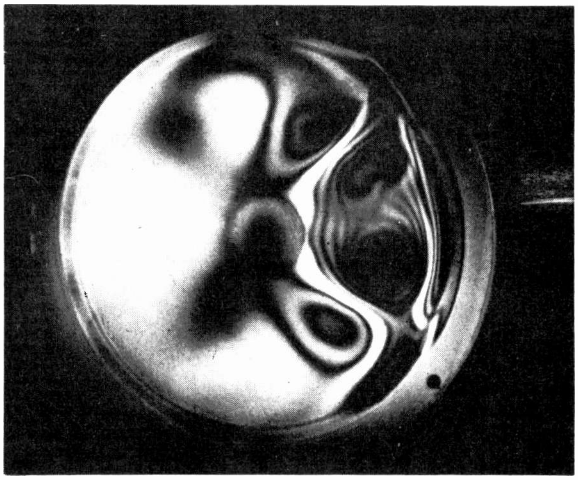


Fig. 7. Holographic interferometry shows that this faulty loudspeaker diaphragm is only vibrating over half its surface. The heading photograph at the beginning of this article shows the holographic image of a 40cm sonic transducer, designed for underwater operation, while the transducer was vibrating. The brightest regions correspond to the stationary nodal regions

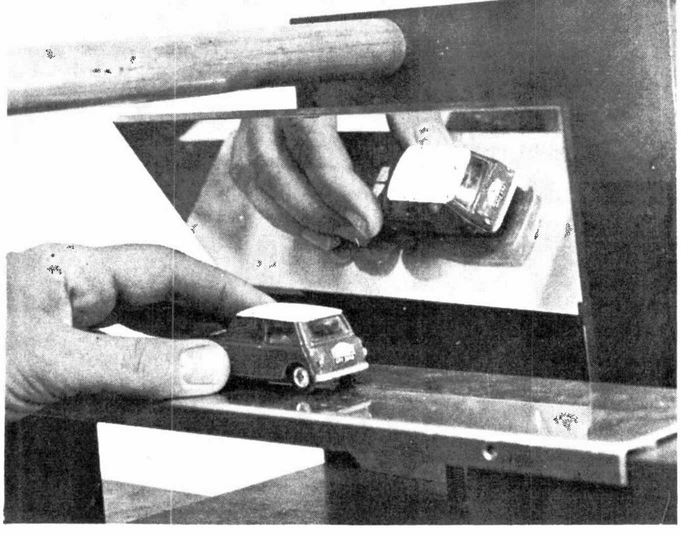


Fig. 5 (left). A toy car is placed on the "bridge" halfway through the holographic exposure

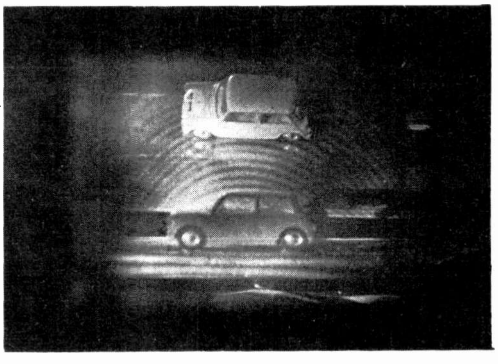


Fig. 6 (below). The holographic image shows how the weight of the car has deflected the bridge—each dark semi-circle represents half a wavelength of light deflection

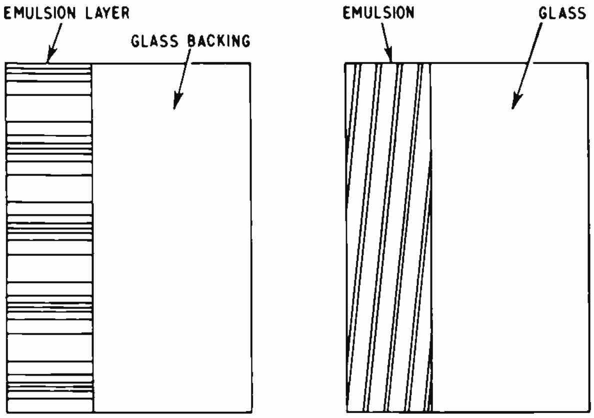


Fig. 8. The interference fringes layed down in a reflection hologram (right) differ from those recorded in an ordinary "transmission" hologram

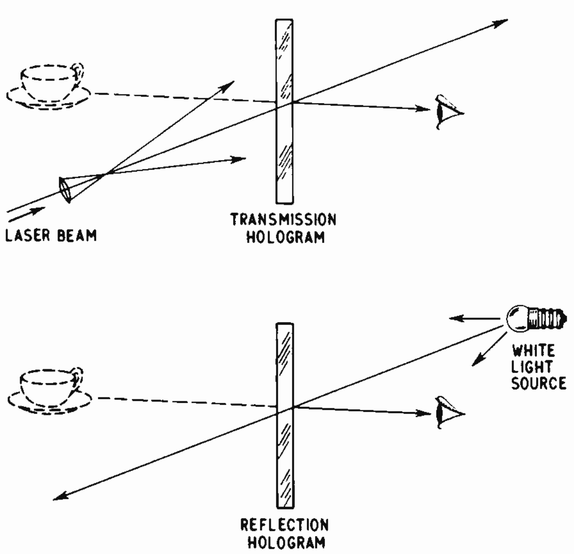


Fig. 9. Viewing transmission holograms and reflection holograms

You may have noticed that the images recorded in the holograms are of small objects, no more than a foot or so across. This is not due to a shortage of laser light. The reason is that even lasers are not sufficiently monochromatic but emit light with a narrow, but finite bandwidth. Referring to Fig. 3, the object light travels from the beam splitter, via M1, L1 and the object, to the hologram. If this object light gets out of step with the reference light, travelling via M2 L2 L3, by more than six inches or so, then it turns out that we are unable to record any interference fringes on the hologram—the two beams are said to be mutually incoherent. It is possible to make sufficiently monochromatic lasers to look at large objects, but a lot of light is lost in reducing the bandwidth.

The other problem in making holograms, that of keeping the equipment stationary during the exposure, can be overcome by the use of pulsed lasers. A pulsed ruby laser can be made to emit a 10 nanosecond burst of light. Moving objects can thus be "frozen", and holograms have been made of bullets travelling at hundreds of feet a second.

FUTURE DEVELOPMENTS

We can now look to the future and see how holography may develop. At the present time most effort seems to be going into interferometric applications, where small object movements require measuring. Various workers in the U.S.A. have made multi-colour reflection holograms—by using different coloured lasers in making the hologram a multi-coloured image can be obtained. A lot of work has still to be done however, before other than very small objects can be imaged in colour.

Projects such as holographic television are even less developed. At least two big problems remain unsolved—the nature of the "television tube", and the large bandwidths required. If we recall that a hologram is a "window" through which we look at the scene beyond, then it is clear that the "window-frame" has to be quite large in order not to intrude on the viewer. Since the picture has to change at about 25 frames per second, we must "read in" the hologram onto the screen at this rate, and also erase it. Unfortunately, an ordinary television tube cannot be used to project holograms, and the possible alternatives, such as the existing Eidophor projection television system, simply do not have the image resolution required.

This brings us to the other problem, that of bandwidth. Suppose that our hologram window is one foot square. The required fringe detail in the hologram is about 1,000 lines per mm (see Fig. 4)—thus the number of "picture points" required is about 10^{11}. To project this at a rate of 25 frames per second requires the enormous electrical bandwidth of 2·5 tera-cycles per second. Despite the possibilities of bandwidth compression techniques, it is evident that an acceptable holographic television system is still a number of years away.

There is, however, no need for gloom about the prospects for holography. After a protracted infancy, from 1947 to 1964, the last three years have shown considerable improvements in equipment and technique, and this progress is still continuing—the future prospects for holography look distinctly inviting. ★

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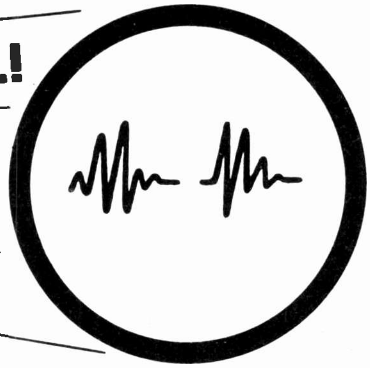

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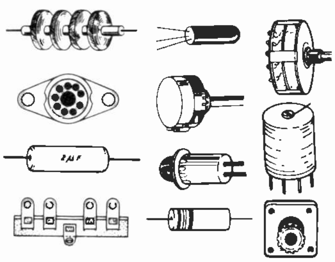

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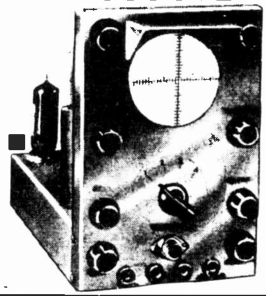

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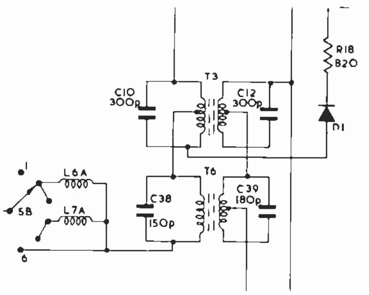

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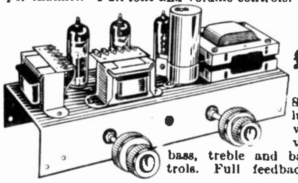

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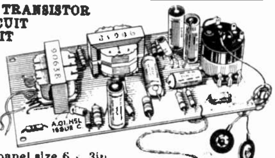

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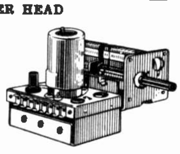

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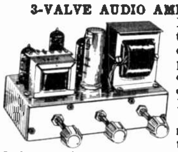

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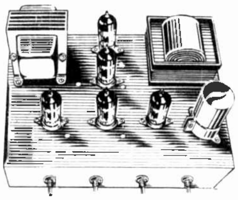

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Uncut motor board size 14½in. × 12in. clearance 2in. below, 5½in. above. Will take above amplifier and any B.S.R. or GARRARD Autochanger or Single Player Unit (except AT60 and SP25). Size 18in. × 15in. × 8in. **PRICE £3.9.6.** P. & P. 9/6.

VYNAIR AND REXINE SPEAKER AND CABINET FABRICS app. 54in. wide. Usually 35/- yd., our price 13/6 per yd. length. P. & P. 2/6. (min. 1yd.). S.A.E. for samples.

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E.M.I. 13½in. × 8in. with high flux ceramic magnet, 42/-. (15 ohm, 45/-). P. & P. 5in. 2/-, 6½in. & 8in. 2/6, 10in. & 12in. 3/6 per speaker.

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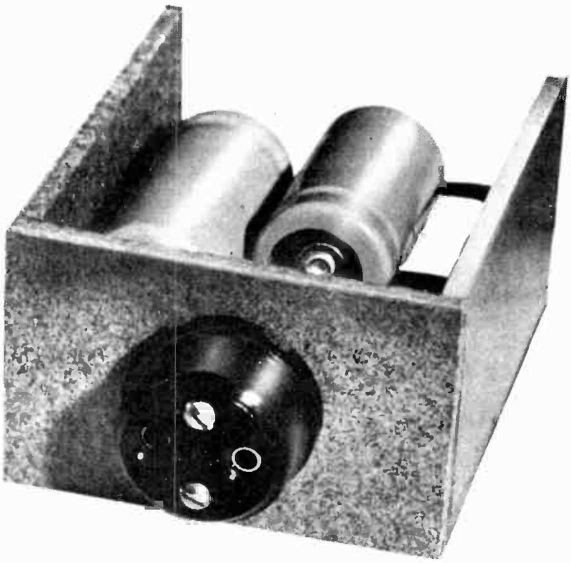
SHAVER ADAPTOR



By
S.F. HANNAFORD

THE voltage doubler described here was built to enable a 200–240 volt a.c./d.c. electric shaver to be used on 100–115 volt a.c. mains when travelling abroad. The output is 200–240 volt d.c. depending on the input voltage. The razor was found on test to take 60 to 70mA at 240 volts, the output of the voltage doubler being ample for this as the rectifiers are rated at 500mA at 250 volts. The circuit is shown in Fig. 1.

The 16μF 150 volt working capacitors were used because of their small size, but are not as easy to obtain as the higher voltage types; these may be used instead but will make the unit more bulky.

CONSTRUCTION

The two capacitors are soldered to a six-way tag strip and arranged side by side, with the positive of one capacitor joined to the negative of the other, see Fig. 2. Where the ends of the capacitors are soldered to one tag a lead from the 110–115 volt flex should also be soldered on to the same tag.

The rectifiers are soldered to the opposite ends of the capacitors together with the output leads. It is important to observe the polarities of the rectifiers and capacitors. When soldering, a pair of pliers should be used to act as a heat shunt from the leads.

The other ends of the rectifiers are soldered together on to the tagstrip and the remaining 110–115 volt lead is soldered to this junction point.

Once all the wiring to the tag strip is completed it should be fitted in a small hardboard, or similar material, case. A large diameter cardboard roll would be ideal. The output leads can be wired to a socket bolted to the end of the case or can be the actual shaver leads.

It is advisable that the components be mounted in an insulated case, but if a metallic case is used, this must be connected to earth. *The 240V output terminals must not be connected to the mains supply.* ★

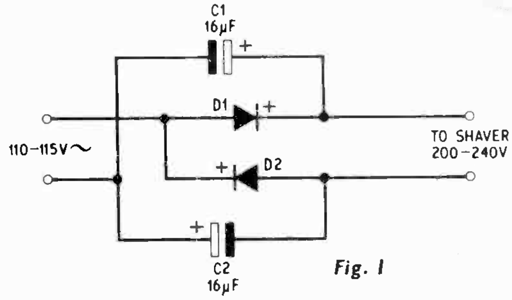


Fig. 1

COMPONENTS . . .

Capacitors
C1, C2 16μF elect. 350V (2 off)

Diodes
D1, D2 REC51A (Radiospares) (2 off)

Miscellaneous
Six-way tag strip. Plug and socket. Hardboard for case, see text

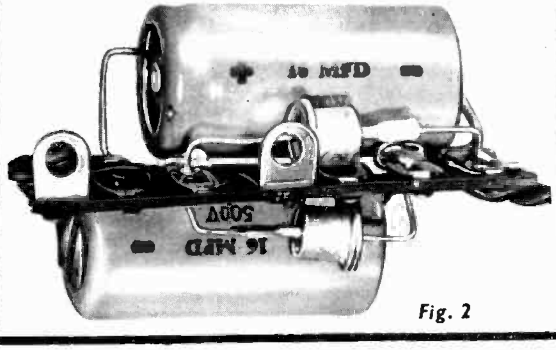


Fig. 2

Introducing . . . . PEAC

A low cost, general purpose analogue computer of modern design, intended for the amateur or student.

A useful tool which is capable of solving complicated problems at high speed.

Can be used as a model to simulate mechanical systems and electronic networks.

Extends enormously the scope of the amateur experimenter.

This series of articles will explain in detail the design, construction, and operation of PEAC.

ANALOGUE

Most of the publicity afforded to computers favours digital equipment. However, digital methods tend to be disproportionately expensive for small installations. On the other hand, although analogue equipment is ideally suited to limited, low-cost applications, it was not until the silicon transistor had become firmly established, and enough practical published information was available, that a start could be made on designing analogue computing equipment to yield a reasonable standard of performance in the lowest possible price range.

A WORTHWHILE PROJECT

No doubt many readers will think that construction of a true computer could involve them in a great deal of time, money, and effort. They might also believe that an average understanding of mathematics would not be sufficient to equip them to operate a computer effectively. However, the amount of time and money spent building PEAC need be no more than is consumed by a home constructed hi fi outfit of normal proportions and performance, and the computer will solve even simple problems a great deal faster than the human mind or slide rule, once it has been programmed to do so.

In fact, a general purpose computer can find application in almost every sphere of technical activity, and is particularly useful in the electronic workshop, to the point of becoming indispensable after a short period of use.

UNIT CONSTRUCTION

PEAC is arranged in the form of units, and is organised in such a way that reasonably advanced computations may commence upon completion of the first unit, UNIT "A". The cost of building UNIT "A", based upon typical retail prices at the time of writing, will not be much above £25, and yet it will solve algebraic polynomial equations, simultaneous linear equations, simple differential equations, and can also be used to simulate the behaviour of many elementary mechanisms and electronic networks.

UNIT "A" is designed primarily to satisfy a minimum user requirement, for experimental and educational work, but it also serves as a convenient starting point for the addition of further units to expand the computer to almost any desired degree of capability and complexity. The additional facilities provided by the add-on UNITS "B", "C", and "D" are described in the specification. See also the block diagram, Fig. 1. 1.

A comprehensive PEAC installation, equipped with a function generator and multiplier, and with full integrating facilities for the fast solution of a range of differential equations, might finally cost around £60: not a lot to pay for an item of workshop equipment which can solve electronic formulae in 10ms, and which may also be employed as a variable waveform generator, 18 input high quality audio mixer, variable characteristic high *Q* audio filter, large inductance or capacitance simulator, d.c. or a.c. millivoltmeter, and many other things besides.

COMPARISON BETWEEN ANALOGUE AND DIGITAL COMPUTERS

Although popularly regarded as an inaccurate machine of limited usefulness, the analogue computer is to be found in the Polaris missile, spacecraft, aircraft, large scale chemical processes, and many automated production lines, quite apart from basic research work, where flexibility and ease of working are often considered to be more important than extreme accuracy. The analogue computer is, in most cases, very much faster than its digital counterpart, and can offer far more in the way of general facilities for a given outlay.

The time taken to solve a problem on an analogue computer is independent of problem length. All circuits operate in parallel, simultaneously. A typical solution might be arrived at in 20ms, and this solution can then be repeated at the rate, say, of 25 solutions per second. In human terms the solution is virtually immediate and continuous, therefore, any adjustments made to problem parameters (terms of an equation) while the computer is working will be immediately reflected in the solution readout. This rapid response allows the operator to quickly gain an insight into the workings and structure of a problem.

In contrast, digital computers perform many mathematical operations in a pre-determined and comparatively lengthy sequence, which bears little obvious relationship to the structure of the problem, but they do offer the very high degree of accuracy essential for calculations involving money or very precise data.

The computer of the future will undoubtedly combine the best of both worlds with analogue and digital equipment in hybrid form.

ANALOGUE METHODS

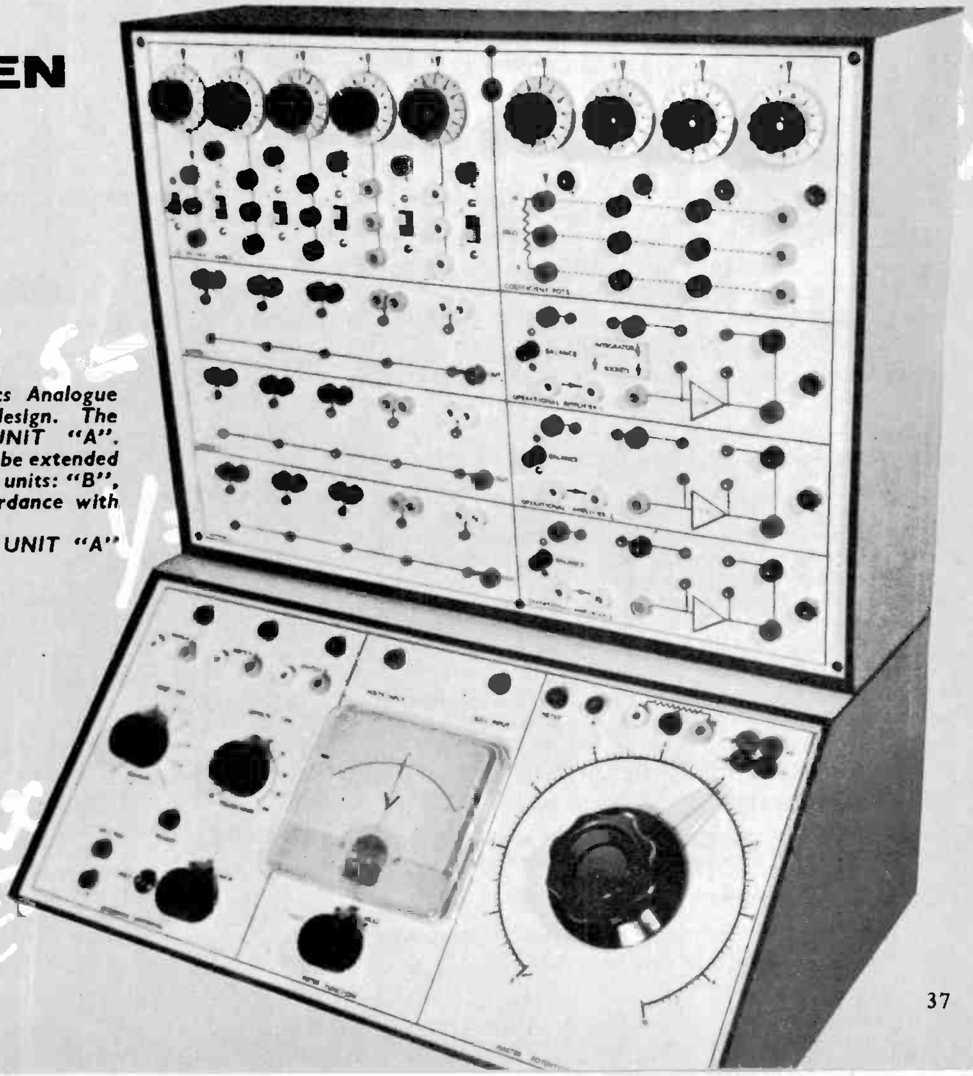
The statement that an aeroplane is a machine for solving sets of differential equations is not very far removed from the truth. If the aeroplane did not solve its equations correctly it would not be able to fly at all. Almost all relationships or events can be described mathematically, or in turn be represented by an analogy. A model aeroplane in a wind tunnel solves, by analogy, roughly the same equations which govern the behaviour of the real aeroplane, although in much simpler and less expensive fashion.

