

# Practical Electronics

JUNE 1965

PRICE 2/6

## FREE!!

### 2 Double-sided BLUEPRINTS

- \* R/C BRIDGE
- \* ELECTRONIC TRUMPET
- \* INTRUDER ALARM



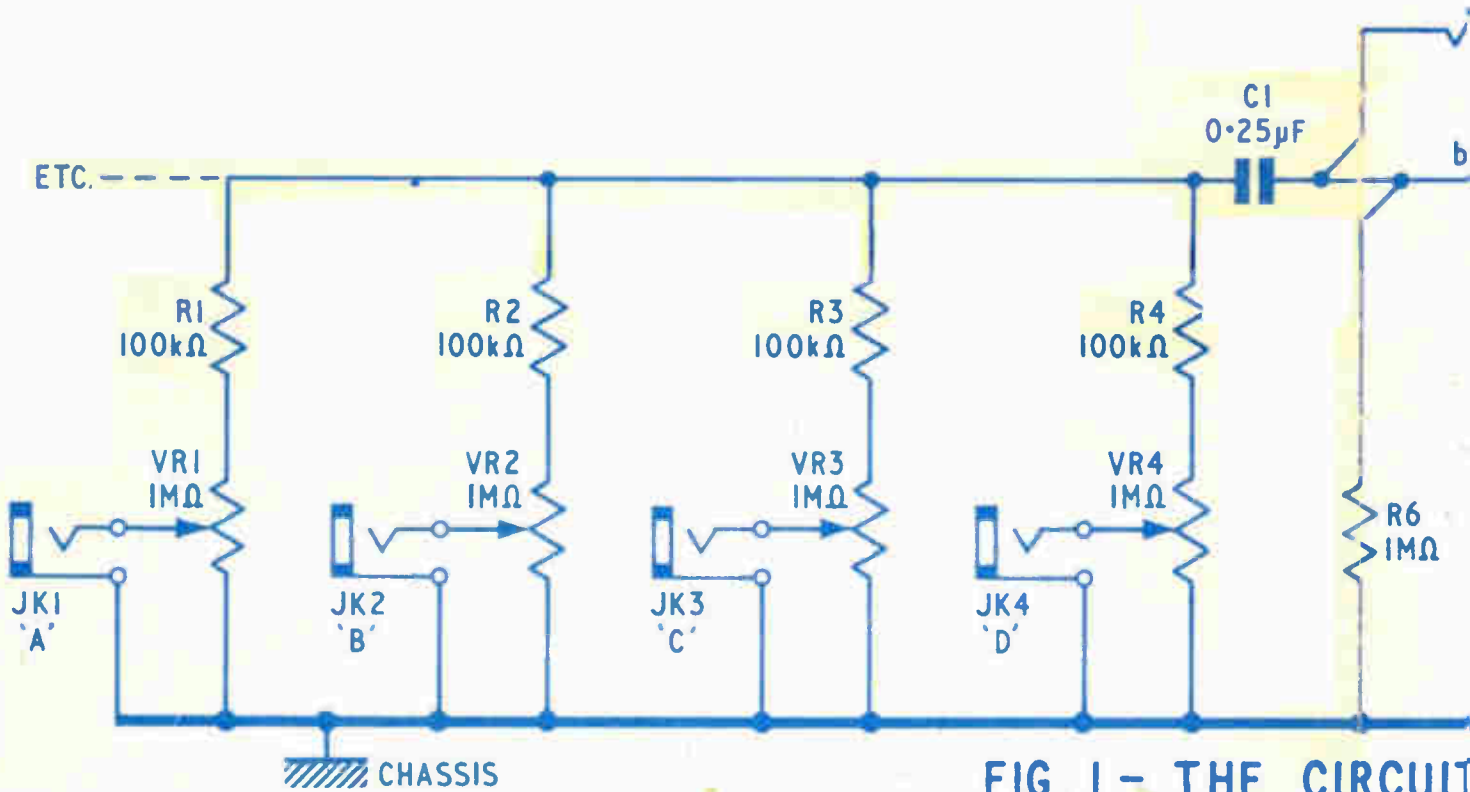
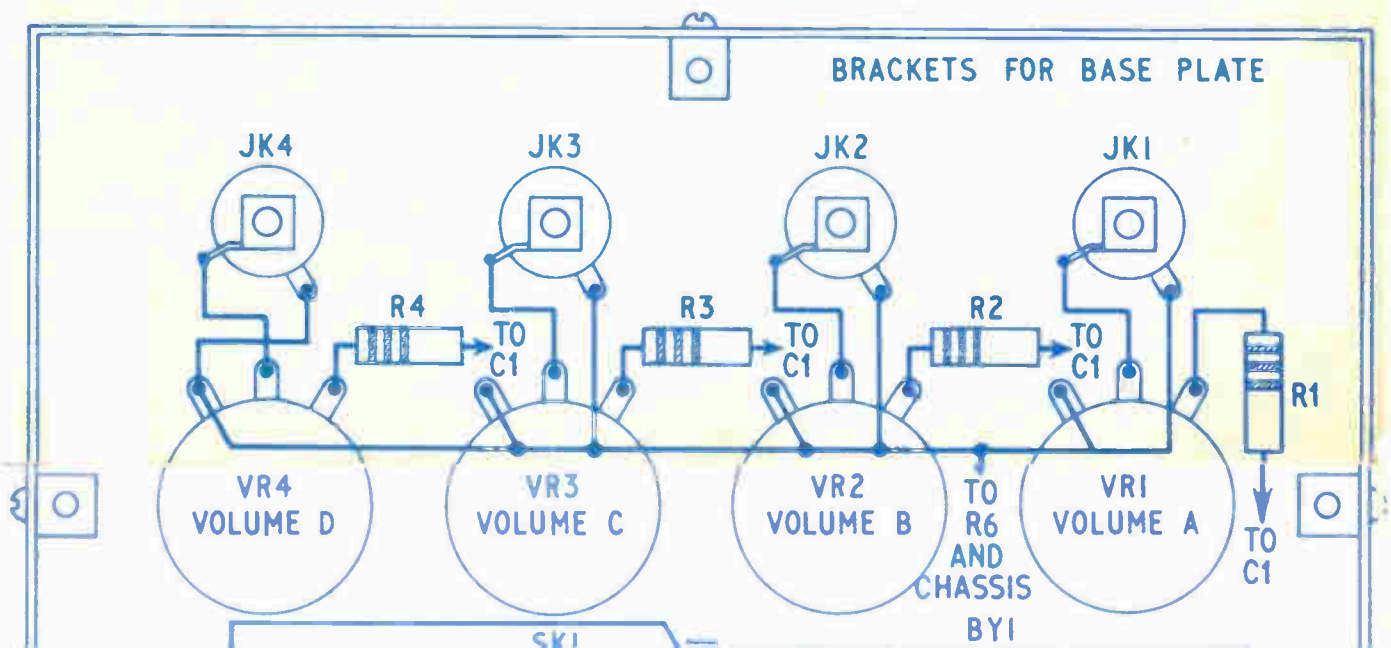