An analogy of a physical or mathematical process could be achieved by a system of gears, pulleys, and levers; or by the controlled flow of gases or liquids. But in the last couple of decades electronic methods of simulation and equation solving have become almost universal, because of the accuracy, availability, and adaptability of standard electronic components.

The main purpose of the analogue computer is to allow a model to be set up quickly and easily, to simulate the behaviour of a full scale system, and at

COMPUTER

By D. BOLLEN



The Practical Electronics Analogue Computer is of flexible design. The basic equipment is UNIT "A". Computing facilities may be extended by the addition of further units: "B", "C" and "D", in accordance with user requirements. This photograph shows UNIT "A" standing on UNIT "B"

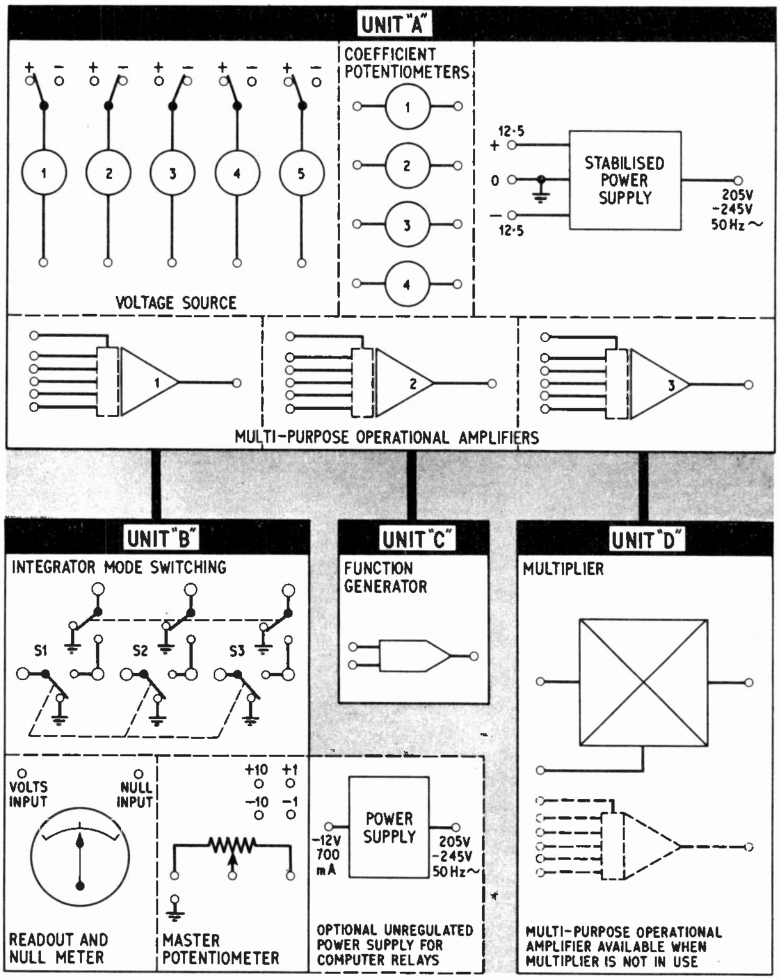


Fig. 1.1 Block diagram of

PEAC

SPECIFICATION

UNIT "A"

POWER SUPPLY

Input 205V—245V 50Hz. Output ±12·5V d.c. Voltage regulation better than 1% for loads of 0—200mA, and 2% for 0—300mA. Total ripple 2mV. Complete short circuit protection.

AMPLIFIERS

Three multi-purpose operational amplifiers, each with five silicon transistors. Open loop voltage gain greater than 5,000. Output ±10V at 5mA. Current demand (average) 40mA. Equivalent input drift under normal room conditions better than ±0·5mV per hour. Unity gain frequency response within 1% for 0—10kHz, and 5% for 0—25kHz. Typical noise and hum at output 3mV.

VOLTAGE SOURCE

Five independent outputs, each continuously variable in three steps giving ±0—0·1V, ±0—1V, and ±0—10V. Dial setting accuracy better than 3% of full scale between dial divisions 1—10. Total current demand 50mA.

COEFFICIENT POTENTIOMETERS

Four 10 kilohm 270° potentiometers. Dial setting accuracy better than 5% of full scale between dial divisions 1—10.

SUMMING NETWORKS

Three five-input summing networks provided with voltage check sockets, and plug-in computing components.

UNIT "B"

MASTER POTENTIOMETER

25 kilohm 300° wirewound, 25 watt. Two voltage measuring ranges ±0—1V and ±0—10V. Scale length 14in. Accuracy better than ±0·5% of full scale.

READOUT METER

Centre zero 100—0—100μA, calibrated 0—0·3V, 0—1V, 0—3V, and 0—10V. Accuracy better than ±2% of full scale.

INTEGRATOR SWITCHES

Provision for three or more integrating amplifiers. Compute times ranging from 10ms—1s. Single shot or repetitive mode with "hold" facility. Current demand around 65mA.

UNIT "C"

FUNCTION GENERATOR

Diode function generator for parabolic and other functions. Typical accuracy 2%. Frequency response to several kHz.

UNIT "D"

MULTIPLIER

Four quadrant multiplication of two or more variable voltage inputs. Also incorporates an operational amplifier which may be used on its own to supplement the amplifiers of UNIT "A". Frequency response generally better than 0—50Hz. Approximate current demand around 75mA.

the same time solve the equation which represents the system. Sometimes the computer will be used just for solving equations or, alternatively, as a working model only, depending on the nature of the problem. The advantage of the electronic computer is that it will do each, or both at the same time, with ease.

The computer is set up, or "programmed", for a particular task by inserting computing components, i.e. resistors and capacitors, into sockets on the front panel. This procedure will be described in full detail in due course.

ANALOGUE COMPUTER CIRCUITS

In the electronic analogue computer, the analogy is created fundamentally by manipulating sets of d.c. voltages. There is nothing to prevent a.c. voltages being used—in fact they often are—except that a.c. measurement techniques are generally less accurate at low levels than d.c. However, when simulating dynamic processes with d.c. voltages, the computer will be handling a voltage which varies with time. In this context it is more appropriate to regard a waveform, even if it is a pure sinewave, as a d.c. voltage varying with time according to a formula which describes the nature of the waveform.

The main computing element is the "operational amplifier". As far as operational amplifiers are concerned, the decibel is much too coarse a unit to use for the measurement of frequency response, so amplitude linearity is usually expressed as a percentage variation over a fairly restricted range of audio frequencies. In some cases, for example, an operational amplifier and its attendant circuits will be expected to respond to inputs from d.c. to 5kHz with an accuracy of a fraction of 1 per cent, and up to 10kHz at no worse than 1 per cent.

COMPUTING ELEMENTS

The majority of problems can be solved by the varied application of only five analogue elements, but the size of the problem to be handled will in turn depend on the quantity of elements available, and hence on the overall size of the computer.

The five computing elements are shown in Fig. 1.2, together with their conventional symbols and generalised functions. The symbols are used as a kind of shorthand when drawing up a computer programme.

The first thing to note about the simplified circuit diagrams of Fig. 1.2 is that the common earth return is often completely ignored. Computer supply voltages are usually positive and negative in relation to an earthed centre tap. Since the input and output terminals of each computing element are arranged to be very close to earth potential in the absence of an input voltage, it is feasible to take the earth rail for granted and regard all circuits as having only two terminals, instead of the usual four.

Although the symbol and function of each of the elements of Fig. 1.2 are common to all analogue computers, the actual circuit design and choice of components will naturally vary from one computer to another. For example, the time-division multiplier of Fig. 1.2e is only one among many possible circuit configurations for achieving multiplication of independent variables. Alternative approaches include the Hall effect, the servo, logarithmic, and quarter square multipliers.

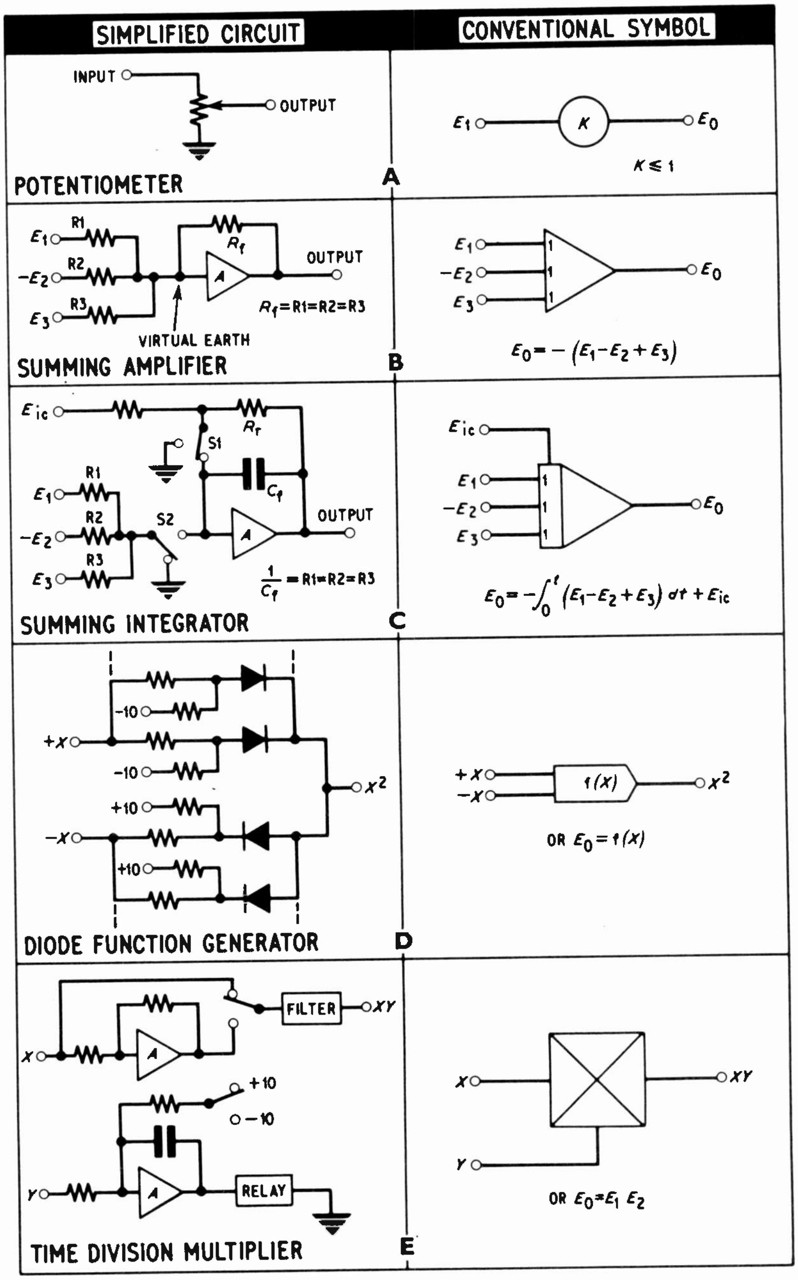


Fig. 1.2 Analogue computing elements

It is proposed to examine computing elements in greater detail when they are dealt with individually at a later stage, but in the meantime a brief survey will suffice.

COMPUTING POTENTIOMETER

The potentiometer of Fig. 1.2a may be used for multiplying a variable voltage (often called a machine variable) by a constant of less than unity.

Example: potentiometer input 1·5 volts. Slider set exactly half way along resistance track, corresponding to a constant of 0·5. Output voltage E_o therefore equals $1{\cdot}5 \times 0{\cdot}5$, or 0·75. As set, the potentiometer will multiply any input voltage by 0·5.

When incorporated in the feedback loop of an operational amplifier, the potentiometer will divide a machine variable by a constant smaller than 1. The fact that potentiometer constants are less than unity is no real disadvantage. It is a simple matter to either increase input voltages by a factor of ten, or increase the gain of an operational amplifier ten times, to bring the potentiometer constant above unity. Like the slide-rule, it is simply a matter of deciding in advance where the decimal point should be.

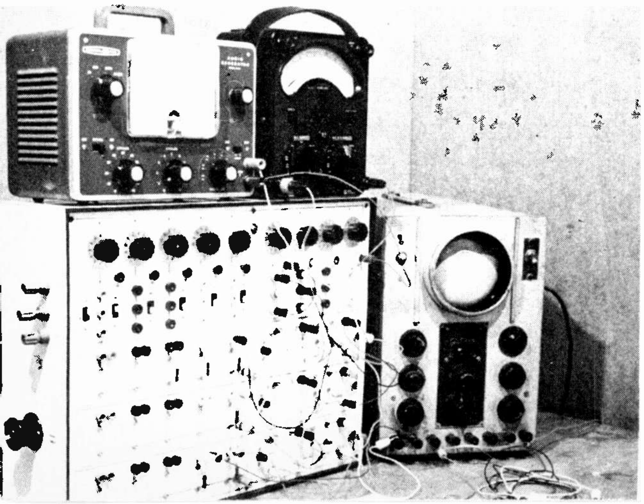
SUMMING AMPLIFIER

The summing amplifier of Fig. 1·2b uses a high gain operational amplifier with several inputs to achieve addition and subtraction of machine variables. When the operational amplifier has a voltage gain equal to several thousand, input voltages will be accurately summed together, without unwanted interaction. The summing junction SJ is at "virtual earth", a way of saying that SJ will never be more than a few millivolts above or below earth potential, and is also, to all intents and purposes, shunted by a resistance of only a few ohms. Compared with input resistors R1–R3, the SJ shunt resistance is very low indeed, a condition necessary for accurate summing of voltages.

A definite relationship exists between resistors R1–R3, and feedback resistor R_f, and if these resistors are arranged to plug into the amplifier, many problem conditions can be met by "ringing the changes" on preferred values of fixed resistor, including multiplication by a constant as well as addition.

If a voltage E_1 is applied via resistor R_1 (in Fig. 1.2b) ot the summing junction SJ, the output voltage E_o will

This photograph shows UNIT "A" being used to simulate a tuned LC circuit, consisting of an inductance of 5H in series with a capacitance of 5μF. The oscilloscope is displaying phase shift within the simulated circuit at the resonant frequency of 31Hz, and the trace also gives an indication of the damping factor or "Q" of the circuit



be $-\,E_1\dfrac{R_f}{R_1}$. The operational amplifier is designed to invert an input voltage, hence the minus sign in front of this expression. The ratio between input resistor and R_f holds good for each input.

Example: apply three input voltages $E_1 = 5$, $E_2 = -\,3{\cdot}5$, and $E_3 = 2$ to the summing junction via $R_1 = 10$ kilohm, $R_2 = 2$ kilohm and $R_3 = 100$ kilohm. Let the feedback resistor $R_f = 10$ kilohm. The relationship between voltages and resistances will be

$$E_o = -\left(E_1\frac{R_f}{R_1} - E_2\frac{R_f}{R_2} + E_3\frac{R_f}{R_3}\right)$$ Substituting values

$$E_o = \left(5\frac{10}{10} - 3{\cdot}5\frac{10}{2} + 2\frac{10}{100}\right) = (5 - 3{\cdot}5 \times 5) + 0{\cdot}2),$$

therefore $E_o = 12{\cdot}3$.

In the above example, the summing amplifier has not only summed negative and positive inputs, but has also multiplied E_2 by 5, and E_3 by a constant of 0·1, merely by selection of appropriate values of input resistor.

SUMMING INTEGRATOR

The summing integrator is used for the detailed investigation of time dependent variables, and for the solution of problems involving calculus.

The integrator of Fig. 1.2c is based on the inverting operational amplifier, with capacitor C_f acting as the feedback component. The output from a single integrator, in response to a steady voltage input, is a linear ramp voltage which increases with time at a rate dependent on choice of input resistor, feedback capacitor, and input voltage. Once again, precise relationships must exist between computing components and voltage, but now time is introduced as an additional analogue variable.

The action of electronic integration is best explained by a working example, and reference should be made to the diagram of Fig. 1.3a.

Example: a fairly sluggish motor car accelerates from rest at a steady rate of 20ft/second/second. Examine the progress of the motor car during the first four seconds of its motion. The computer is set up to operate in "real time", that is to say, the time actually occupied by the motor car when accelerating. The problem layout of Fig. 1.3a shows a computing potentiometer "A" coupled to the input of Integrator "1", which in turn feeds Integrator "2". Voltmeters are connected into circuit to display the three parameters of interest. Potentiometer "A" is first adjusted so that its dial reads 2, corresponding to multiplication by the constant 0·2, to represent 20ft/s^2 scaled down to yield a voltage of appropriate magnitude for the integrators to handle. The output from the potentiometer is a steady voltage analogue of a steady rate of acceleration.

As soon as switch S3 is closed to the +V position, the velocity and distance meter pointers will start to move in a manner analogous to the motion of the motor car. Velocity will increase linearly with respect to time, while distance will be displayed as an accelerating pointer movement. Integrator "2" computes distance (s) as a voltage function of the square of time, in terms of $s = \frac{1}{2}at^2$.

With the problem of Fig. 1.3a, acceleration, velocity, and distance are immediately available to the computer operator as dial and meter readings. He can vary acceleration just by turning the dial of the potentio-

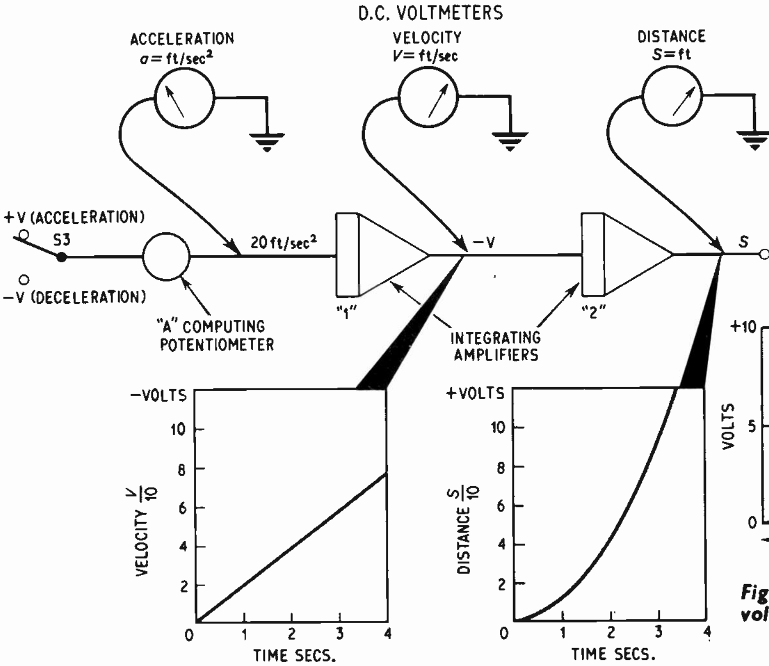


Fig. 1.3a (left). The use of integrators is illustrated in this diagram. In this example the rate of acceleration, velocity, and distance covered by a motor car are computed and can be read off the potentiometer dial and meter scales

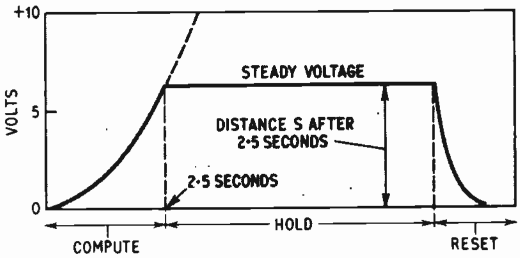


Fig. 1.3b. Arresting a computation to give a steady voltmeter reading

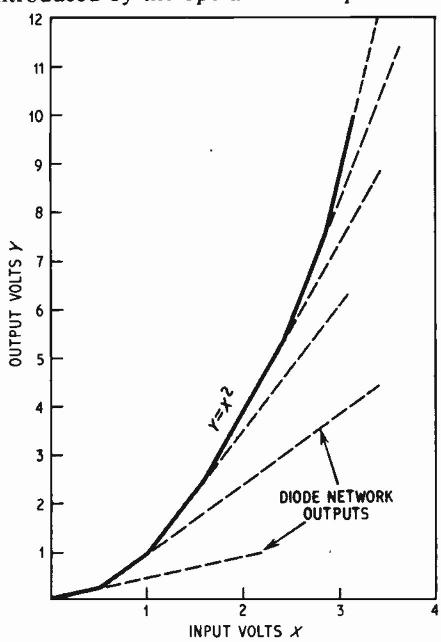
meter. If switch S3 is moved to the −V position, the car will decelerate and stop.

COMPUTE, HOLD AND RESET

It is obviously inconvenient to take readings from voltmeters when pointers are on the move, and it is impossible to do so if time t is very short, as with fast events, or when the computer is speeded up to some fraction of real time. The sequence governing switches S1 and S2, in Fig. 1.2c, is therefore arranged to provide three facilities, called "compute", "hold", and "reset".

The purpose of the "hold" facility is to allow a steady meter reading to be taken at any point on the voltage/time curve output of an integrator. The high gain introduced by the operational amplifier effectively multiplies the capacitance of C_f when the integrator input is disconnected from input resistors and reset resistance R_r. With amplification, C_f becomes the equivalent of a very large capacitor which is capable of holding a charge for a relatively long time. In practice, the ability of an integrator to "hold" or store a voltage will also depend on low amplifier drift.

Fig. 1.3b shows graphically the effect of compute, hold, and reset modes, when applied to the distance curve of Fig. 1.3a. In this case, it is necessary to halt the computation after an elapsed time of 2·5s, and obtain a value for distance in the form of a steady meter reading.



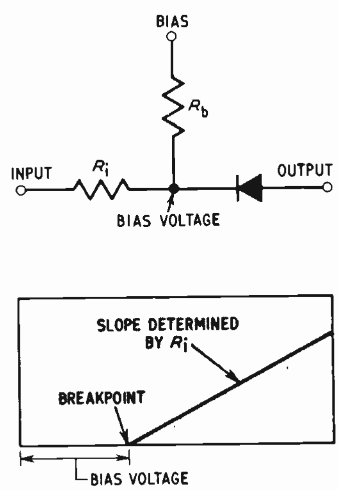


Fig. 1.4a (left). Illustrating how a mathematical function can be constructed from a series of straight line tangents

Fig. 1.4b (above). A single diode network and its output characteristic

The compute mode is initiated by opening S1 and closing S2 (Fig. 1.2c). After 2·5seconds, S2 automatically opens and the amplifier input is left floating, with C_f still connected between input and output and holding a stored charge. A meter coupled to the integrator output will show the distance travelled after 2·5s of acceleration.

The "hold" period can occupy several tens of seconds, and is usually at the discretion of the operator. To begin a new computer run, S1 is closed, discharging C_f through R_r, thus resetting the integrator output to zero. The input E_{ic} in Fig. 1.2c, is to allow an initial condition to be applied to the integrator, as in the case of a motor car which does not start from rest, but is already in motion when it accelerates. When computing and resetting times are shorter than about 1s, voltmeter answers will appear to be given at the instant of pressing the button which initiates the S1, S2 cycle.

The above description relates to a "single shot" computer run, where the operator adjusts, takes a reading, adjusts, and so on. In the repetitive mode, the hold facility is ignored and the computer keeps on repeating the answer curve, for display on an oscilloscope, chart recorder, or XY plotter.

DIODE FUNCTION GENERATOR

In many computer applications it is necessary to generate a voltage which varies according to some non-linear function not provided by normal operational amplifier techniques. The diode function generator of Fig. 1.2d will allow a mathematical function to be constructed from a series of straight line tangents, as shown in Fig. 1.4a.

Each straight line characteristic is obtained from a single diode-resistor network, and when the outputs from several networks are summed together a complete function will result. The shape of the final approximated curve is determined by adjustment of the network resistors. Apart from powers of x, and other functions, roots are achieved by placing the function generator in the feedback loop of an operational amplifier.

A single diode network appears in Fig. 1.4b, and the slope of its output characteristic can be varied by adjustment of R_1. The diode breakpoint (the voltage at which the diode starts to conduct) is dependent on the value of R_b.

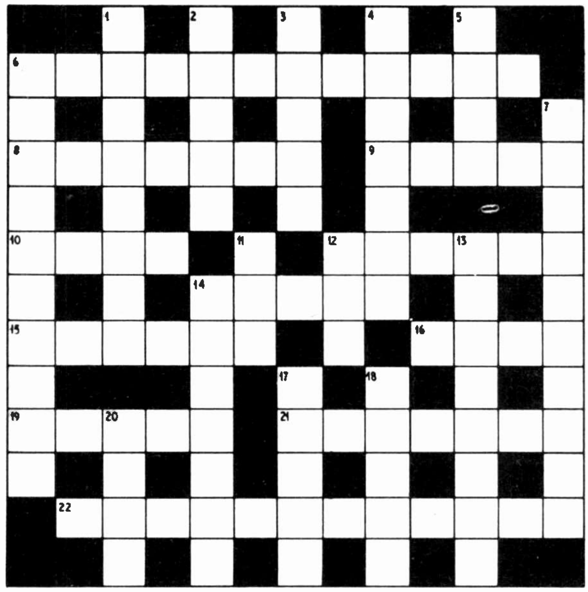
MULTIPLIER

The computing potentiometer will multiply a variable by a constant, but special techniques must be used to multiply one variable by another variable. The process employed in modern computers is akin to modulation, where the gain of a circuit is controlled by an applied voltage.

The multiplier should yield a product of correct sign when multiplying negative or positive variables, and this is readily achieved with the self-excited time division circuit of Fig. 1.2e. The time division multiplier operates on the principle of modifying the mark-space and amplitude of a square wave in accord with two voltage inputs. The filter of Fig. 1.2e extracts the mean level of d.c. from the square waveform. An additional advantage of the Fig. 1.2e circuit is that it can be arranged to cater for more than two variables. For example, inputs $X1$, $X2$, and $X3$ multiplied by input Y.

Next month: Commencing the construction of UNIT "A".

CROSSWORD . . .



CLUES

Across

6. An integral part of the Wheatstone Bridge (9, 3)
8. One million megohms (7)
9. Dye (5)
10. An electrode of 11 down (4)
12. He patented the incandescent filament lamp (6)
14. A thousand start to consume the poet (5)
15. Nonsense and knaves could be so described (6)
16. β (anagram) (4)
19. Adipose (5)
21. Electronic effect favoured by some instrumentalists (7)
22. It fixes a valve's working point (8, 4)

Down

1. This describes "j" (8)
2. "Flip-flop" is one in the language of electronics (5)
3. Zurich Banker? (5)
4. Special forms of procedure (7)
5. A Schmitt trigger would hardly fire this gun (4)
6. Well known operational amplifier (10)
7. This radar valve gets Norman confused (10)
11. Semiconductor with circuit applications similar to a valve (abbr.) (3)
12. Greek letter (3)
13. Below the audio range (8)
14. Would this attenuate a batsman's scoring? (4, 3)
17. He shows a lot of self control (5)
18. Denary equivalent of binary 0111 (5)
20. These numbers are integrally divisible by two (4)

Solution next month

POINTS ARISING

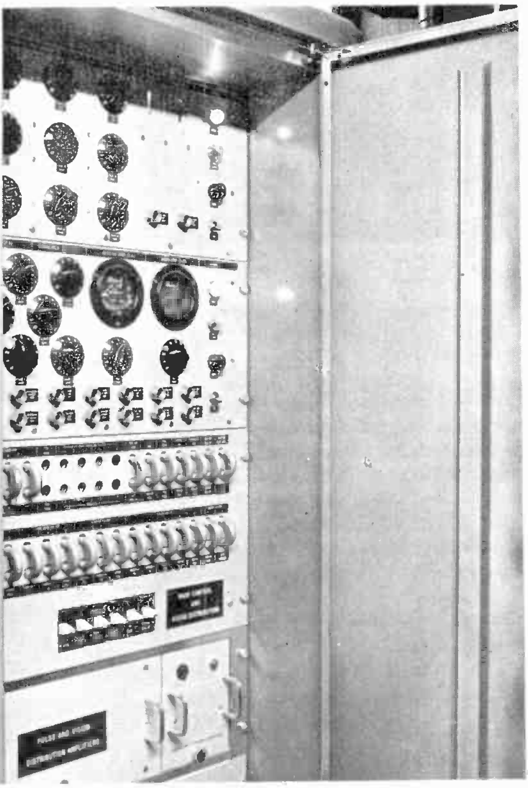
ANTI-DAZZLE DRIVING MIRROR (December 1967)

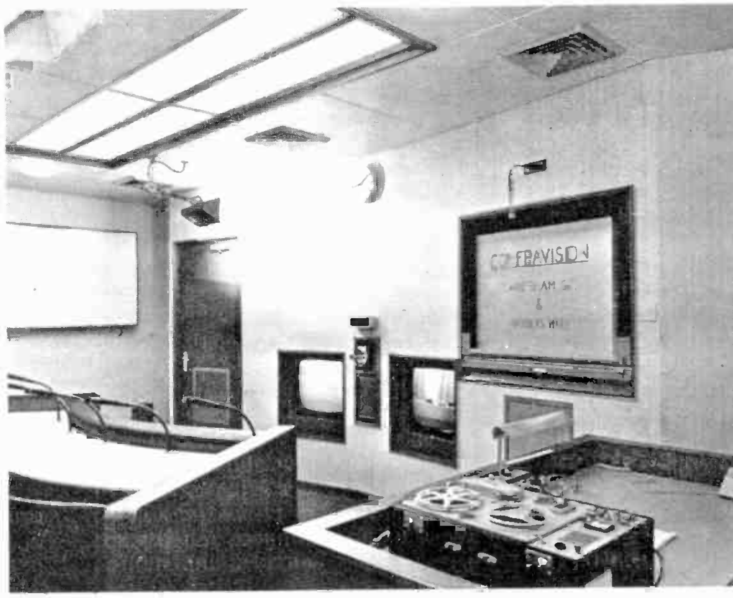
Transistor types in components list should read as follows:

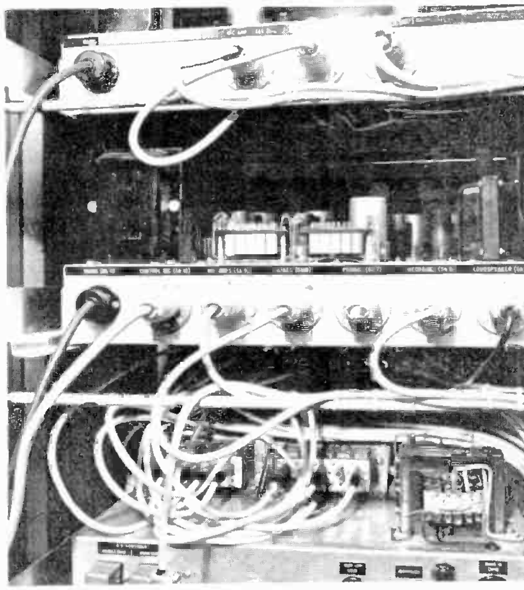
TR4 XA701 or 2N1304
TR5 XC141 or OC35

The second type mentioned in both cases is the more recent type of transistor and is the preferred choice.

ELECTRONORAMA







"Confravision" Launched

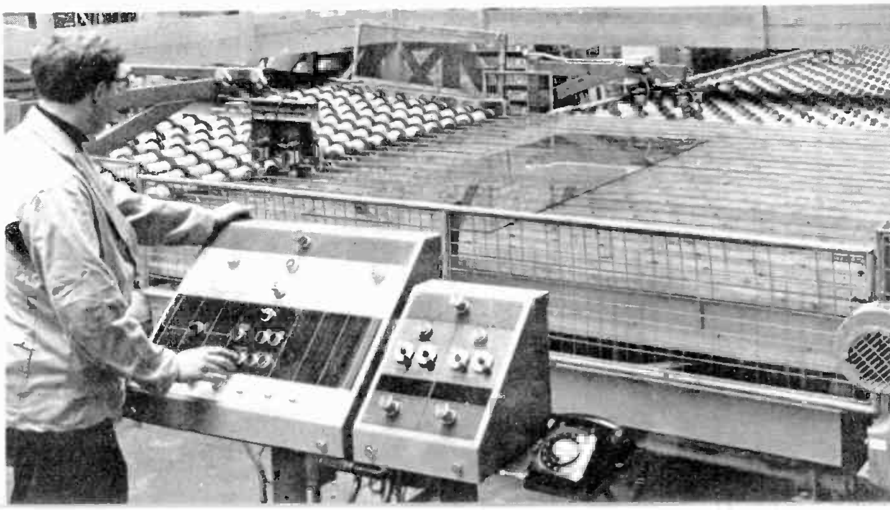
CONFERENCES between two distant locations can now be conducted through the medium of closed circuit television. Following a demonstration of the system between Gresham Street in the City of London, and the Post Office Research Station at Dollis Hill, North-west London (about 10 miles apart), our correspondent joined the panel in the City and found that greater relaxation was experienced while conversing with the other panel over the television link. By the inclusion of "privacy" equipment; proceedings would be kept confidential; a scrambling code is brought into operation to obviate telephone tapping. A translucent blackboard with written or drawn material can be monitored from behind it and transmitted to the distant studio.

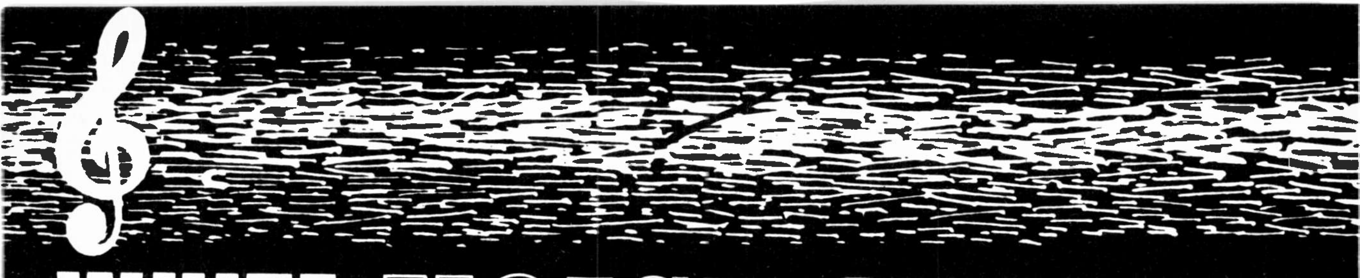
The photographs (by courtesy of the Postmaster-General) show the front of the main equipment rack (above left), the studio in London (above right), and the rear view of the equipment rack (right).

Logicon Controls Float Glass

AUTOMATIC control of float glass processing, involving cutting, snapping, squaring, and berthing has been installed at the Pilkington plant at St. Helens, Lancashire. Under automated control from AEI Logicon solid state electronic systems, the operation forms part of a continuous process in producing a continuous ribbon of glass which is cut into patterns of a required size. The glass is then trimmed and snapped before being conveyed into the warehouse.

Control of the speed of the plant is effected by adjustment to the frequency of the output. A mains standby transformer can be used to enable the plant to be run at constant speed from the mains supply. Signals from over 300 vane-operated magnetic proximity switches, which can detect the presence of glass, initiate the Logicon system controlling the various operations.





WHITE NOISE GENERATOR

By A.J. BASSETT

WHITE NOISE is a very special form of audible sound, in that it has no special pitch or waveform, but contains a random mixture of pitches and waveforms, covering the entire audio spectrum. This makes it a very interesting subject for the audio experimenter, who can, from a given sample of white noise, electrically or acoustically filter out and make use of sounds of any desired pitch, or within any chosen passband. It is also possible to adjust the envelope waveform of a given sample of white noise, either before or after filtering.

By means of these manipulations, it is possible to produce a wide range of very interesting sound effects, many of which are of practical use in making electronic music. Some examples of these effects are: steam locomotive; heavy surf; wind effects; cymbals; rhythmic wood-blocks; and an effect very loosely termed "phasing", which finds considerable favour as a "psychedelic audio experience". More about these special effects will come later.

The circuit of the white noise generator operates from a power supply of 18 to 24 volts, although a 9 volt battery can be used, as described later, and gives rather less output. Construction is based on a standard P.E. *Bonanza Board* printed circuit as shown on the full size pattern in Fig. 2a.

HIGH LEAKAGE DIODE

Electrical power is fed to diode D1 through resistor R1. The diode is reverse biased, but passes quite a considerable leakage current with the result that a random output or white noise output is produced at the junction. The way in which this happens is described in considerable detail in various textbooks. The output from the diode is at a fairly low level, so is fed via C2 to a high gain transistor stage TR1, which amplifies the white noise output to a more useful level. This output is available from the collector of TR1, and is fed to the output connection point through the coupling capacitor C4.

CONSTRUCTION

Obtain the components listed except diode D1, and resistor R1, which are mentioned later in the text, and solder to the printed circuit board in the positions shown in Fig. 2b. Connect also the link wires shown. Connect the circuit to the power-source (a suitable power supply unit was given in the *Spring Line Reverberation Unit* last month) or a 9 to 18 volt dry battery. The voltage across TR1 (collector to emitter) should be about half the supply voltage. If it is not near this value, change the transistor or select a different value for R3 accordingly.

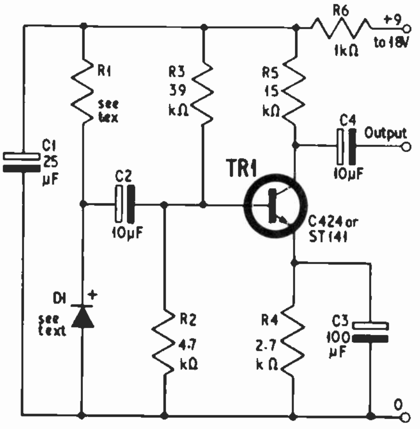


Fig. 1. Circuit diagram of the white noise generator

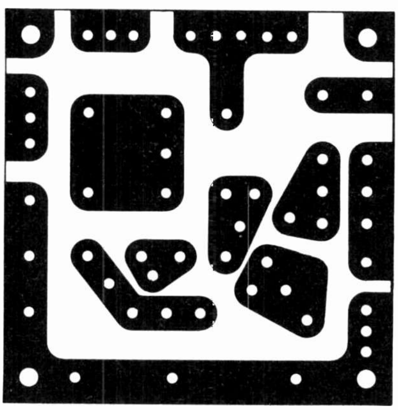


Fig. 2a. Printed circuit pattern of the "Bonanza Board"

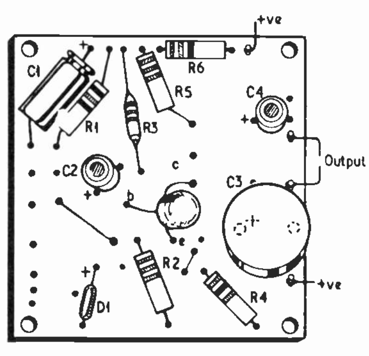


Fig. 2b. Final layout of components on the printed circuit board

COMPONENTS . . .

Resistors

R1	see text	R4	2·7kΩ
R2	4·7kΩ	R5	15kΩ
R3	39kΩ	R6	1kΩ

All 10%, ¼ watt carbon

Capacitors

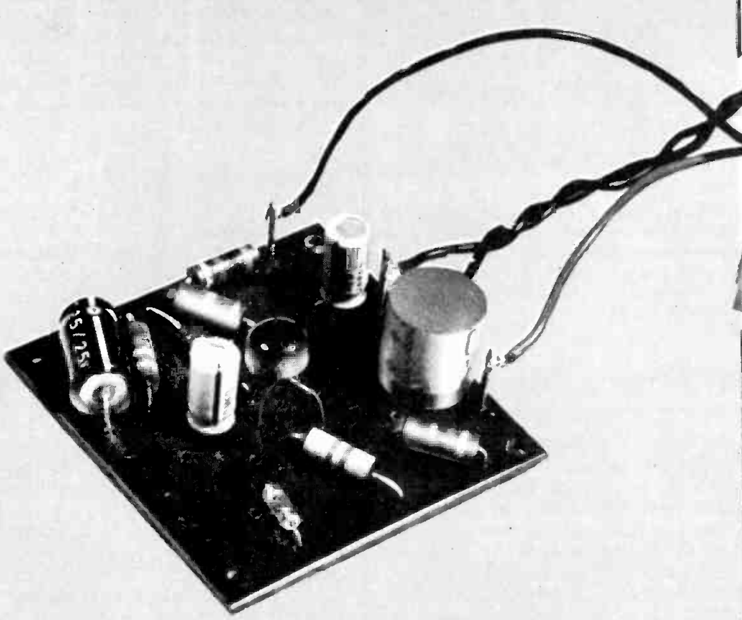
- C1 25μF elect. 25V
- C2 10μF elect. 25V
- C3 100μF elect. 12V
- C4 10μF elect. 25V

Transistor and Diode

- TR1 C424 (S.G.S. Fairchild) *or* ST141 (Sinclair)
- D1 Point contact diode (see text)

Miscellaneous

- Printed circuit board (see Fig. 2)
- Potentiometer 1MΩ for diode selection (see text)
- Crystal earpiece for testing (see text)



The diode used by the author is a miniature glass-encapsulated unmarked germanium point-contact type intended for use in a crystal radio set in place of the old-fashioned "cat's whisker" and galena crystal. These diodes are often so very leaky in the reverse direction that they may be said to have no definite peak inverse voltage rating! This leakage is put to good use in this white noise generator. The diode is cheap to buy and is usually found at component surplus suppliers for about 6d to 1s.