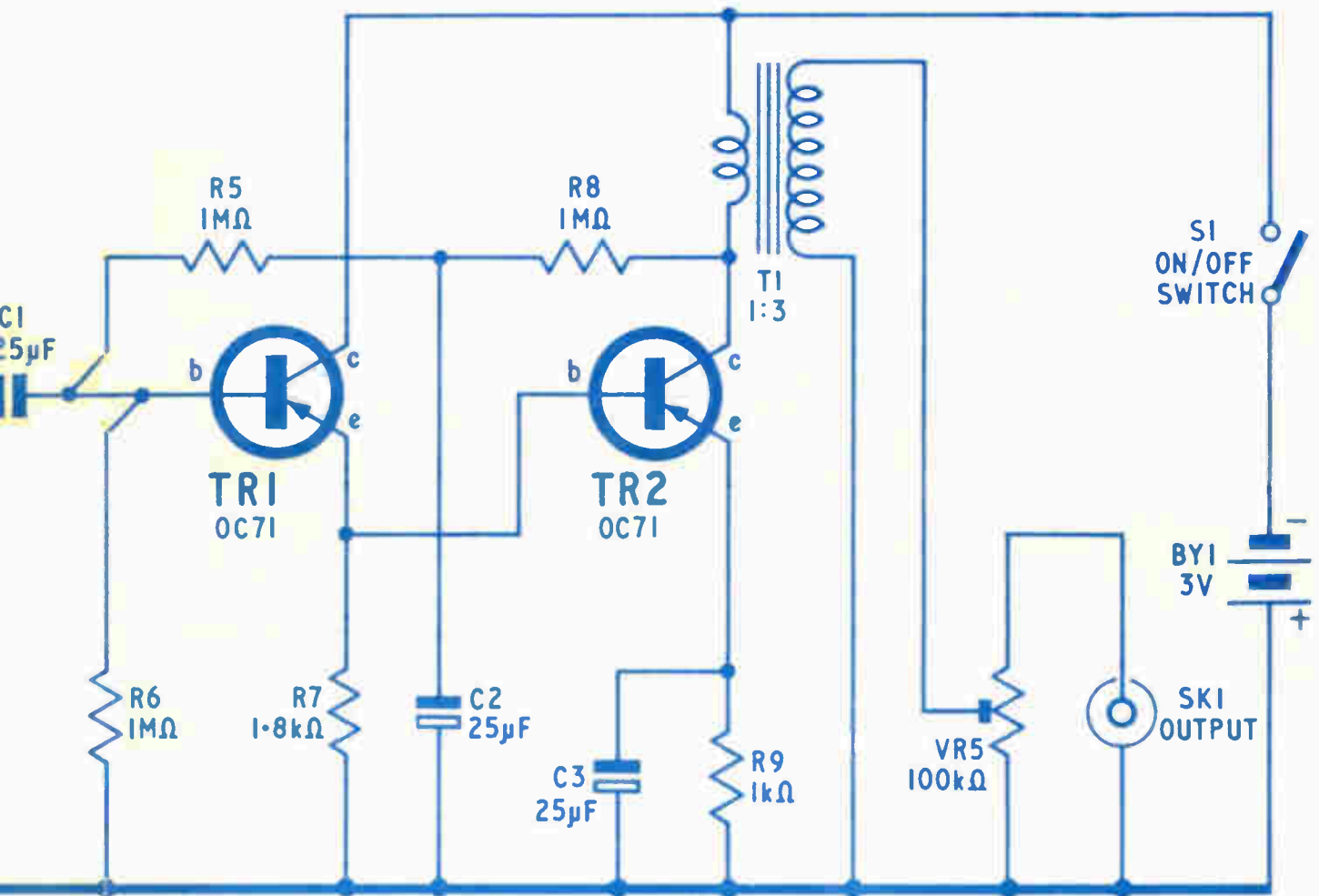
FIG. 1 - THE CIRCUIT



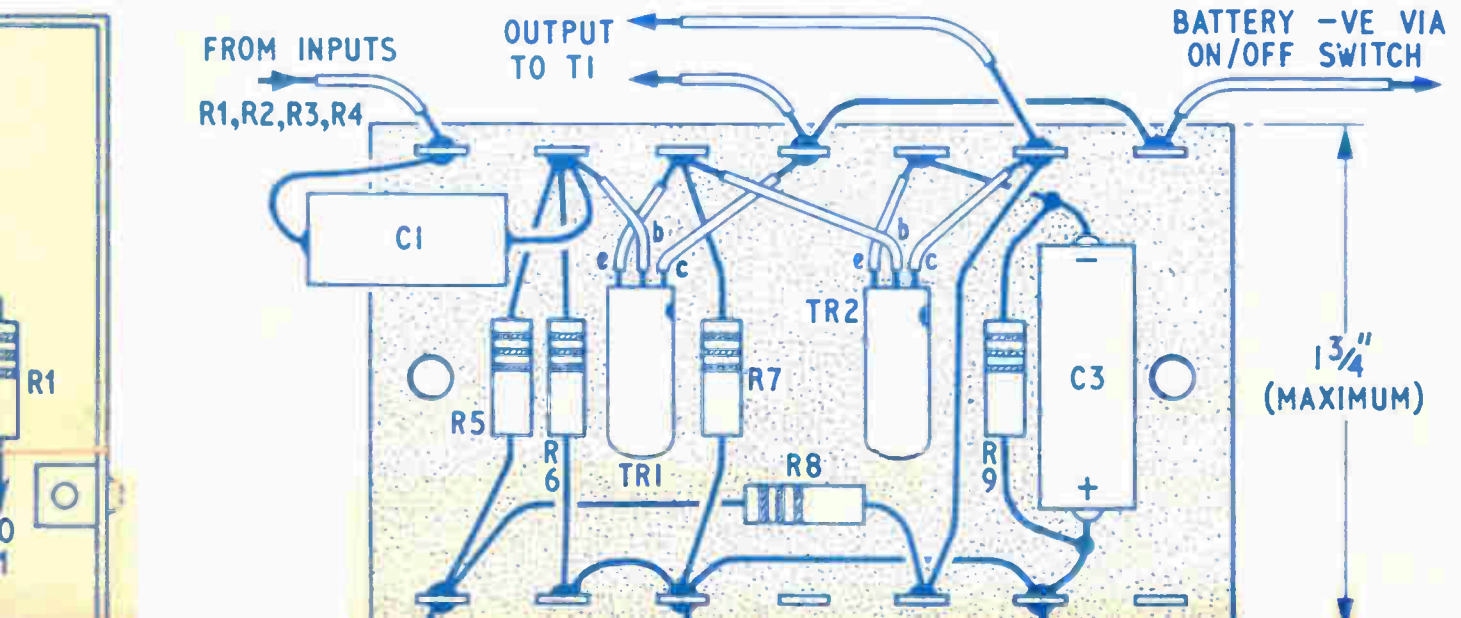
# ONE MIXER UNIT

PRICE 5/-

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TOWER HOUSE, SOUTHAMPTON STREET,  