Various types of crystal diodes were tried by the author, but those which produced the most noise were unbranded, and the best way to obtain a suitable diode appears to be to buy a few and select one which generates a considerable noise level. (It has been said that almost any crystal diode can be caused to generate more noise, by passing a very heavy current through it for only a few seconds, so that it glows like a dimly lit bulb. The author did not need to try this process, as there were many diodes in the spares box which were very noisy already.)

SELECTING A DIODE

In order to select the most suitable diode from a number which may be to hand, carry out the following experiment. Connect in place of R1 a 3·3 kilohm resistor in series with a 1 megohm potentiometer (see Fig. 3). Connect in place of D1 two short flying-leads with crocodile clips attached, so that diodes can be quickly tested and passed on.

The easiest way to check the diodes is to listen to the noise output by connecting the output of the generator to a crystal earpiece or an audio amplifier. Other methods are by means of a signal strength meter or an oscilloscope.

Check the diodes in turn, adjusting the potentiometer in each case for highest noise output. If you connect a diode wrong way round so that it is forward biased, no harm will be done, but the noise level is not so great when connected this way. If you are using the higher supply voltage (18 volts or above), it is worth using the emitter junction of a C424 transistor as a noise generator diode, with R1 set at 100 kilohms; this does not work well at lower voltages.

The white noise will, in most cases, be heard as a steady hissing or rushing sound, but some diodes are uncertain, with intermittent fading effects. These should be rejected; a diode giving a loud, steady output should be chosen.

When you have chosen a diode, remove the 3·3 kilohm resistor and the potentiometer without altering its setting, and measure the total resistance. Choose a fixed resistor of the nearest standard value and solder in place as R1. Solder the diode in place as D1.

The white noise generator should now be ready for use. ★

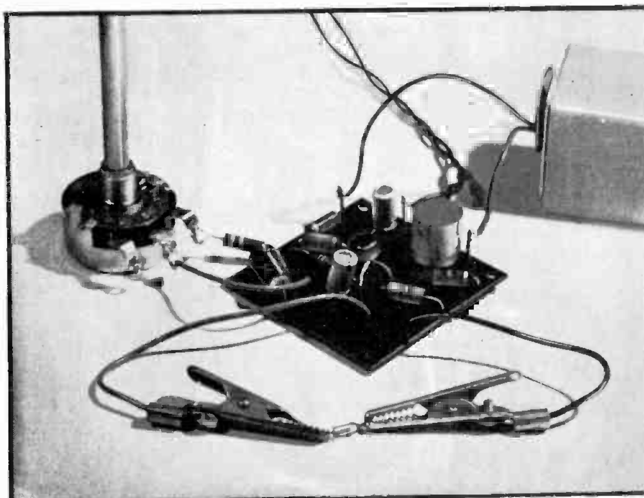


Fig. 3. Set up the module for finding the most suitable diode and adjust the potentiometer to given optimum bias and noise output

MARKET PLACE

Items mentioned in this feature are usually available from electronic equipment and component retailers advertising in this magazine. However, where a full address is given, enquiries and orders should then be made direct to the firm concerned.

SEMICONDUCTORS

The case for the use of monolithic circuits in the audio field is now beginning to make an increasing impact and will surely be generally accepted in time, just as the transistor is now firmly established.

The MC1554G monolithic circuit from **Motorola Semiconductor Products Inc.,** is a high performance audio amplifier of one watt output with a harmonic distortion of 0·4 per cent over a frequency range of 20Hz to 20,000Hz.

The input impedance is 10kΩ and the output impedance is 0·2Ω. The low output impedance is optimised for driving a 16Ω load, usually found in audio and servo applications.

Housed in a 10-pin metal can, this device needs to be powered by a 16 volt d.c. supply; the drain current is only 15mA d.c. with a zero signal input.

Further details and nearest retailer of the MC1554G can be obtained from Motorola Semiconductor Products Inc., York House, Empire Way, Wembley, Middlesex.

Three new silicon *npn* transistors announced by **Mullard** have been designed for mobile f.m. transmitters that operate from a 13·8 volt supply. Types BLY34 and BLY55 are intended as drivers, but can also be used in the output stages of small v.h.f. transmitters. Type BLY36 is intended for use in the output stage of larger v.h.f. transmitters.

SGS-Fairchild have announced price reductions over their whole range of silicon planar devices. In some cases these reductions are over 50 per cent. We hope that these reductions will be passed on to the public by retailers.

SHOPPING GUIDE

Now to items that would make suitable gifts!

Something that will hold the interest of younger people, and the serious designer will also find useful, is the S-Dec "breadboarding" system marketed by **S.D.C. Products (Electronics) Ltd.**

A single unit or "building block" consists of two panels with seven parallel rows of phosphor bronze double-leaf spring contacts. Each row has five connecting holes, drilled in the panel, which are linked electrically.

To make up circuits, component leads are simply pushed into the panel holes and can be removed quite easily for any circuit alterations. If more than one unit is required, they can be joined together by keys and keyways on the four walls of the boxes.

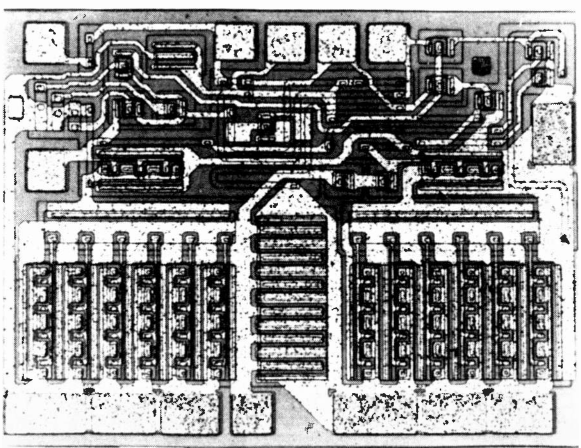
S-Dec costs 29s 6d each unit and further details can be obtained from S.D.C. Products (Electronics) Ltd., Pump Lane, Springfield, Chelmsford, Essex.

Items for the workshop include a set of three tools: 5in engineers' pliers; 5in diagonal cutters; and 5½in long-nosed pliers, produced as a set in a p.v.c. wallet by **Elliott-Lucas Ltd.**

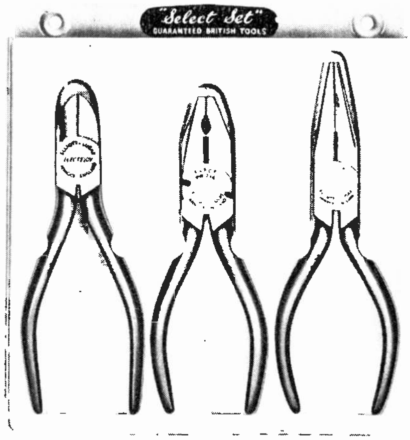
Bib Home Electrician's Kit by **Multicore Solders Ltd.** contains virtually every item needed to carry out minor electrical repair work in the home.

The kit costs 14s 6d and contains a Bib Model 8 Wirestripper and Cutter; three flex shorteners; Ersin multicore tape solder, which can be melted with a match; insulating tape; fuse wire rated at 5 and 15 amps; and a screwdriver with a blade designed to suit all plugs in general use.

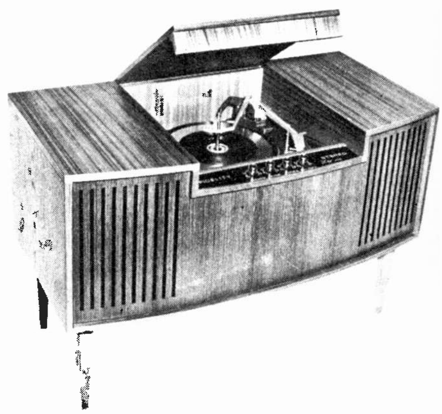
A riveter's skill is brought within everyone's reach with the "Pop"



The MC1554G One Watt Audio Amplifier from Motorola



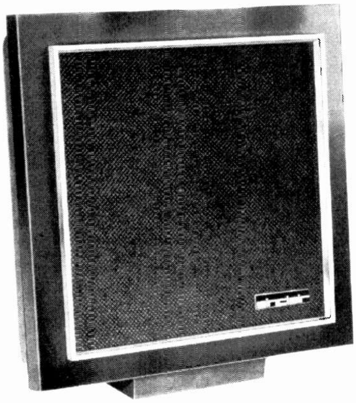
"Select Set" from Elliott-Lucas Ltd



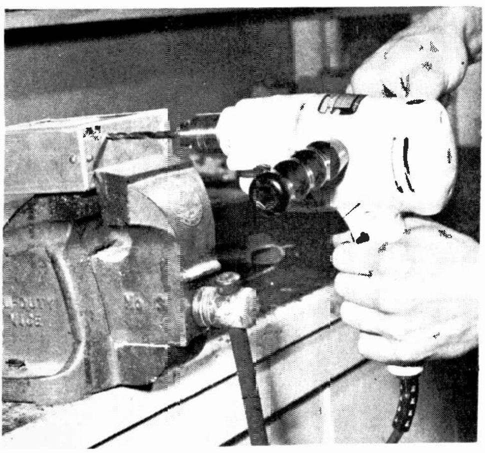
Fidelity HF36 Stereo Record Player

"Pop" Rivet Kit marketed by United Marketing (Leicester) Ltd

Simoniz Ltd. Fire Extinguishers



Sinclair Q14 Loudspeaker



D520 Two-Speed Drill from Black and Decker

rivet kit and should prove most helpful in the workshop. Marketed by **United Marketing (Leicester) Ltd.,** it is priced at 39s 11d and contains a riveting tool; a supply of rivets in three lengths; washers; a 3·3mm drill bit; and an instruction leaflet. A feature of the kit is that it can be used where only one side of the work is accessible and a nut and bolt cannot be used.

Finally, two items that are invaluable in the home workshop.

First, a fire extinguisher should always be kept handy. **Simoniz Ltd.** are offering two in a Christmas pack at 55s. Weighing only 1lb it is claimed that this extinguisher will snuff out a car engine fire in five seconds and a television fire just as quickly.

Secondly, a power tool has numerous uses for the many cabinet making and chassis drilling jobs that are always needed when making any equipment.

Both the **Black and Decker** D500 and D520 models have $\frac{5}{16}$in chucks, and retailing at £5 10s and £8 19s 6d respectively, are always welcome gifts.

The two-speed model D520 is particularly useful for low speed drilling with high torque, such as required for drilling steel sheet and masonry. Maximum recommended hole sizes are $\frac{5}{16}$in for steel and masonry and $\frac{3}{8}$in in hardwood at the slow drill speed of 900 r.p.m. The drill can be used to cut larger holes for components up to 1in diameter if used with a "holesaw".

The presentation of audio equipment can cost from a few shillings to several pounds. For example, there is the Bib Tape Head Maintenance Kit for 12s 6d or the Fidelity HF36 console stereo record player at 45gns.

The **Fidelity HF36** is finished in fine teak veneer and is fully transistorised. The turntable is a Garrard four speed auto/manual type, taking eight records on auto. Four watts output per channel is fed to two 8in speakers in acoustically designed chambers.

The new **Sinclair Q14** loudspeaker at £6 19s 6d measures only 9½in × 9½in × 4¾in and is claimed to produce a smooth level response between 60Hz to 16,000Hz. The full frequency range is claimed to be 45Hz to 18,000Hz and it can handle 14 watts r.m.s. at 1,000Hz. The impedance of the speaker is 15 ohms.

The demand for tape recorders has steadily increased over the years, so a tape recorder spool or accessory may be another useful gift.

Mastertape (Magnetic) Ltd. are now producing their 5in, 5¾in, and 7in reels in a strong black polypropylene box in the form of a book, with grained front and back covers. The spine has the brand names and a label printed in a colour which identifies the type, reel size and length of recording, i.e. red for standard play, yellow for long play, etc. Prices range from 20s 6d for a 5in spool of standard play tape to £5 for a 7in spool of triple play tape. The "books" also contains a printed card index and tape clip.

The 4in, 5in, 5¾in, and 7in Synchrotape spools are available from **Adastra Electronics Ltd.,** 167, Finchley Road, London, N.W.3, and include a 12-page guide to playing times and speeds, editing and storage hints, technical data and a recording log for individual tabulation of recordings. Coupons are given with these spools enabling a tape splicer to be purchased at half price.

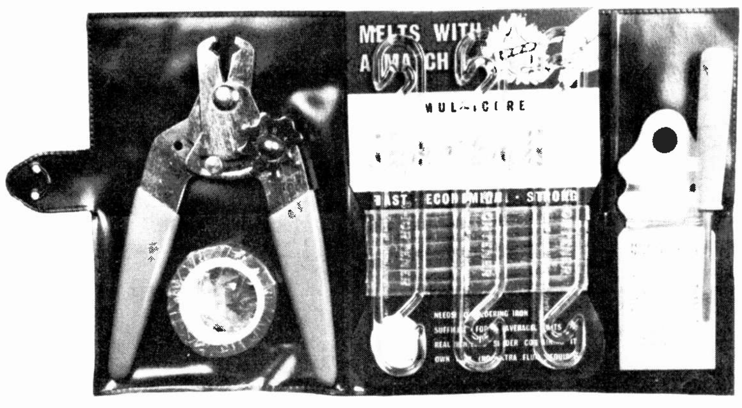
The care and maintenance of tape recorders is important if good service and reproduction is to be maintained throughout the life of the recorder. So at 12s 6d the Bib Size E Tape Head Maintenance Kit is a worthwhile consideration for those who really care about tape recorder maintenance; others need encouragement, too!

The kit consists of a bottle of instrument cleaner; cleaning tissues; applicator and polishing tools and sticks; double-ended brush and a five-page instruction booklet.

NOTE

In the **G.S.P.K. (Electronics) Ltd.** advertisement (December 1967) for their Printed Circuit Kit, the price was incorrectly given as being £1. The correct price is £1 5s 0d plus 3s 6d postage and packing.

Bib Home Electrician's Kit by Multicore Solders Ltd



SEMICONDUCTOR BASICS

2—DIODE PROPERTIES

By G. J. KING

LAST MONTH's article described how semiconductors are formed from carefully prepared crystalline materials. Now, going a little deeper this month, the actual crystal structure will be shown to have specific properties.

A common crystal for semiconductors is germanium which, in its pure state, has a very low conductivity. However, its conductivity rises steeply with increase in temperature and above 100 degrees C it is so high that current control becomes a bit of a problem.

TWO MAIN TYPES

Germanium is extracted from flue ash formed from the burning of Northumberland coal. In this state it is an oxide containing a great deal of impurity and, for semiconductor applications, it has to undergo a purifying process called "zone refining". Here the germanium ingot is placed in a radio frequency heating field in such a way that only a small part is affected, producing a molten zone. This is arranged to "sweep" along the ingot from one end to the other, and because the impurities are concentrated in the molten zone they are, in effect, "swept" out of the crystal to one end. After several sweeps the heavily contaminated end is cut off the ingot, leaving the bulk of pure crystal.

Silicon is another common semiconductor material. This has a lower electrical conductivity (more resistance to current flow) than germanium, and is thus more suitable for high power devices than germanium. It can also be used at higher temperatures without posing the current control and heating problems of germanium.

Pure germanium has a resistivity of about 60 ohm-centimetres, while pure silicon is much higher, rising to about 60,000 ohm-centimetres. The controlled addition of impurities, referred to last month, reduces the resistivity of the pure crystals to about 2 ohm-centimetres at room temperature. Fig. 2.1 shows the scale of resistivities of pure germanium and silicon relative to copper at one end of the scale and glass at the other end.

CRYSTAL LATTICE

The structure (called crystal lattice) of pure crystal materials is composed of atoms which are effectively bound to their partnering atoms by the pairing of their outer or *valence* electrons. This gives so-called electron-pair bonds, as shown in Fig. 2.2. Because each of the four valence electrons per atom is linked to the electrons of an adjacent atom, no electrons are available for the conduction of electricity (there are no current carriers), which is why a pure crystal has such a high resistance.

However, partial collapse of the lattice occurs when the crystal is heated owing to the result of thermal

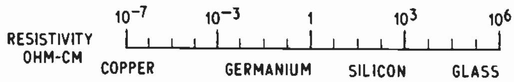


Fig. 2.1. Scale of resistivities of pure germanium and silicon relative to copper and glass

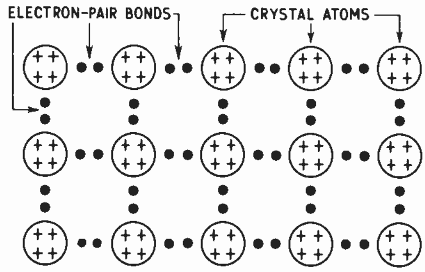


Fig. 2.2. Construction of a crystal lattice, showing the atom crystals and the electron-pair bonds

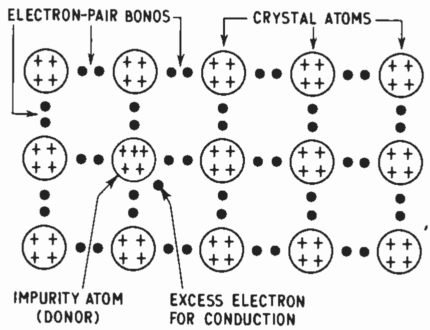


Fig. 2.3. N-type semiconductor material. The excess electron for current conduction is given by the impurity atom, which has five electrons against the four of the crystal atoms

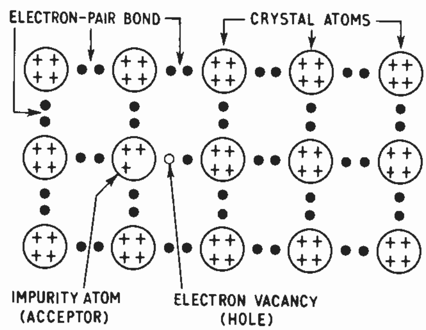


Fig. 2.4. P-type semiconductor material. The electron vacancy (hole) is given by the impurity atom, which has three electrons against the four of the crystal atoms

energy. This releases electrons from the bonds, making them available for current conduction, which lowers the crystal's resistance.

If heated crystal is arranged to pass an electric current, more heat is generated due to normal power dissipation. This allows even more current to flow and the effect, which is cumulative, eventually results in the destruction of the lattice. Germanium is more influenced by temperature rise than silicon.

Fig. 2.3 shows what happens in the lattice when an infinitesimally small amount of impurity is added to give *n*-type material. The impurity atom fits into the lattice, but because it has one more electron than the atoms of the crystal this becomes available for current carrying. The diagram shows that the crystal atoms each have four electrons, while the impurity atom has five electrons. Four are used for the bonding into the lattice and the excess one for conduction.

Fig. 2.4 shows what happens when an impurity atom is added to the crystal to produce *p*-type material. Here the impurity atom has only three valence electrons and, while these pair-up with the electrons of adjacent crystal atoms, one of the bonds in the lattice cannot be completed because the impurity atom lacks the final valence electron. This gives rise to the so-called hole, or positive current carrier, explained last month.

It will be appreciated now that holes encourage conduction by electrons, since they provide a "channel" in the semiconductor material through which electrons can flow. A hole, for instance, exerts an attractive force on any electron, and if this is one liberated from a crystal atom it may combine with the hole, but will have left a hole behind it. This process is continuous within the crystal, thereby constituting a flow of positive current carriers, as shown in Fig. 1.4 last month.

The impurities added to the pure crystal to give it *n*- and *p*-type characteristics are called respectively donor and acceptor atoms, the first giving negative current carriers and the second positive current carriers (i.e. electrons and holes).

PN JUNCTION

When *p*- and *n*-type materials are brought close together and effectively diffused at their junction, the well-known *pn* junction diode effect is achieved. This is illustrated in Fig. 2.5. Contrary to expectation, electrons do not flow from the *n*-type material into the *p*-type material to neutralise the holes.

As soon as holes flow from the *p*-type and electrons from the *n*-type material, the *n*-type develops a positive charge and the *p*-type a negative charge, because the *p*- and *n*-type materials are electrically neutral. These charges inhibit any further interchange of electrons and holes across the junction.

A "charge barrier" is, in fact, developed across the junction, and is often referred to as "potential barrier", "space-charge", "transition region", and "depletion layer". All these terms mean the same thing—the charge developed across the junction due to the initial interchange of holes and electrons.

It should be understood that the electric charge exists only across the junction, and it cannot be measured by connecting a voltmeter between the *p*- and *n*-type materials, but it can be represented by an imaginary battery connected within the two crystals at the junction, as shown in Fig. 2.6.

JUNCTION BIASING

This depletion layer has a fundamental effect on the action of the two materials so united when an external supply is connected. Suppose an external source of electricity is connected across the *p*- and *n*-type materials with a polarity that will counteract the potential developed across the junction. This is shown in Fig. 2.7a. A potentiometer, connected so that this source can be varied upwards from zero, and a means of measuring the current flowing, should show that very little current flows when the voltage is first applied, but after a certain small value, the current rises fairly steadily as the voltage is increased.

The initial slow start is due to the external supply overcoming the potential across the junction, and from then onwards the "barrier" is broken and electrons in the *p*-type material, near the positive terminal of the supply, break their electron-pair bonds and enter the supply, thereby producing new holes.

Simultaneously, electrons from the negative terminal of the supply enter the *n*-type material and diffuse towards the junction. Excess electrons from the *n*-type then flow across the depletion layer and move, via the holes in the *p*-type, towards the positive terminal of the battery. This flow continues as long as the external supply is connected, and it is called forward current flow due to forward biasing of the junction.

When the external supply polarity is reversed, giving reverse biasing of the junction (as shown in Fig. 2.7b) the potential within the material across the junction is effectively reinforced—it becomes wider. This is because the free electrons in the *n*-type are attracted

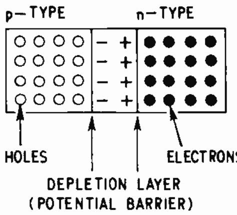


Fig. 2.5. Showing the union of p- and n-type semiconductors. Observe the negative charge on the p-type side of the junction and the positive charge on the n-type side

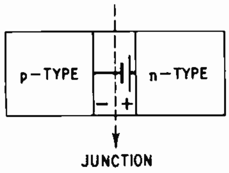


Fig. 2.6. The potential barrier can be represented by an imaginary battery

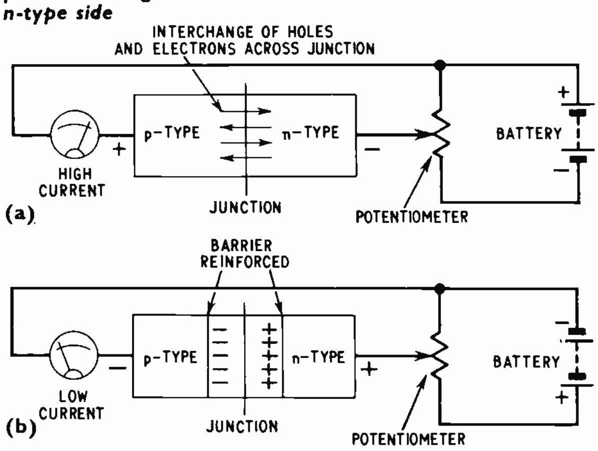


Fig. 2.7. Junction biased for forward current (a) and for reverse current (b)

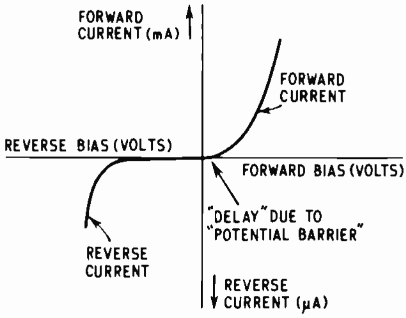


Fig. 2.8. Forward and reverse characteristics of a typical semiconductor diode

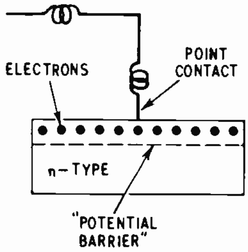


Fig. 2.9. Basic point-contact diode action. Note the formation of a depletion layer or "potential barrier"

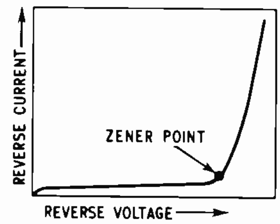


Fig. 2.10. Breakdown of the reverse characteristic gives the Zener effect

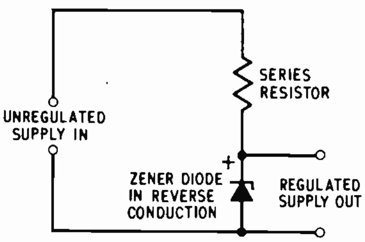


Fig. 2.11a. Voltage stabilisation using a Zener diode

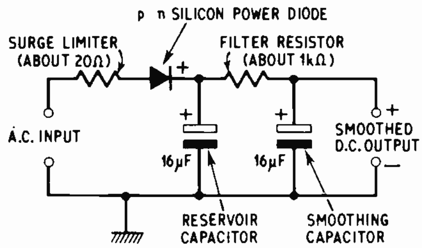


Fig. 2.11b. Junction diode rectifier circuit

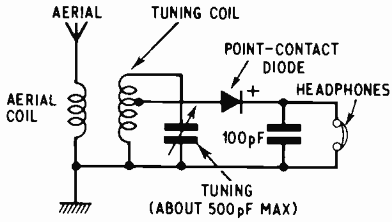


Fig. 2.11c. Simple crystal receiver using a point-contact diode

towards the positive terminal, away from the junction, while the electrons from the negative terminal of the supply enter the *p*-type and diffuse towards the junction, filling the holes as they approach the junction. Current flow is then extremely small, it being called reverse current.

Fig. 2.8 shows the forward and reverse characteristics. In the forward-bias region, current rises swiftly as the voltage is raised, while in the reverse-bias region the current is much lower (being microamperes as opposed to milliamperes and amperes in the forward direction).

The reverse current is caused by minority carriers due to the impossibility of obtaining absolute purity in the basic crystal, and being considerably aggravated by temperature increase, releasing current carriers due to thermal energy.

The "diode effect" can also be created by introducing, say, a piece of *n*-type material, into the surface of which is embedded a pointed piece of wire called a cat's whisker. This is after the style of the old crystal detector used in radio receivers of yesteryear. *N*-type material, for instance, has a surface layer of electrons and an adjacent layer of positively charged donor atoms. These produce a potential barrier or depletion layer similar to that of a junction diode as shown in Fig. 2.9.

This type of construction is called a point-contact diode, and is adopted extensively for small low capacitance diodes for radio detection and similar, low power applications.

The junction type of diode is used more for power rectification applications and for voltage stabilisation, using the Zener effect explained below.

ZENER DIODES

If a diode is reverse biased with increasing voltage, there comes a point when the current rises very rapidly. This is called the reverse breakdown voltage or Zener voltage, after the name of the engineer who discovered it. In normal applications diodes are not subjected to such reverse stresses, but for stabilisation applications special diodes have been developed to work at and beyond reverse breakdown potentials. One name for these is the Zener diode.

If such a diode is reverse biased from a supply through a series resistor, the voltage applied to a load circuit from across the diode will remain fairly constant in spite of changes in load current. Further, the voltage will hold constant even though the input voltage may alter. Fig. 2.10 shows why this happens.

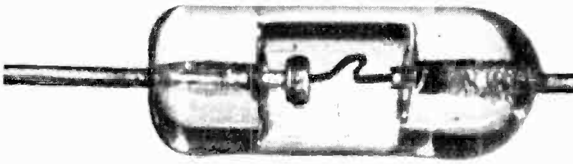
Here the current curve rises sharply at the breakdown point, so that if the load takes an increasing current, the current in the series resistor tends to increase likewise. This is prevented, however, by the diode passing a small Zener current, thereby holding the current in the series resistor constant. Fig. 2.11a shows how the Zener diode is used in a circuit.

VARIABLE CAPACITANCE DIODES

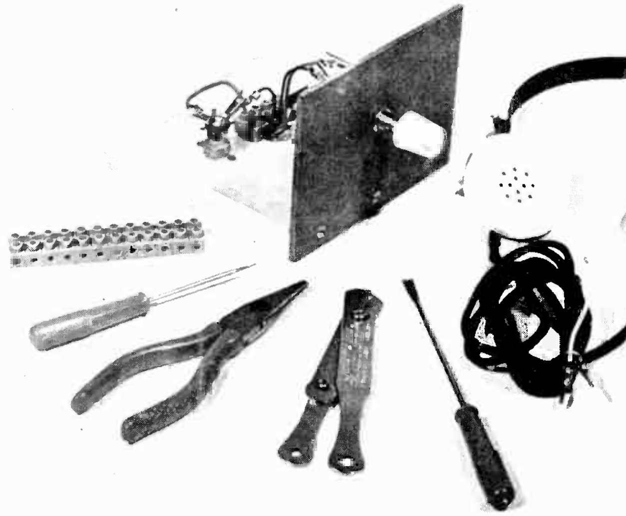
The depletion layer of a *pn* junction diode has a value of capacitance determined by the effective width of the depletion layer. The greater the width, the smaller the capacitance. Therefore, when unbiased, the capacitance is determined by the diode's design, but as the reverse bias is increased, the capacitance falls since the width of the depletion layer increases.

This basic principle is exploited in the variable capacitance diode which is used for remote tuning of radio and television circuits, for automatic frequency correction in radio, television and f.m. receivers, for parametric amplifiers and for hosts of other applications.

Figs. 2.11b and 2.11c show respectively applications of the junction diode as a power supply rectifier and the point-contact diode in a simple radio receiver, the up-to-date version of the crystal set.



Crystal Receiver



While the Semiconductor Basics series (introduced last month) is running, it is intended to publish each month a simple constructional item for the real beginner, based on the particular semiconductor device currently under discussion.

As our opening project, the semiconductor diode is presented in a modern version of the crystal set to illustrate its ability to function as a signal rectifier.

A few words in general about these special beginners projects . . .

A **non-soldering method of construction** has been adopted throughout this series. The method used has the virtue of being simple and inexpensive, and even the youngest novice need have no fear to embark upon the building of these electronic circuits. Careful reading of the text and close study of the illustrations is all that is required.

The only **tools** needed are: a pair of long-nosed pliers; an electrician's small screwdriver, a larger one for fixing the terminal strip and front panel; a wire stripper; and drills and saw for making the baseboard and front panel.

Components specified in all these projects are readily available from the usual retailers; in case of local difficulty, components can be ordered from various firms specialising in mail order service who advertise in this magazine. (Copy out the full description given in the Components List).

The approximate **cost** of components will be stated for each project. This figure will be based upon brand new "top" prices. The actual cost could well be somewhat lower if the reader is prepared to do some "shopping around".

EARLY crystal sets were very elaborate "instruments" with the crystal detector taking pride of place on a highly polished ebonite top panel, itself mounted on an oiled-wood box about 9 in square and 6 in deep. This panel also carried a large tuning knob and a very scientifically-constructed tuning coil; and there were large, instrument-type brass terminals for aerial, earth, and headphones.

Today's crystal set works on exactly the same principles as the first ever made 40-odd years ago; but it can take advantage of the incredible developments in components since those early days, particularly so far as the crystal detector and tuning coil are concerned.

THE CIRCUIT

The circuit of our constructional item is given in Fig. 1, which is very straightforward, indeed. The coil L1 picks up the signals from the aerial. This coil is tuned by the variable capacitor VC1. When the resonant frequency of the combination L1, VC1 matches the frequency of the required signal a large r.f. signal voltage is developed across the tuned circuit. This is the "carrier" voltage of the transmission, while its "envelope" carries the audio information, as shown at a and b in Fig. 2.

A pair of headphones connected directly across this "tuned-in" r.f. voltage would fail to respond in spite of the presence of audio information on the envelope because of the symmetrical nature of the wave. One half cycle would cancel out the other, and the net result would be no movement of the diaphragm. However, by rectifying the wave (this is where the crystal detector—or diode—comes in), the asymmetrical

PE BEGINNERS PROJECT

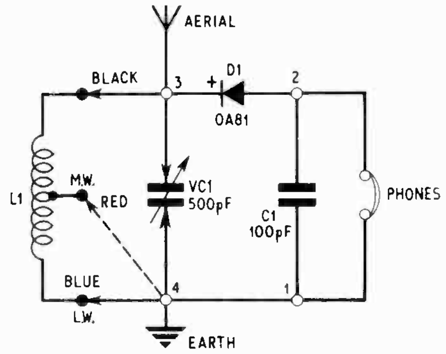
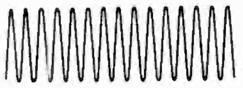
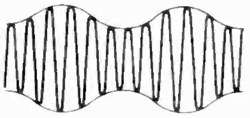


Fig. 1. Circuit of the crystal set. The numbered circles represent the terminal strip connections; arrow heads represent crocodile clips


(a)

Radio frequency carrier wave, unmodulated


(b)

Carrier wave modulated with programme "audio" signal


(c)

Rectified modulated carrier wave, after passing through D1


(d)

Resulting audio wave which is applied to the headphones; the r.f. component is filtered out by C1

Fig. 2. These waveforms illustrate the process of "detection"

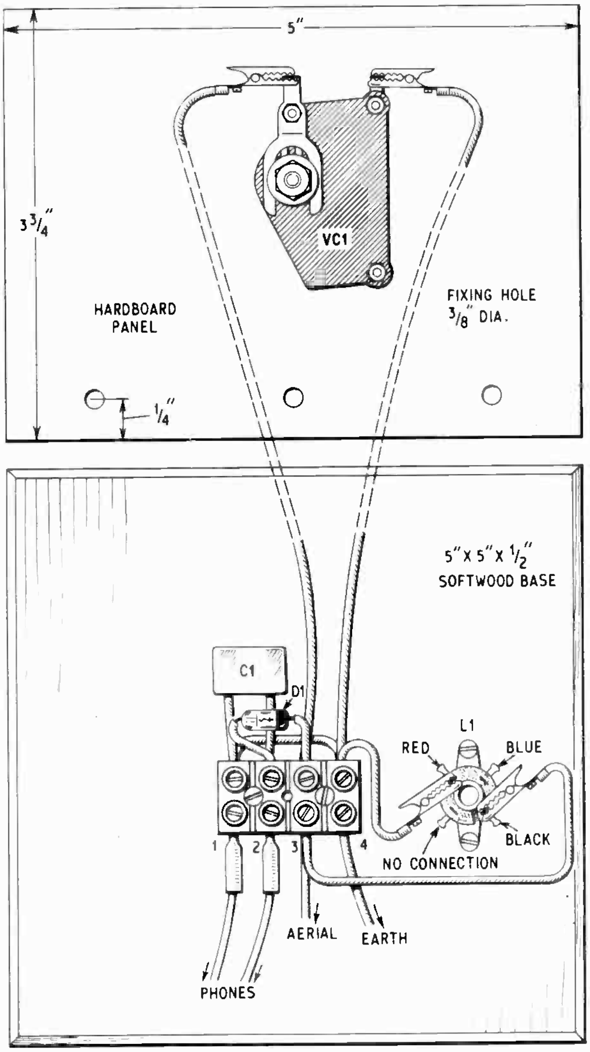


Fig. 3. Constructional and wiring details. The front panel has been layed flat for clarity

COMPONENTS . . .

Capacitors

C1	100pF	Mica
VC1	500pF	Solid dielectric variable tuner (Dilecon)

Diode

D1	OA81	Germanium diode (Mullard)

Coil

L1	DRX1	Duel range crystal set coil (Repanco)

Miscellaneous

Headphones, high resistance, Eagle SF20 (Electroniques)
One 12-way plastics terminal strip (see text)
Wooden baseboard 5in × 5in × ½in
Hardboard front panel 3¾in × 5in
Woodscrews for mounting coil, terminal strip and front panel to baseboard
Four miniature crocodile clips
One knob
Plastic covered, single core copper wire (Woolworths)

TOTAL COST £1 10s 6d

waveform of Fig. 2c is produced. Capacitor C1, across the headphones, by-passes the r.f. carrier wave and leaves only the audio information, Fig. 2d, which operates the headphones.

GOOD AERIAL ESSENTIAL

It will be appreciated that the phones are powered by the *actual transmitter signal* as picked up by the aerial, so it is essential that the latter be very efficient. This means a long outdoor aerial, as high as possible. A good earth connection is also needed; this supplements the aerial. An earth connection can be made to a cold water pipe, or to a metal spike inserted into the ground. *Do not use gas mains, hot water, or radiator pipes for this purpose.*

WAVE BAND SWITCHING

L1 is a dual band coil. The whole winding is used for long waves; the top section only for medium waves. To change from long to medium wave remove the crocodile clip from the blue tag and fit to the red tag.

Any kind of tuning knob can be used fitted to the tuning capacitor VC1. Slow-motion tuning is not necessary for the selectivity of this kind of set is not great. The headphones which should have a resistance of about 2,000 ohms (not less than 1,000 ohms) are connected direct to the terminal strip (1 and 2).

CONSTRUCTION

The first stage in construction is to measure and cut a baseboard 5in by 5in from any ½in thick softwood. The hardboard front panel measuring 3¾in × 5in is cut and drilled as shown in Fig. 3 and screwed to one of the edges of the baseboard with three ½in No. 6 countersunk wood screws. The variable capacitor VC1 and coil L1 should next be mounted on the front panel and baseboard, respectively, in roughly the positions indicated in the photos and Fig. 3.

Once the capacitor and coil have been secured in position the next step is to wire-up the four-way terminal strip which has been cut from the 12-way strip (the remainder of this strip will be used in later projects). The strip can be cut with a sharp pocket knife, or a Junior hacksaw.

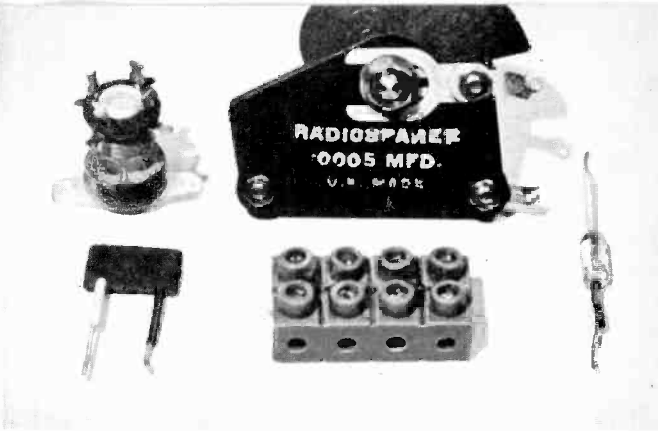
It is best to wire the terminal strip *before* mounting on the baseboard and the terminal screws should not be tightened up until all component wires for that particular terminal have been positioned. Each wire should be given a slight pull to ensure it has made contact and is held fast by the screw once it has been tightened. Refer to Fig. 1 and Fig. 3 for connections.

When the terminal strip has been wired-up, four miniature crocodile clips should be fixed to the four leads which connect the tuning capacitor and coil to the terminal block.

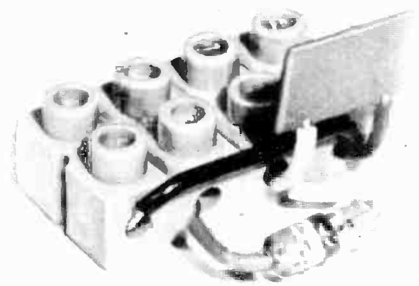
Once the crocodile clips have been fixed to the four leads the terminal block should be checked and screwed on to the baseboard by two ¾in No. 4 countersunk wood screws. The four crocodile clips should be attached to the capacitor VC1 tags and coil L1 tags as shown in Fig. 3. The clips should not be allowed to short out on each other.

Finally, once the wiring has been carefully checked, the aerial, earth and headphones should be connected as indicated in Fig. 3. As stated earlier it is important to have a good aerial *and* earth if the Crystal Receiver is to give good results.