LONDON, W.C.2.



CIRCUIT DIAGRAM





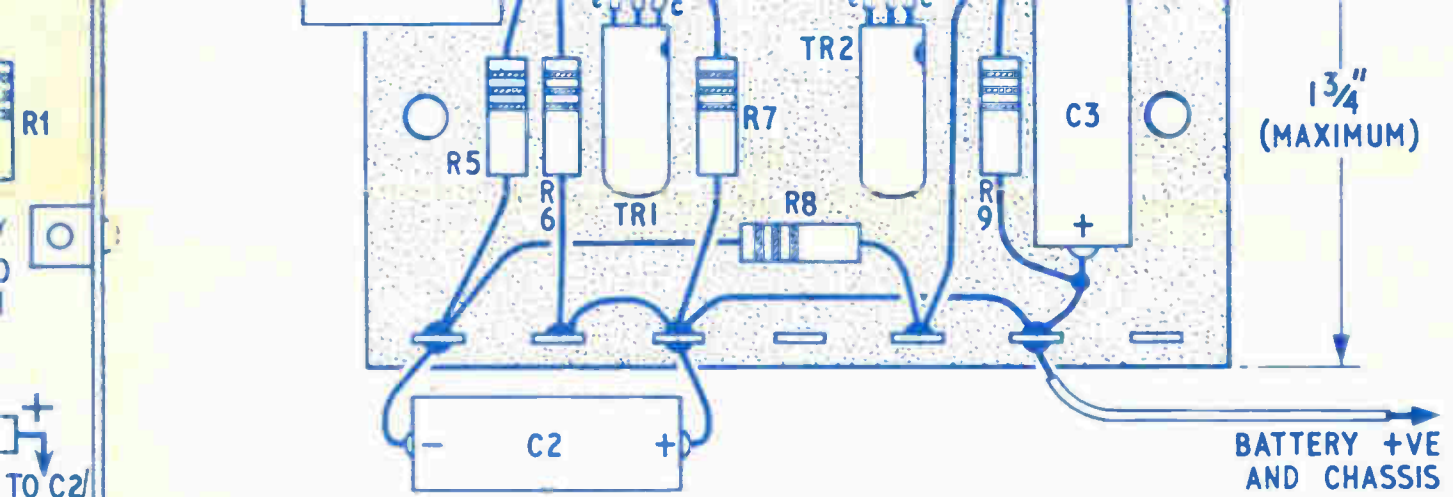


FIG. 3 - AMPLIFIER PANEL WIRING

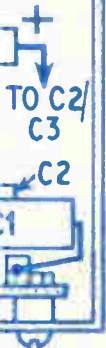


FIG. 2 - LAYOUT OF CHASSIS  
(FULL SIZE)