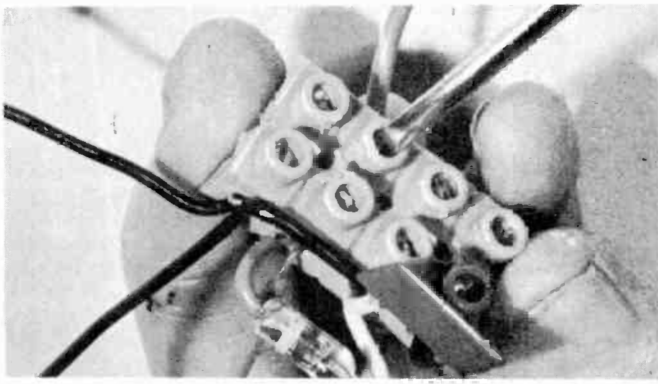
Next month: A transistor audio amplifier



All circuit components for constructing the crystal receiver

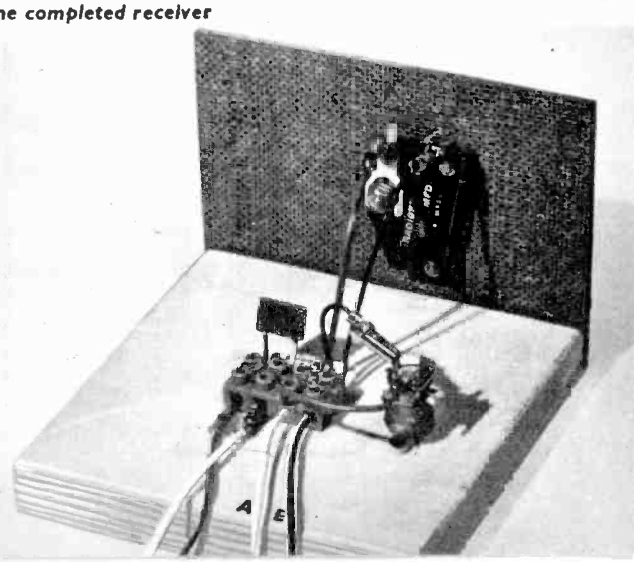


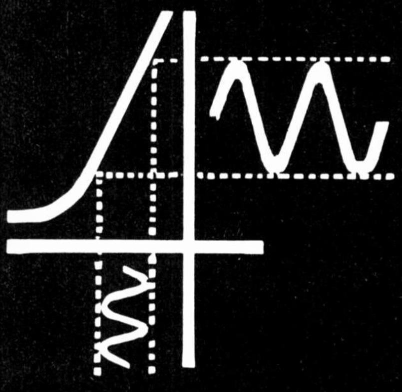
Mounting the capacitor, diode and link wire between terminals. Avoid sharp bends close to components



Fixing the connecting wires to the block. When the wires have been fixed the block should be mounted on the baseboard

The completed receiver





DETERMINING VOLTAGE AMPLIFICATION

By G.R. WILDING

QUITE frequently when designing, modifying or constructing valve audio amplifiers and the a.f. stages of receivers, it is desired to know the voltage amplification effected by each stage so that the output stage can be correctly loaded from the applied input.

Furthermore, if it is necessary to include a pre-amplifier to boost low level signals to any desired degree, determination of the gain required will indicate what type of valve and load resistor to use.

It is quite a simple matter, and always interesting and informative to calculate valve amplification, using one of three separate formulas.

VALVE STAGE GAIN

The most commonly used is

$$A = \frac{\mu R_L}{r_a + R_L}$$

where A is the amplification or stage gain obtained, μ is the valve amplification factor, r_a the valve anode impedance (both obtained from manufacturers' charts), and R_L is the value of the anode load resistor employed.

Thus to give an actual example, suppose an ECC40 triode was incorporated in a pre-amplifier to boost a low voltage microphone input, what magnification would it give with a load resistor of 39 kilohms, and what voltage would appear across the load resistor, for transmission to a later stage, if the input is only 0·2V?

$$A = \frac{\mu R_L}{r_a + R_L} = \frac{30 \times 39 \times 10^3}{(11 + 39)10^3} = \frac{1170}{50} = 23{\cdot}4$$

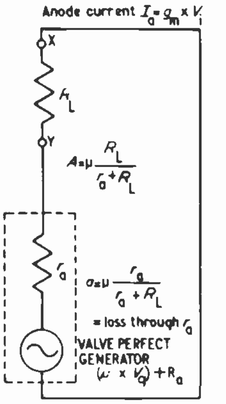


Fig. 1

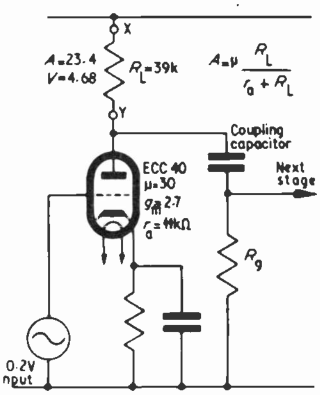


Fig. 2

With an input of 0·2V, there would be an a.c. voltage of 0·2 × 23·4 = 4·68 developed across the anode load resistor.

Thus the theoretical amplification factor of 30 was not equalled in practice, and although an increase in R_L would increase gain beyond the 23·4 realised, the full figure can never be quite attained.

In Fig. 1 it can be seen that a loaded valve amplifier can be regarded as a perfect signal generator of amplification factor μ, in series with a resistor r_a equal to its own impedance, and R_L equal to its effective load, so that the total gain developed is divided between the two resistors relative to their proportional values.

COUPLING COMPONENTS

The formula given ignores the effect of the coupling capacitor and grid leak resistor of the succeeding stage, which are virtually shunted across the load resistor, thereby reducing it in effective value.

This is because in most instances the following grid resistor has a value greatly in excess of the load resistor and will only reduce its value by a trifling amount. If R_L is in the region of 200 kilohms or more, the effect of even a 500 kilohm grid leak will be appreciable. Ignoring the capacitive reactance $1/\omega C$ of the coupling capacitor, the effective value of the load resistor becomes

$$R_L = \frac{R_L \times R_g}{R_L + R_g}$$

where R_g is the grid leak resistance.

continued on page 69

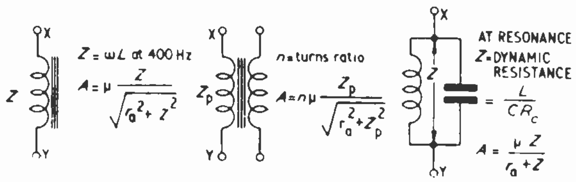


Fig. 3

***Fig. 1.** Theoretical circuit of a valve considered as a perfect generator. The ratio of $R_L/(r_a + R_L)$ determines the proportion of μ obtainable from the static characteristics*

***Fig. 2.** Actual valve circuit where the stage gain A is calculated for different types of anode load R_L*

***Fig. 3.** Alternative types of anode load with the appropriate formulae for calculating the stage amplification*

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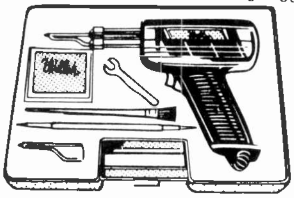

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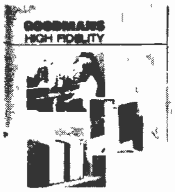

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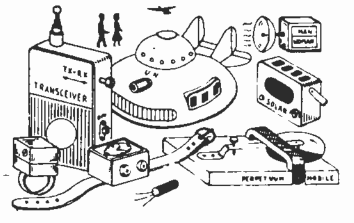

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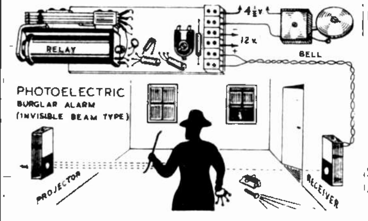

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SINE TO SQUARE WAVE CONVERTER

By A. FOORD

Since a square wave contains many harmonics as well as a basic frequency, square wave testing of an audio amplifier is more representative of actual operating conditions on speech and music than mere sine-wave testing. The circuit shown in Fig. 1 can be used to convert a sine wave to a square (or rectangular) wave.

SCHMITT TRIGGER

This circuit, commonly known as a Schmitt trigger, is a two stage amplifier with positive feedback via R5, this resistor being common to both TR1 and TR2. It has two stable states: TR1 conducting and TR2 off, and TR1 off with TR2 conducting—depending on the amplitude of the input. Due to the positive feedback the circuit switches rapidly from one state to the other, and can be used to produce a square or rectangular wave.

If TR1 is non-conducting, the base of TR2 is biased via R1, R2, and R3 at about +6·8V, and the emitter of TR1 and TR2 will be at +6·2V (0·6V base-emitter drop for silicon), so that for TR1 to be off (as was assumed) the input must be less than +6·2V. As the input approaches 6·2V a critical voltage is reached where TR1 begins to conduct, and positive feedback brings TR1 on rapidly and cuts TR2 off, so that a good rise time is achieved. If the input is now lowered below a similar critical value TR2 will conduct and TR1 will be cut off.

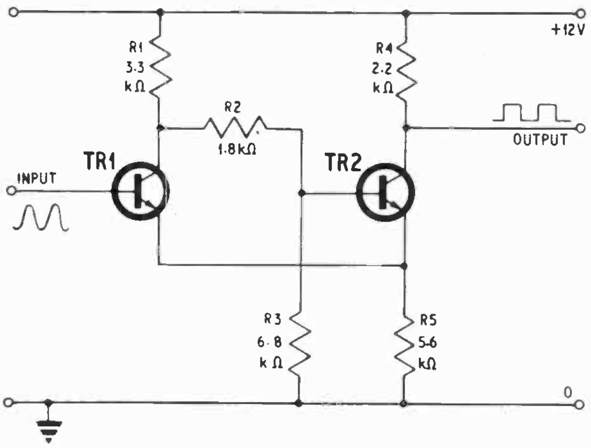
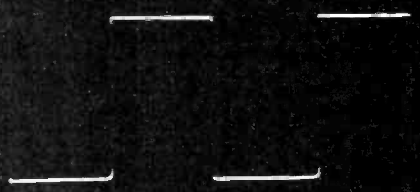
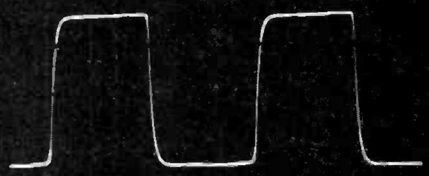


Fig. 1. The basic Schmitt trigger circuit



1. Square wave output at 1kHz



2. Square wave output at 100kHz

3. Marker pips at 10kHz

4. Marker pips at 1kHz, showing non-linearity of timebase used to display these pips

THE PRACTICAL CIRCUIT

The practical circuit has several additions, as will be seen by reference to Fig. 2. The 220 kilohm resistor R1 is used to bias TR1 on, and the signal cuts TR1 off. The addition of the two diodes D1, D2 prevents the base-emitter junction of TR1 from being reverse biased. (Transistors such as the OC71 have a reverse rating of about 10V, the much faster 2N2926's have a reverse rating of 5V, and the diodes prevent this from ever being exceeded; when the input falls below the trip voltage the emitter of TR1 is clamped to the base via a diode.)

Using a 6V supply the output achieved with this circuit was 1V peak to peak, for a 12V supply it was 2·5V peak to peak, and for a 15V supply it was 3V peak to peak. The results tabulated below and shown graphically in the photographs are for a 12V supply.

PERFORMANCE

Input impedance	2 kilohm
Input (for square-wave output)	1·5V pp sinewave at 1kHz 2V pp sinewave at 100kHz
Output	2·5V pp square wave
Rise time	less than 1μs

The first photograph 1 shows the output at 1kHz. On this scale the rise time of 1μs is so fast that the vertical edges do not photograph. The second photograph shows the output at 100kHz. Here the rise and fall times are clearly visible (but the square wave is reasonably good, an amplifier of 300kHz bandwidth would noticeably degrade these edges!)

DIFFERENTIATING CIRCUIT

By adding a differentiating circuit as shown in the right hand portion of Fig. 2, this unit can be used to provide a variable time calibration for an oscilloscope.

For a 1kHz input this differentiator would give pips every 1ms. In use the pips would be displayed, and the oscilloscope time base varied to give a convenient calibration on a graticule (say, 1ms per cm). If the pips were removed and a signal displayed, time intervals could easily be measured. Those fortunate enough to own a double beam oscilloscope can of course display both signal and marker pips simultaneously.

The time constant chosen for the pips is a compromise; at 10kHz (photo 3) the pips are easily seen, but at 1 kHz (photo 4) the pips are very narrow compared with the interval. Photo 4 actually shows the poor timebase linearity of a simple oscilloscope (not the one used to take the other photo's!); the timebase is slightly cramped at the start and appreciably cramped at the end.

If the add-on circuit is used for markers it should be connected via a switch as shown in the diagrams since it loads the square wave and degrades its edges.

COMPONENTS . . .

Resistors

R1	220kΩ	R5	2·2kΩ
R2	3·3kΩ	R6	5·6kΩ
R3	1·8kΩ	R7	10kΩ
R4	6·8kΩ	R8	10kΩ

All $\pm$10%, $\frac{1}{4}$W carbon

Capacitors
- C1 10μF elect. 20V
- C2 10μF elect. 20V
- C3 1,000pF ceramic or paper

Transistors
- TR1, 2 2N2926 yellow or green spot (2 off)

Diodes
- D1, 3 OA81 (3 off)

Sockets
- SK1-3 Coaxial socket (3 off)

Switch
- S1 Single pole changeover, small slide type

Miscellaneous

Battery, 12V. Veroboard. Diecast box 4$\frac{3}{4}$in $\times$ 2$\frac{3}{4}$in $\times$ 1in. Two feed-through terminals. Spacers, screws and nuts, insulating material.

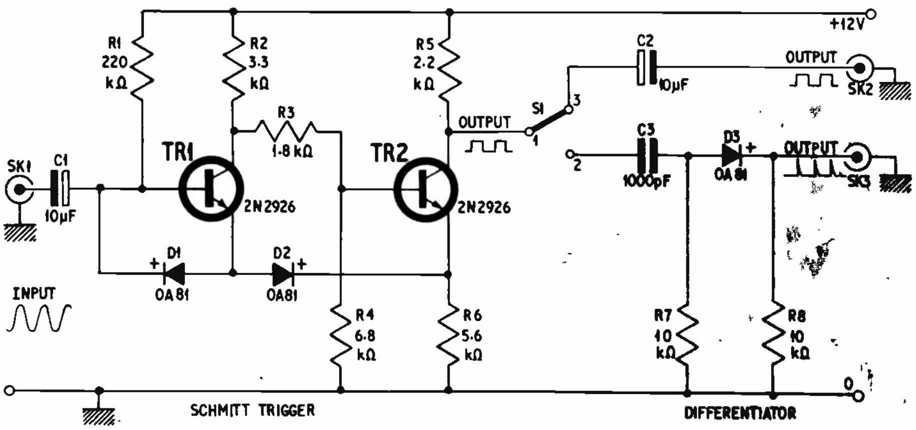
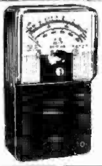


Fig. 2. Circuit diagram of the complete sine to square wave converter



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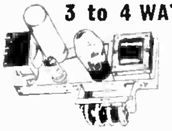

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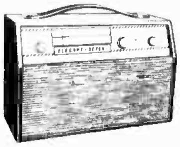

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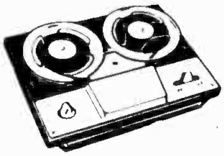
BSR TAPE DECKS



200/250 v. A.C. mains
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P. & P. on each 7/6.

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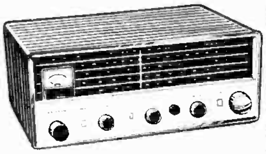

Frequency range: 535 kc/s-30 Mc/s. 4 wavebands. 5 valve superhet. Incorporates BFO, bandspread tuning, "S" meter, external telescopic aerial and ferrite aerial. Built-in 4in. speaker. Easy-to-read dial. For 240v. A.C. operation. Complete, brand new, with full instruction manual. 15 gns. P. & P. 10/-.

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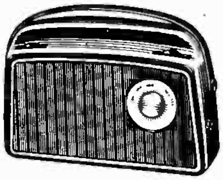
Transistor Portable Radio

plus Baby Alarm Facilities



Completely modulised high quality portable radio featuring complementary N.P.N. and P.N.P. output stage.

The comprehensive easy-to-follow drawings supplied make this the easiest-ever transistor radio set of parts, with the following features:

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- Pre-aligned R.F./I.F. module built and tested.
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- Sensitivity: M.W. at 1 Mc/s 10 microvolts plus or minus 3db. L.W. at 200 Kc/s 40 microvolts plus or minus 4db.
- High Q internal ferrite rod aerial on both wavebands.
- Finger tip controls.
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- All components(except speaker) mount on the printed circuit board. Easy to follow instructions. Size of cabinet 12″ long, 8″ high and 3″ deep.

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Features NPN and PNP Complementary Symmetrical Output Stage. The elimination of transformers ensures maximum efficiency and frequency response. Automatic heat compensation. Combined AC/DC feed back. Class B output stage, i.e. output power is proportional to total current consumption, this ensures long battery life. Under no signal condition (IQ) current drain is approx. 12mA at 9 volts (4mA in the output pair). Printed circuit construction, size: 2¼″ × ⅞″ × ⅞″. Speaker output impedence 12 ohms. Output power 600mW at 5% distortion, 400mW at 2.5% distortion, 750mW at 10% distortion. Supply 9 volts. Total current consumption at a reasonable listening level approx. 35–40mA at full power (speech and music), average 65mA. Sensitivity for 50mW output is 10mW. Frequency response -3db points 90 c/s and 12 Kc/s. Price 15/- plus 1/- P. & P. 7″ × 4″ speaker to suit. 13/6 plus 2/- P. & P.

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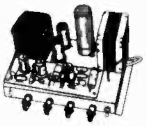

Size 9″ × 6″ × 1½″. A.C. Mains, 200-250 v. 4 valves. For use with Std. or L.P. records, musical instruments. All makes of pick-ups and mikes. Output 8 watts at 5 per cent of total distortion. Separate bass and treble lift control. Two inputs, with controls for gram. and mike. Output transformer tapped for 3 and 15 ohm speech coils. Built and tested. £4.4.0. P. & P. 11/-. 8″ × 5″ Speaker to suit. Price 14/6 plus 1/6 P. & P. Crystal Mike to suit 12/6 plus 1/6 P. & P.

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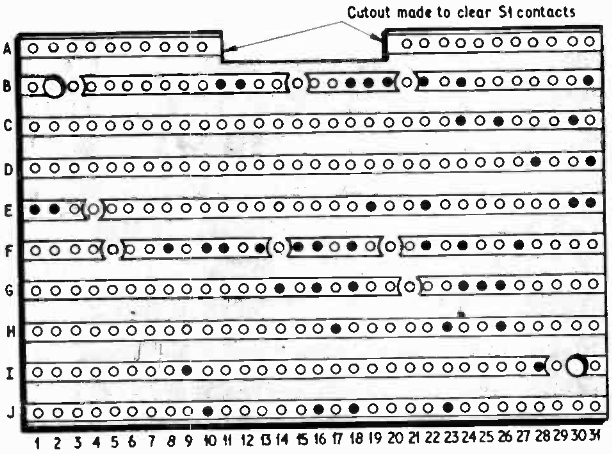


Fig. 3. Underside view of Veroboard

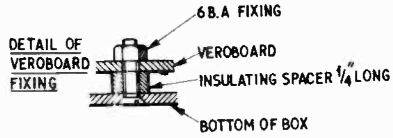


Fig. 5.