## COMPONENTS LIST

### Resistors

R1	100k $\Omega$	R6	1M $\Omega$	H.S.
R2	100k $\Omega$	R7	1.8k $\Omega$	H.S.
R3	100k $\Omega$	R8	1M $\Omega$	
R4	100k $\Omega$	R9	1k $\Omega$	

All 10%, 1/4W carbon

### Potentiometers

VR1-VR4 1M $\Omega$  carbon, logarithmic  
VR5 100k $\Omega$  carbon, logarithmic

### Capacitors

C1 0.25 $\mu$ F paper  
C2 25 $\mu$ F electrolytic, 25V  
C3 25 $\mu$ F electrolytic, 25V

### Transistors

TR1 OC71  
TR2 OC71

### Transformer

T1 Intervalve transformer, 1:3 ratio

### Switch

S1 Single pole, on off toggle switch

### Sockets

JK1 JK4 normal 2-contact insulated jack socket (Igranic or Radiospares)  
SK1 Coaxial socket

### Battery

BY1 3V battery (two 1.5V pen cells)

### Miscellaneous

Four matching knobs. Aluminium box 7in x 5in x 2 1/2in, with removable bottom panel. Four small rubber feet

# AUDIO OSCILLATOR

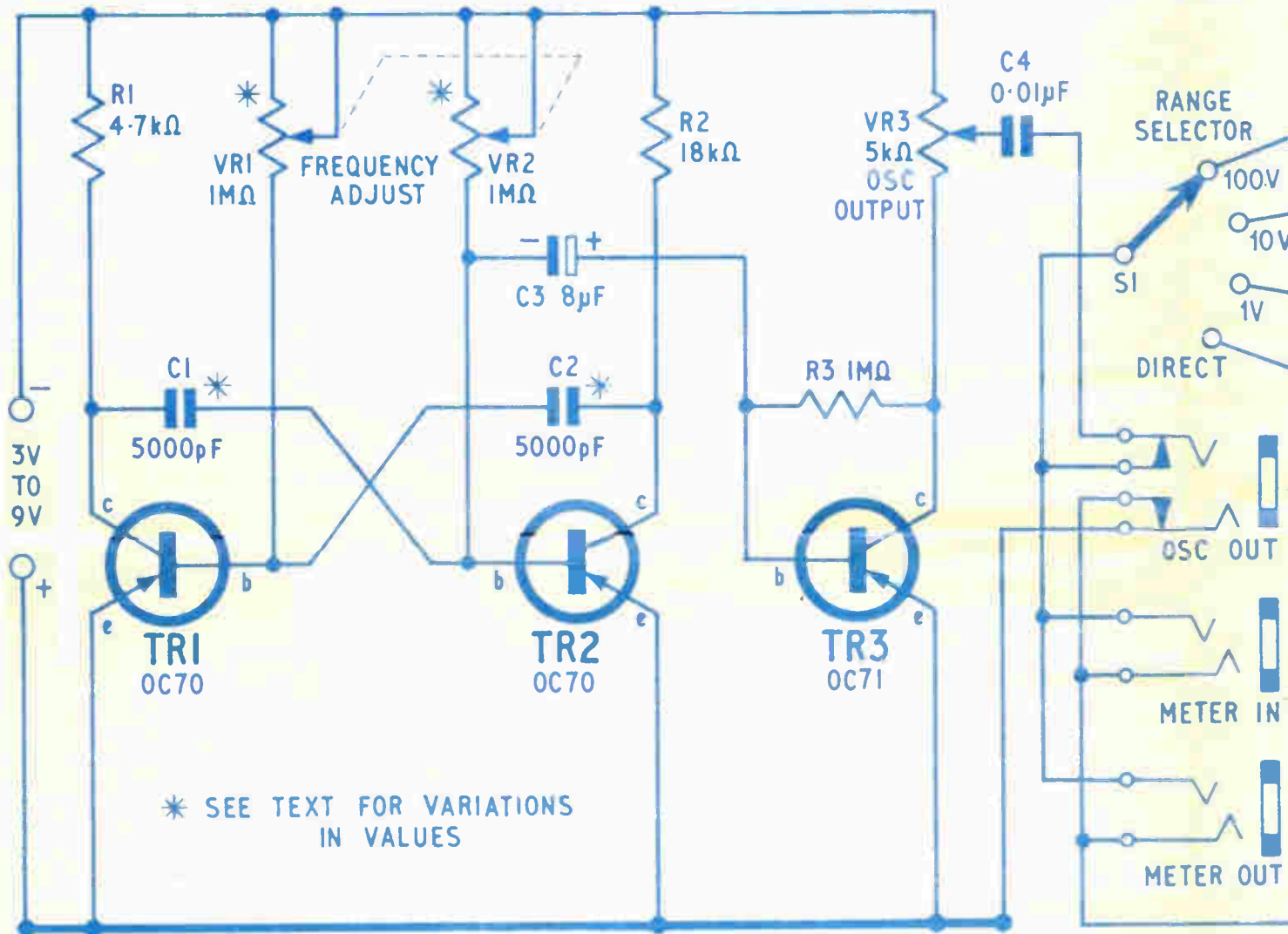
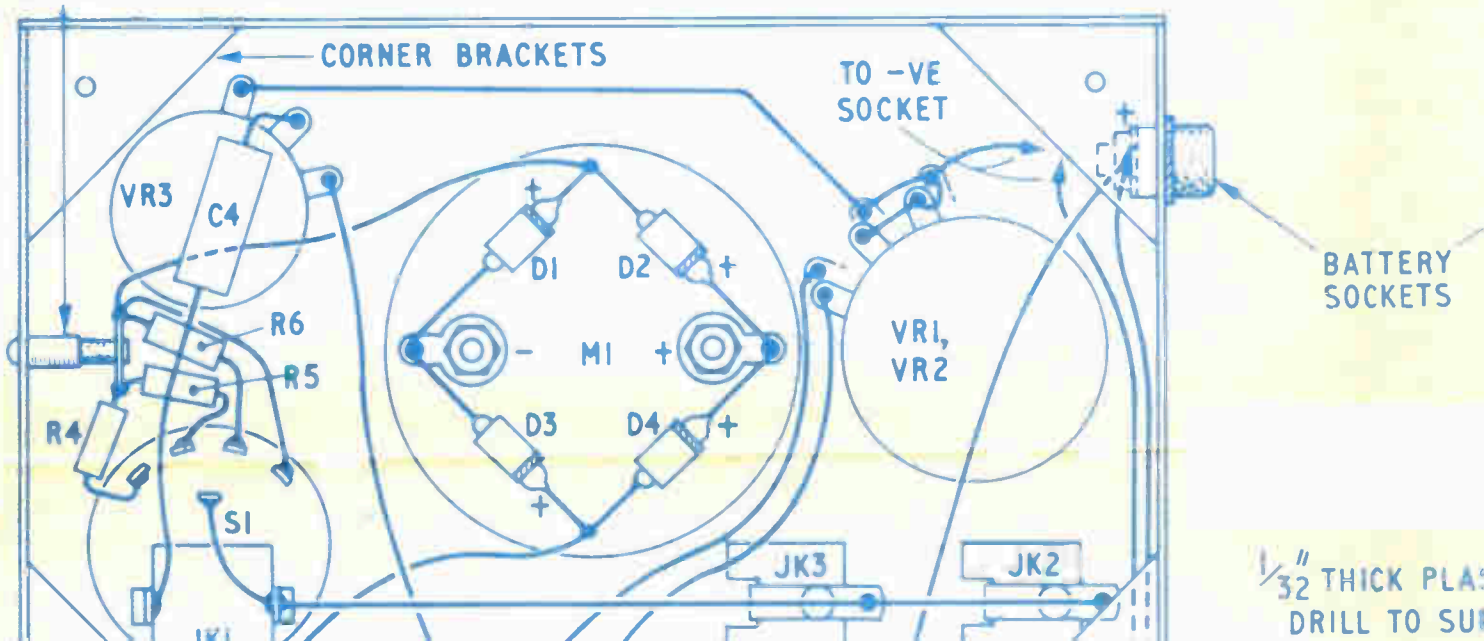