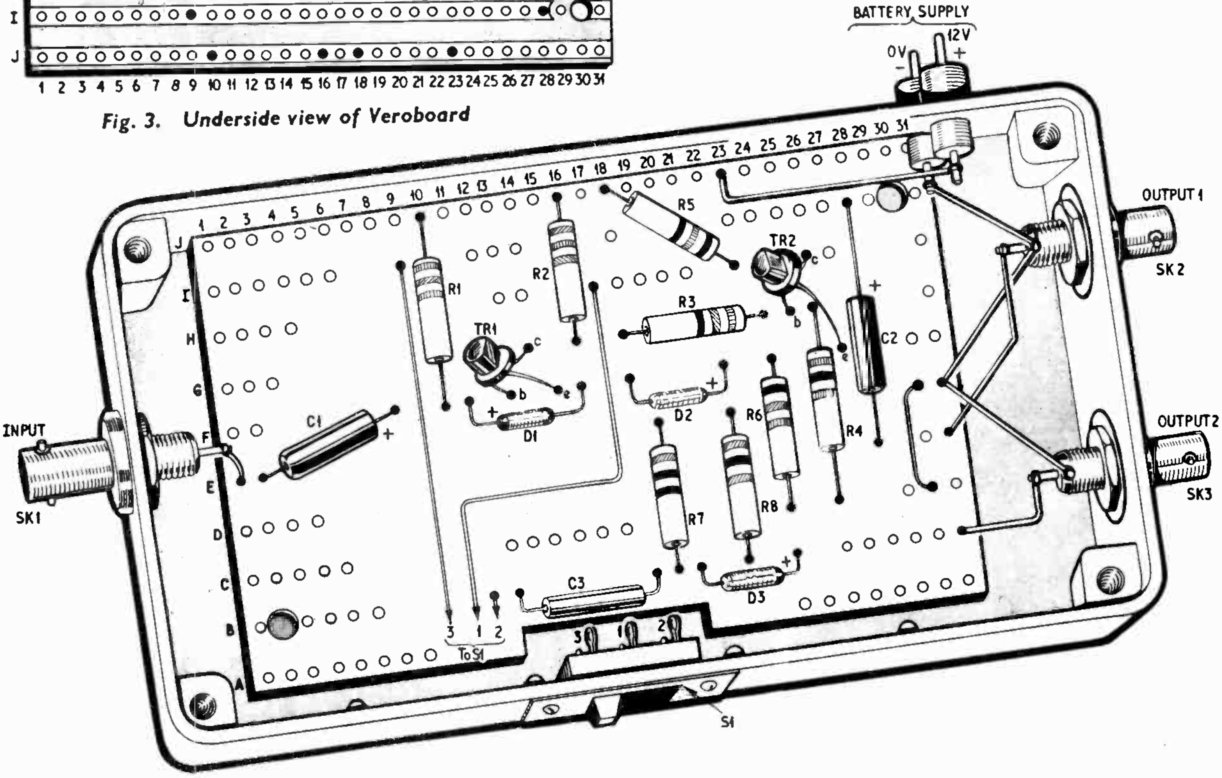
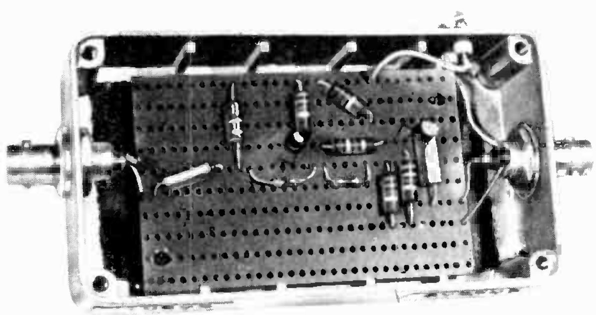


Fig. 4. The completed assembly of the converter



CONSTRUCTION

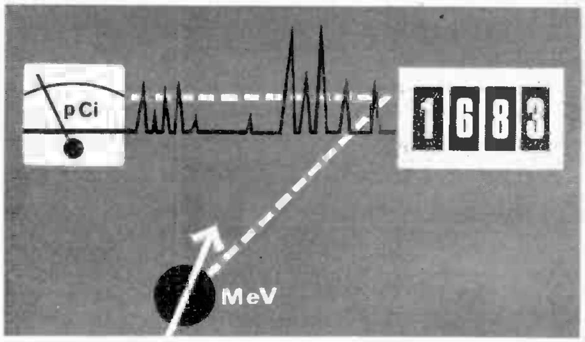
Full details of the construction of this sine to square wave converter appear in Fig. 3, Fig. 4 and Fig. 5. The equipment depicted here relates to the complete circuit given in Fig. 2. It should be noted that the model shown in the photograph is the simpler version, i.e. it does not include the differentiator; thus S1 is omitted and C2 is connected directly between TR2 collector and SK2.

Whichever version is built, it is a good idea to utilise a small diecast box as the housing, as illustrated. The circuit components are mounted on a piece of Veroboard which is prepared according to Fig. 3.

The diecast box is drilled to accommodate the coaxial sockets, switch S1, and feed-through battery supply terminals. Two holes are made in the bottom of the box for the 6 B.A. screws which secure the Veroboard in position (see Fig. 5). It is a wise precaution to cover the bottom of the case interior with a piece of insulating material to ensure complete isolation of case from circuit board and its connections.

★

nucleonics for the EXPERIMENTER



By M.L. Michaelis M.A.

3—ESSENTIAL PARTS OF A NUCLEONIC EQUIPMENT; RADIATION DETECTORS (GAS IONISATION TYPES)

LAST month we introduced the subject of measuring nuclear radiation in a general way, and pointed out that electronic methods for such measurements can be explained most clearly on the basis of a typical equipment. Fig. 2.1 (last month) showed the complete block diagram of the equipment chosen for this purpose. This equipment, called STRACE, has been designed specially for this series of articles, and experienced readers will be able to construct all or parts of it from the theoretical circuits given in the course of discussions. However, our chief aim is to provide the general reader with a practical introduction to the electronic principles and methods of working with nucleonic equipment, as electronic devices for detecting and measuring nuclear radiation are called.

NUCLEONIC EQUIPMENT

Nuclear radiation is never a continuous stream such as water flowing out of a tap, but rather a series of disjointed and essentially independent events. Each such event is the emission of one or more gamma rays and/or particles from an unstable atom, whereby the emission process may be considered as instantaneous. Furthermore, the unstable atoms (radioactive atoms) do not influence each other in any way. In other words, the decay of a particular atom does not influence the point in time or the nature of the decay of any other atom in any way whatsoever.

Nucleonic equipment consists of three fundamental sections, see Fig. 3.1. The first section is the *radiation detector*. Its purpose is to produce a brief pulse of electric current in response to the nuclear radiation of interest. Since the decay of radioactive atoms and consequent appearance of nuclear radiation amounts to a random series of isolated events, all radiation detectors produce a random sequence of pulses as output. Random here refers to the time intervals between any two successive pulses, which are quite unpredictable. All that *is* predictable is a most probable interval, which means that if very many pulses are counted over a very long time (compared to the most probable interval), a more or less constant average rate (pulses per unit time) will be found. This average rate is a measure of the *activity* of the radioactive sample.

The conventional unit used for stating activities in nucleonics is the *curie*. One curie (symbol 1Ci) is the activity of 1 gram of pure radium, and was named after the discoverer of radium. The curie is a measure of the number of disintegrating atoms per unit time, without taking account of the type or energy of the emitted radiations. One curie represents an average rate of $2{\cdot}2 \times 10^{12}$ atoms distintegrating per minute in the sample.

This is a very large, for amateur purposes immediately lethal, activity. It is thus convenient to employ sub-units, the commonest of which are the pico-curie (pCi) and the nano-curie (nCi) for studying small activities, e.g. under amateur and educational conditions.

1 pico-curie (pCi) = 10^{-12} curie = 2·2 atoms/minute decaying on the long-term average

1 nano-curie (nCi) = 10^{-9} curie = 2,200 atoms/minute decaying on the long-term average

Although legislation is not quite clear in all respects, amounts of 100nCi of individual radioactive substances generally represent the maximum quantities which are sold without special permits or precautions. For some substances, much smaller amounts already represent the "free" limit, where the nature of the emitted radiation entails increased biological hazards.

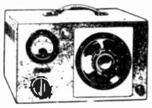
All radioactive substances involved in the course of this series for specific experiments are available in the UK from the Radiochemical Centre, Amersham, Bucks. Schools and legitimated responsible private persons can purchase the materials from this source without special permit for the required amounts, and no further precautions beyond those customary for highly poisonous chemicals are required in storage and use thereof.

RADIATION METER

Whereas the radiation detector, as first section of a nucleonic equipment, supplies a random sequence of individual pulses, the activity registering unit, as third section of the equipment, must indicate or record some steady reading corresponding to the average rate of arrival, i.e. the *mean repetition frequency* of the pulses.

The radiation meter unit, as second section of the equipment, between the radiation detector and the activity register, must perform the transformation from a random pulse sequence to a "d.c." output signal corresponding to the average repetition frequency of the pulses. In the simplest case, an ordinary moving coil meter can fulfil both functions, since the inertia of the pointer will give a more or less steady reading on any *rapid* sequence of

VARIABLE VOLTAGE TRANSFORMERS



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A.C. MAINS MODEL Incorporates Mains Transformer, Rectifier and special relay with 3, 5 amp mains c/o contacts. Price inc. circuit **47/6** plus 2/6 P. & P.

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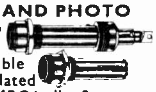

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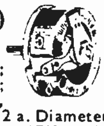

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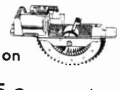

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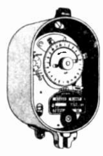

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pulses. The simplest complete nucleonic equipment thus consists of a detector, a conventional amplifier and a moving coil meter.

The need to devise more refined radiation meter units, which provide a true "d.c." output, arises from the fact that we have to deal with rather slow pulse sequences in many cases. Intervals between successive pulses may be several seconds, or even hours in extreme cases. A better "storage" device than the sluggishness of a meter pointer is then obviously required. However, it is quite clear that any radiation meter unit is essentially a *frequency meter*.

The problems are twofold in this special case: firstly very low frequencies (down to small fractions of 1Hz) have to be dealt with, and secondly, the momentary frequency is quite irregular. The second problem is by far the more serious one. If the mean pulse rate is, say, 1Hz, pairs of pulses may appear at much shorter intervals. A frequency meter suitable for steady oscillator frequencies up to 1Hz, is thus quite unsuitable for determining the mean rate of random pulse sequences up to 1Hz. The steady-frequency resolution limit must be many times greater than the highest desired random pulse frequency measurement, otherwise missed pairs of rapidly consecutive pulses will lead to intolerable errors. It is possible to make quite good arithmetical corrections here, but it is always better to avoid the source of error by designing the radiation meter unit with adequate time interval resolution for the envisaged measurements.

ANALOGUE AND DIGITAL METHODS

The transformation from a random pulse input sequence to a "d.c." output reading corresponding to the mean pulse frequency, can be effected by two inherently different means. These are the *analogue* method and the *digital* method, a duality of possibilities for almost any basic computer function.

The digital method (Fig. 3.2) is theoretically the simpler, since it merely amounts to numerical counting of the individual pulses for a definite time determined by some form of stopclock. Each pulse from the radiation detector, after suitable amplification, is made to advance a cyclometer-type digital counter mechanism by one unit. The total number of clocked-up pulses must subsequently be divided by the time of running, to obtain the final activity reading.

This method of working is clearly the more advantageous, the smaller the mean pulse frequencies involved. For fast pulse rates, i.e. greater than 25 to 100Hz, mechanical counting mechanisms fail to respond sufficiently rapidly. It is then necessary to resort to digital electronic techniques, at least for pre-division of the pulse sequences (called *scaling*), and ultimately for the digital displays and registers themselves. This rapidly leads to extensive equipment, a disadvantage of digital methods.

The analogue method (Fig. 3.3), here also known as the *ratemeter* method, leads to a true d.c. output signal which can be displayed directly on a moving coil meter with scale calibrated in activity values. Individual pulses arriving from the radiation detector cause little or no visible change of the meter reading. Instead, each pulse is reshaped electronically to a standard form and then used to pump a definite quantity of electric charge into a large capacitor. A high-value leak resistor connected across the same capacitor continuously drains away the accumulated charge.

It is evident that the average voltage established across the capacitor by this process is directly proportional to the mean number of pulses arriving within the so-called integration time. The latter is the time constant, $C \times R$, where C is the capacitance of the capacitor and R is the value of the leak resistor connected across it. The practical difficulty with such equipment lies in the design of circuits with adequately large CR-values for very slow pulse rates.

A ratemeter circuit is evidently the more elegant in design and performance, the faster the pulse rates to be measured, since then quite small values of C and R suffice. We saw that the digital counter method suffers increasing economic drawbacks just here. The ratemeter is thus favoured for measuring medium and high activities, and there has the advantage of simplicity and direct-reading. But its accuracy becomes increasingly poorer relative to the digital method, as still higher pulse rates are involved. This is because a moving coil meter can be read to an accuracy of little better than 1 per cent, whereas the read-off accuracy of a digital counter is theoretically unlimited, e.g. it is already 0·1 per cent when a thousand pulses have been clocked-up. For this reason, professional equipment makes extensive use of complex digital counting equipment for measuring fast pulse rates, in spite of the apparent suitability of a ratemeter on superficial considerations.

At the other extreme, the ratemeter is definitely ineffective for dealing with very low pulse rates, e.g. where only a very few pulses arrive per hour, as is the case in some professional studies of low alpha-activities. A digital counter is then eminently suitable and can be very simple for such low pulse rates, since only a conventional amplifier is required between the radiation detector and an electromechanical counting mechanism.

Summing up, we thus see that the ratemeter is preferable for all except the lowest counting rates, provided that no great demands are placed on read-off accuracy. If high demands are placed on read-off accuracy, the digital counter method is *always* essential, and it is the only practicable method for extremely low counting rates. These considerations make it quite clear that a general-purpose amateur nucleonic equipment should be designed around the ratemeter principle, as our STRACE equipment is. Nevertheless, we shall have recourse to amateur digital circuits in the course of this series, and will of course mention professional digital techniques at the appropriate points.

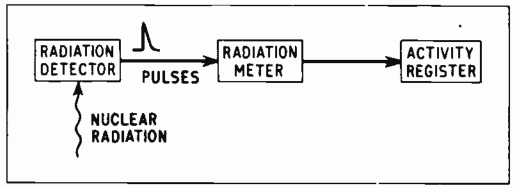

Fig. 3.1. The three essential sections of a nucleonic equipment for measuring nuclear radiation

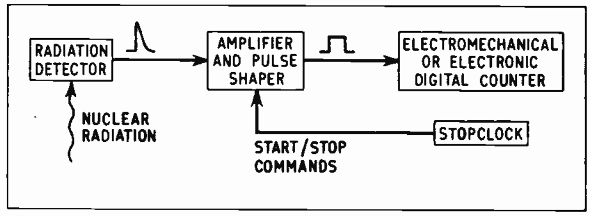

Fig. 3.2. Digital equipment for measuring nuclear radiation

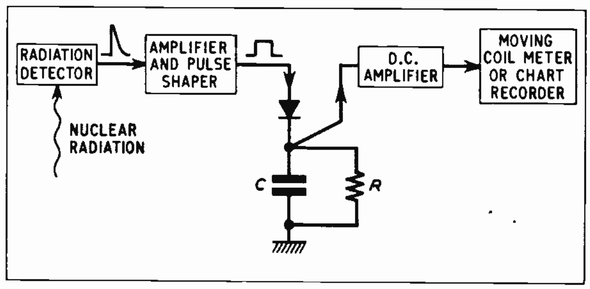

Fig. 3.3. Analogue equipment (ratemeter) for measuring nuclear radiation

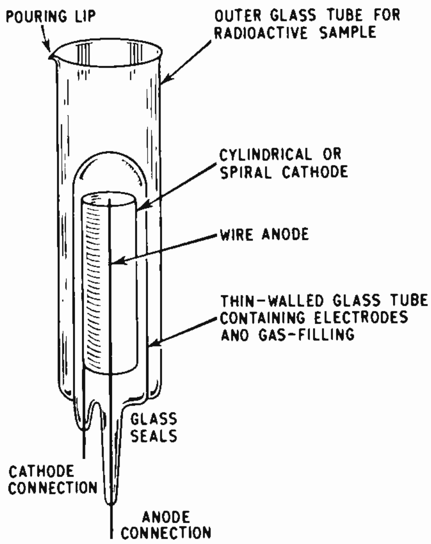

Fig. 3.4a. G.M. counter tube (Mullard MX124/01)

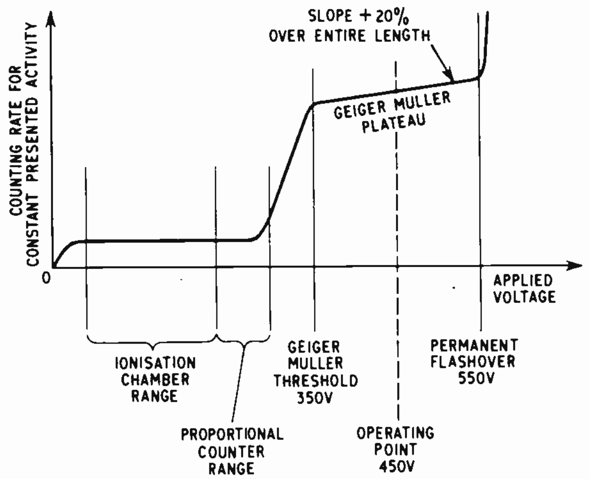

Fig. 3.4b. Detection efficiency characteristic for a G.M. counter such as that depicted in Fig. 3.4a

RADIATION DETECTORS

All radiation detectors are based on the exploitation of *ionisation* produced when nuclear radiation is absorbed by matter. Each radiation particle or quantum of gamma radiation dissipates its kinetic energy by dislodging electrons in the structure of the matter absorbing it. The absorbing matter may thereby be a gas, a liquid or a solid. It is convenient to consider radiation detectors according to this classification. A second parallel classification is concerned with the manner in which the ionisation is made to produce an electric current pulse, or some other effect.

THE GEIGER-MÜLLER TUBE

The gas-ionisation group of radiation detectors includes the most familiar device for detecting nuclear radiation, the Geiger-Müller counter tube, often simply referred to as a *Geiger counter* or G.M. tube.

The G.M. tube is a gas-filled diode with more or less cylindrical cathode surrounding a coaxial thin-wire anode, see Fig. 3.4a. The applied voltage is just not sufficient to cause a permanent discharge, but a temporary discharge immediately takes place when triggered-off by ionisation from a quantum or particle of nuclear radiation entering the active volume of gas between the cathode and anode. Two effects then quench the discharge again very rapidly. The first quenching effect is the large voltage drop at the anode as soon as discharge current flows, reducing the voltage across the tube below the level required to sustain a discharge.

The second quenching effect results from the inclusion of heavy or complex molecules in the gas filling, either as principal component (e.g. chlorine in so-called halogen G.M. tubes) or as admixture (e.g. alcohol vapour in argon-filled G.M. tubes). As soon as the electric discharge has built-up in the tube, the heavy vapour molecules are set spinning and vibrating instead of undergoing only ionisation. This removes energy from the ionisation process, so that the discharge can no longer be sustained.

This gas quenching effect is the more important one in modern G.M. counter tubes, and usually is able to quench the discharge even if the electrodes are connected directly to a low-impedance power supply, when the discharge no longer makes the tube voltage drop. However, G.M. tubes should never be operated in this manner, but always via large anode or cathode load resistors of several megohms. Unless otherwise specified by the makers, the total load resistance should be about 1 megohm per hundred volts of applied e.h.t. potential.

THE IONISATION CHAMBER

Two further gas-ionisation radiation detectors closely related to the G.M. tube are the *ionisation chamber* and the *proportional counter*.

Apart from differences in structural detail for practical versions, the only difference in principle lies in the lower applied voltage, see Fig. 3.4b. The ionisation produced by an absorbed particle or quantum of nuclear radiation is then unable to set off a full-scale discharge. When used as ionisation chamber, only a very small voltage (usually under 100 volts) is applied between the electrodes. This achieves no more than drawing-off the primary ionisation produced by the absorbed nuclear radiation.

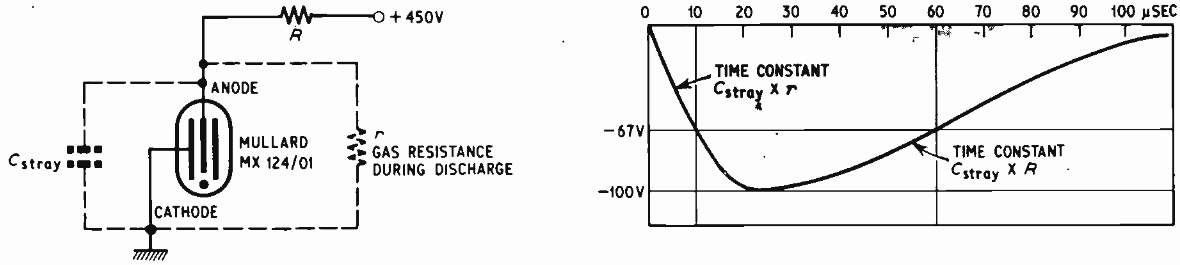

Fig. 3.4c. Voltage pulse at anode of G.M. counter tube (idealised)

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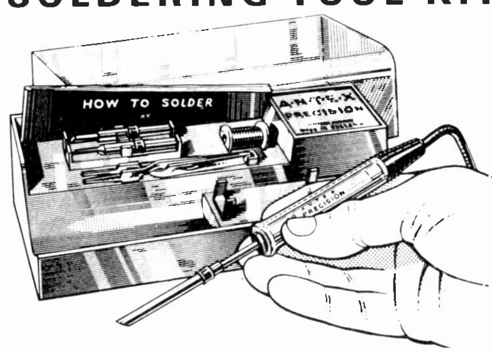

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The resulting electric current will then be strictly proportional to the energy of the absorbed radiation, because this energy determines the number of gas atoms or molecules which the radiation particle can ionise before coming to rest. Ionisation chambers are thus useful for measuring particle energies as well as total activities.

A G.M. tube can measure only activities directly, since the current pulses it produces are all identical; a particle either causes a pulse or does not cause a pulse. The amplitude of the pulses produced by the ionisation chamber is, on the other hand, proportional to the particle energy. But it is extremely small, lying in the microvolt or millivolt range, so that very sensitive amplifiers and amplitude discriminators are required. On the other hand, very large volumes of gas can be employed without technical difficulties, so that radiations with a long range can be completely absorbed within the inter-electrode volume. Hence the term 'ionisation chamber. Sizes up to many gallons are common in professional ionisation chambers.

THE PROPORTIONAL COUNTER

The proportional counter is intermediate in size and function between the ionisation chamber and the G.M. tube, and the applied voltage also lies intermediate, at one or several hundred volts. In this voltage range, primary ions produced by the radiation absorbed in the gas volume are accelerated on their way to the electrodes, producing secondary ionisation by collison with further gas molecules on the way.

The total anode current in the resulting pulse is thus much greater than for an ionisation chamber, but still requires considerable amplification in critical circuits. Proportionality is preserved between pulse amplitude and particle energy, because each primary ion produces a definite mean number of secondary ions, determined solely by the applied voltage.

G.M. TUBE OPERATION

Between the voltage range for proportional counter operation and the G.M. tube range, lies an indefinite region which is of little practical use. Above the G.M. threshold voltage, all particles entering the tube produce a large discharge pulse of fixed amplitude and duration, independent of the particle energy within the range known as the Geiger-Müller plateau. The upper limit of this plateau is the voltage at which a permanently sustained discharge takes place and rapidly destroys the tube.

The G.M. tube type of discharge is known as an avalanche discharge, because the multiplication of primary ionisation through collisions and other effects is cumulative, leading to complete breakdown of the insulation of the gas volume. This discharges the stray capacitance across the tube within a few microseconds, producing a corresponding voltage step across the anode or cathode load resistor, due to the current from the e.h.t. supply which immediately commences to recharge the stray capacitance. The voltage across the load resistor then drops exponentially as the recharge process proceeds, see Fig. 3.4c.

The time constant is thereby usually 30 to 100 microseconds (stray capacitance several pF, load resistance several megohms). This means that the G.M. tube cannot work faster than about 10kHz, which is a serious limitation in professional work. There is no advantage gained in working with smaller load resistors, because the so-called dead time of the tube is also about 60 microseconds. It is the time taken for the quenching and de-ionisation process to be completed, and the sensitivity of the tube for a new particle to be restored.

The discharge of the stray capacitance at the start of the pulse takes place approximately down to the threshold voltage, so that the pulse amplitude is usually about 25 volts, a value which is easily handled by simple electronic circuits.

Next month: Other types of radiation detectors.

DETERMINING VOLTAGE AMPLIFICATION

continued from page 54

Similarly, if the load resistor should be of only medium value, but working into a succeeding stage of medium impedance, the normal

$$\frac{R_1 R_2}{R_1 + R_2}$$

formula for two resistors in parallel should be substituted for R_L only to obtain greater accuracy.

Of course, R_L need not necessarily be a resistor. It could be an a.f. choke, whose value would be determined by ωL at an average frequency handled, usually 400Hz, or the primary of an unloaded intervalve transformer which would also multiply the usual stage gain by its turns ratio.

As the impedance of a choke or untuned transformer primary winding is electrically at 90 degrees out of phase to the valve impedance, the formula must be altered so that they can be correctly related to each other so that A becomes

$$\frac{Z}{\sqrt{(r_a^2 + Z^2)}}$$

With a tuned circuit or transformer at resonance, its impedance or dynamic resistance L/CR_c behaves as a pure resistance and this figure merely replaces R_L in the formula.

FEEDBACK

Naturally, this and all other formulae presupposes that there is no negative feedback present in the stage which means that the cathode bias resistor must be effectively bypassed.

If no bypass capacitor is present the formula for stage gain then becomes

$$A = \frac{\mu R_L}{(\mu + 1) \times R_k + R_L + r_a}$$

Resolving this for the example already computed with a bypass capacitor shows a big decrease in gain.

ANODE LOAD

As well as being able to compute what the stage gain is, it is also convenient to decide what value of anode load resistor should be employed with any specified valve to obtain the exact degree of amplification required.

The static μ of the valve must naturally be comfortably in excess of that required to prevent the use of very high value resistors, which might bring the working point of the valve off the straight part of the I_a/V_g characteristic, and limit the grid input swing.

The formula is

$$R_L = \frac{A \times r_a}{\mu - A}$$

Thus, if it is required to obtain an amplification of just 20 from the same ECC40 triode, whose static μ is 30, the load resistor should be,

$$R_L = \frac{A \times r_a}{\mu - A} = \frac{20 \times 11}{30 - 20} = \frac{220}{10} = 22 \text{ kilohms}$$

An application of 0·2V to such a one-valve amplifier would therefore produce an a.c. voltage of $0{\cdot}2 \times 20 = 4$V across the anode load resistor.

With these two simple formulae therefore it is an easy matter to compute and arrange for any required degree of amplification. ★

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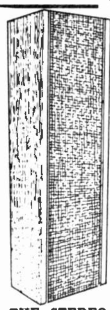

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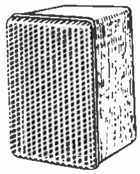

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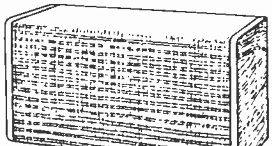

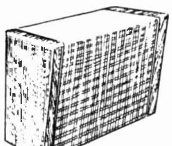

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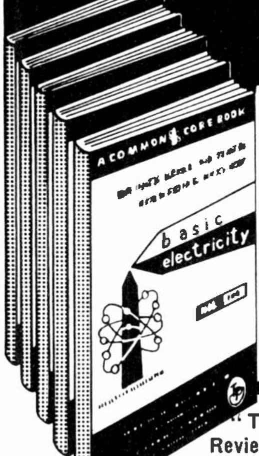

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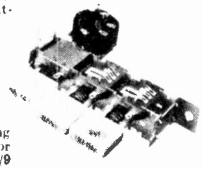

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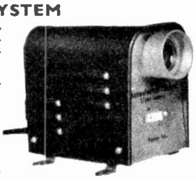
Designed to operate transistor sets and amplifiers. Adjustable output 6V, 9V, 12V for up to 500mA (class B working). Takes the place of any of the following batteries: PP1, PP3, PP4, PP6, PP7, PP9, and others. Kit comprises: mains transformer rectifier, smoothing and load resistor, condensers and instructions. Real snip at only **16/6**, plus 3/6 postage.

FLUORESCENT CONTROL KITS

Each kit comprises seven items—Choke, 2 tube ends, starter, starter holder and 2 tube clips, with wiring instructions. Suitable for normal fluorescent tubes or the new "Grolux" tubes for flash tanks and indoor plants. Chokes are super-silent, mostly resin filled. Kit A—15-20W, **19/6**. Kit B—30-40W, **17/6**. Kit C—80W, **17/6**. Kit D—125W, **22/-**. Kit E—65W, **19/6**. Kit MF1 is for 6in, 9in and 12in miniature tubes, **19/6**. Postage on Kits A and B 4/6 for one or two kits, then 4/6 for each two kits ordered. Kits C, D and E, 4/6 on first kit then 3/6 for each kit ordered. Kit MF1 3/6 on first kit then 3/6 on each two kits ordered.

PHOTO ELECTRIC CONTROL SYSTEM



Comprises a light source unit with optional Infra Red filter and lens system to focus the light. Also a photo-electric Relay control unit. Both are housed in metal cases for bench or wall mounting and there is a sensitivity control as well as mains on-off switch. The outfit works from 230/240V a.c. Mains. Can be used as a simple on/off switch by breaking the beam of light (invisible if Infra Red filter is used) and as such it will operate as a burglar alarm, or will open doors, etc. Also in conjunction with a counter or other equipment it will perform many functions in the factory or warehouse. Price **£9/19/6**, plus postage and insurance 8/-.

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50 OHM 50 WATT WIRE WOUND POT-METER 8/6 each.

1 MEG MINIATURE. Pot-meter Morganite standard, ¼in spindle, 1/- each, 9/- per dozen.

1 MEG MINIATURE. Pot-meter Morganite preset screwdriver control. **9d.** each. 8/- per dozen.

PRE-SET 100K by Welwyn with intrical bakelite knob, 1/- each. 9/- per dozen.

100K POT-METER. Miniature type with double pole switch and standard ¼in spindle, by Morganite. **2/-** each. 18/- per dozen.

BLANKETSTAT GLASS. Enclosed, normally closed circuit, will open should blanket overheat. **4/6** each.

THERMAL RELAY. Can be used to delay the supply of HT while heaters warm up, or will enable 15 amp. loads to be controlled by miniature switches or relays. Regular list price over £2, price **7/6** each.

SIEMENS HIGH SPEED RELAY. Twin 100 ohm coils. Platinum points changeover contacts—ex equipment. **8/6** each.

TOGGLE SWITCH BARGAIN. 10 amp. 250V normal one hole fitting. **2/9** each, or 30/- per dozen.

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Vacuum Cleaner Flex. Non-kinkable ribbed rubber, most pliable but very tough. 24/36 Cores. Normally 1/9 per yard, offered at **£3** per 100 yard coil, post and insurance 8/6.

Sub-Miniature Silicon Diodes. General purpose type with gold-plated leads. 1/- each or 7/6 per dozen.

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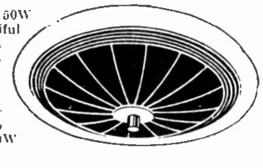
WHITE CIRCULAR FLEX. Ideal for lighting drops, twin made by BICC. Usually 8d yd, 100yd coil for 30/-, plus 6/- postage.

EDGEWISE CONTROL. Morganite, as fitted many transistor radios. 2K or 5K with switch. **2/6** each, or 24/- per dozen.

12V INVERTER. Full transistorised for operating a 20W fluorescent tube, size 6in long 1½ 1½. **£3/10/-**. Post and insurance 3/-.

CIRCULAR FLUORESCENT

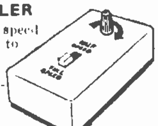


Bring sunshine into your home. 150W of light but uses only 40W. Beautiful fittings with glass, non-plastic centre, fluorescent tube and choke control. Regular price £4/15/-. **Special budget price 65/-** plus 10/- carr. and ins. Please state colour of glass centre, white, pink, blue, red, black, yellow or cream. Also whether plug into lamp holder or ceiling mounting model 80W model **99/6**. 10/- carr. and ins.

CASSETTE LOADED DICTATING MACHINE

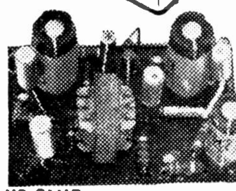
Battery operated and with all accessories. Really fantastic offer, a British made £31 outfit for only **£6/19/6**, brilliantly designed for speed and efficiency—cassette takes normal spools drops in and out for easy loading—all normal functions—accessories include stethoscopic ear-piece—crystal microphone has on/off switch telephone pick-up—tape reference pad—DON'T MISS THIS UNREPEATABLE OFFER—SEND TO-DAY. **£6/19/6**, plus 7/6 post and insurance. Footswitch **18/6** extra. Spare Cassettes at 7/6 each, three for £1.

DRILL CONTROLLER



Electronically changes speed from approximately 10 revs to maximum. Full power at all speeds by fingertip control. Kit includes all parts, case, everything and full instructions. **19/6**, plus 2/6 post and insurance. Or **available made up 32/6.**

750mW TRANSISTOR AMPLIFIER



4 transistors including two in push-pull input for crystal or magnetic microphone or pick-up—feed-back loops—sensitivity 5mV. Price **19/6**. Post and insurance 2/6. Speakers: 3in, **12/6**, 5in, **13/6**, 6 × 4in, **14/6**.

THIS MONTH'S SNIP

Non-flicker fluorescent lighting at silly price, famous A.E.I. (Mazda) instant start lighting transformer for 4ft 40W tube, listed at over £4. Two tube ends and two Terry clips to hold tube. Special snip price, **only 14/6**, plus 4/6 post and insurance—don't miss this tremendous bargain.

RADIO STETHOSCOPE

Easiest way to fault find—traces signal from aerial to speaker—when signal stops you've found the fault use it on Radio, TV, amplifier, anything—complete kit comprises two special transistors and all parts including probe tube and crystal earpiece, **29/6**—twin stetoset instead of earpiece, **7/6** extra—post and ins. 2/9.

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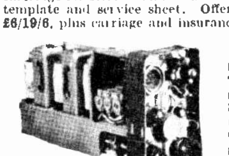
Model 2000

This is one of the latest products of the World's most experienced maker of fine record reproducers. Its superior features include—automatic playing of up to 8 mixed-size records—stopping and starting without rejecting—manual playing—pick-up pivots to give low stylus pressure - large diameter turn-table for max. stability adjustments include pick-up height—pick-up dropping position and stylus pressure. Size is 13½ 11⅞in clearance 4⅞in above, 2½in below—fitted with latest hi-compliance cartridge for stereo—and mono L.P. and 78. Supplied complete with mounting template and service sheet. Offered this month at the Special Snip price of **£6/19/6**, plus carriage and insurance.

EX-WD BARGAIN Easily rebuildable to short wave radio



This is the 46 Receiver/Transmitter. It has a range of approx. 5 miles. Operates from dry batteries. Complete with six valves and in metal case. Size approx. 12 × 6 × 3¼in. Complete but less crystal, not tested nor guaranteed. **19/6** plus 4/6 post and insurance. Should not be operated as a transmitter in the U.K.

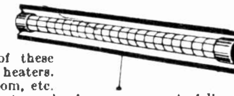
SMALLEST TAPE RECORDER AVAILABLE (6¼ × 2½ × 1¾in)

Will record or play back (into earphones) whilst still in your pocket. Uses standard tape which is re-usable indefinitely. Complete with batteries, ready to work, **£6**, plus 5/- post and insurance.

TUBULAR HEATERS

New and unused made by G.E.C.—rated at 60W per ft.—these are ideal in airing cupboards, bedrooms, offices, stores, greenhouses, etc., curtains or papers can touch them without fear of scorching or fire. Supplied complete with fixing brackets and available in the following sizes.
8ft, **30/-**; 10ft, **36/-**; 12ft, **42/-**.
Prices which are about ⅓ of list price includes carriage by B.R.S.

INFRA-RED HEATERS

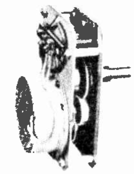


Make up one of these latest type heaters. Ideal for bathroom, etc. They are simple to make from our easy-to-follow instructions—uses silica enclosed elements designed for the correct infra-red wave length (3 microns). Price for 750W element, all parts, metal casing as illustrated. **19/6**, plus 3/6 post and insurance. Pull switch 3/- extra.

HI-FI SPEAKER BARGAIN

12in High fidelity loudspeaker. High flux permanent magnet type with either 3 or 15 ohm speech coil. Will handle up to 10W. Brand new by famous maker. Price **29/6**, With built-in Tweeter **35/-**, plus 3/6 post and insurance.

GEARED MOTOR



HALF REV. PER MINUTE
Made by famous Smith Electric, mains operated and quite powerful. Size 3½ × 2¼ × 1¾in deep. Secondary use as process timer. Internal switch can be made to break circuit within a period up to 2 min. **17/6.** P. & P. 2/6 unless ordered with other goods.

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Know who is calling and speak to them without leaving bed, chair, etc. Outfit comprises microphone with call push-button connecting wire and master intercom. Simply plugs together. Originally sold at £10. Special snip price **99/6**, plus 3/6 postage.

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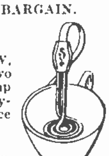
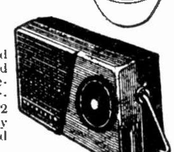
4 speed, gram. motor with lightweight pick-up motor, electronically balanced and free from wow and flutter. Speed change by pushbutton—16, 33, 45, 78 r.p.m. Price **39/6**, plus 4/6 post and insurance.
DON'T MISS THIS TERRIFIC BARGAIN.

QUICK CUPPA



Mini Immersion Heater, 350W, 200/240V. Boils full cup in about two minutes. Use any socket or lamp holder. Have at bedside for tea, baby-food, etc., **19/6**, post and insurance 1/6.

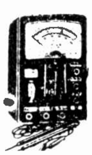
NO SOLDERING POCKET 3



Lots of fun to build and good results when finished—complete kit with detailed instructions and crystal earpiece (batteries 1/2 extra). £5 value only **19/6** plus 3/- post and insurance.

MULTI-RANGE TEST METER

1000 OPV



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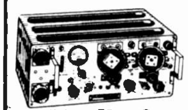

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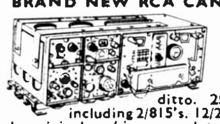

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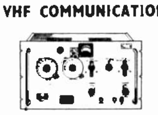

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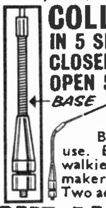

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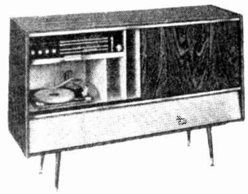

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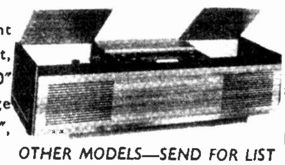

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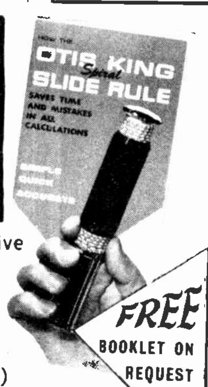

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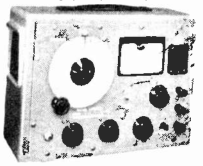

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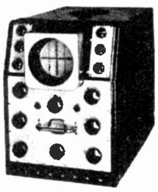

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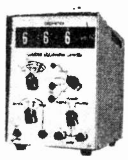

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A.c.–a.c. coupled, approximately equivalent to a shunt impedance of 8K Ω in series with the parallel impedances 180K Ω and 550pF.
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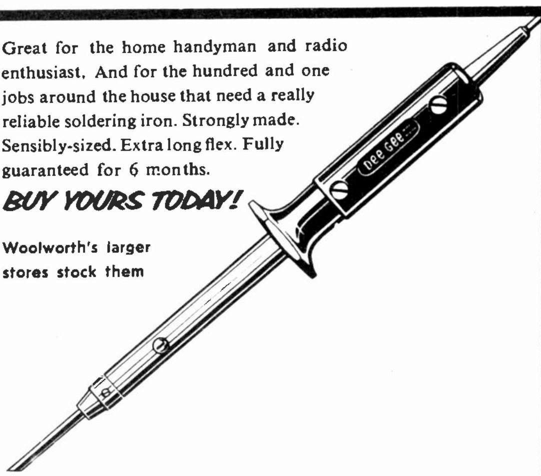

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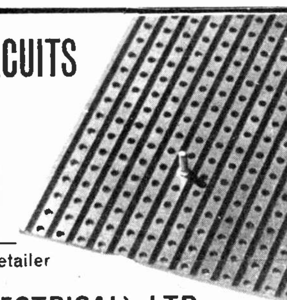

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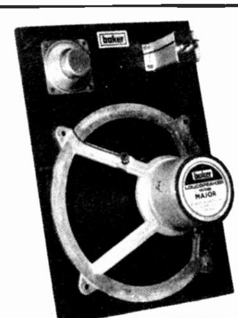

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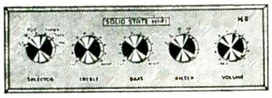
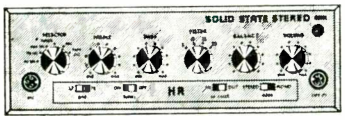
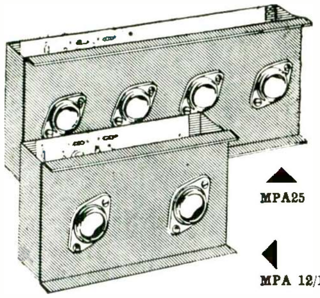


MP3

SP6-2





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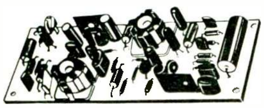

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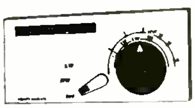

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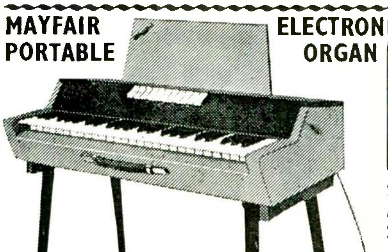

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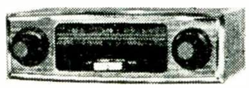

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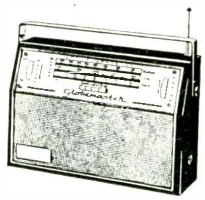

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