FIG. 1 - THE CIRCUIT DIAGRAM

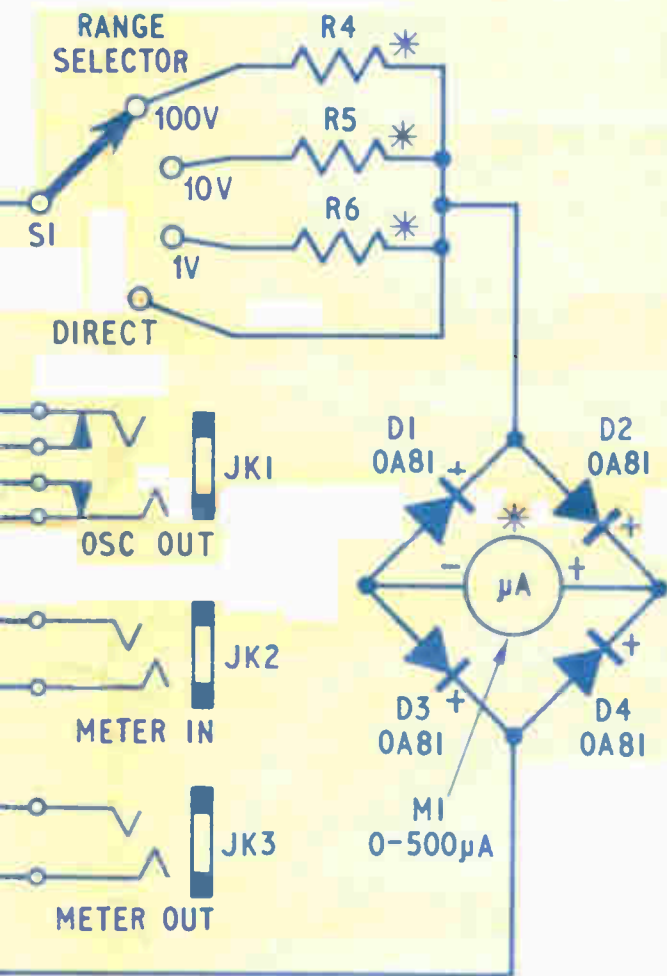
STAND-OFF INSULATOR



# ATOR & OUTPUT METER

**PRICE 5/-**

PUBLISHED BY GEO. NEWNES LTD  
TOWER HOUSE, SOUTHAMPTON STREET,  
LONDON, W.C.2



## COMPONENTS LIST

### Resistors

R1 4.7k $\Omega$  R4 }  
R2 18k $\Omega$  R5 } depend upon meter used--see  
R3 1M $\Omega$  R6 } text  
All 10%, 1/4W carbon

### Potentiometers

VR1 1M $\Omega$  carbon, linear }  
VR2 1M $\Omega$  carbon, linear } ganged  
VR3 5k $\Omega$

### Capacitors

C1 5,000pF silver mica, 5%  
C2 5,000pF silver mica, 5%  
C3 8 $\mu$ F electrolytic, 15V C4 0.01  $\mu$ F Paper

### Transistors

TR1 OC70, OC71 or similar  
TR2 OC70, OC71 or similar  
TR3 OC71, OC72 or OC76

### Diodes

D1-4 OA81 germanium diodes (4 off)

### Jack Sockets

JK1 closed-circuit, insulated jack  
JK2,3 normal 2-contact insulated jack } (Igranic or Radiospares)

### Meter

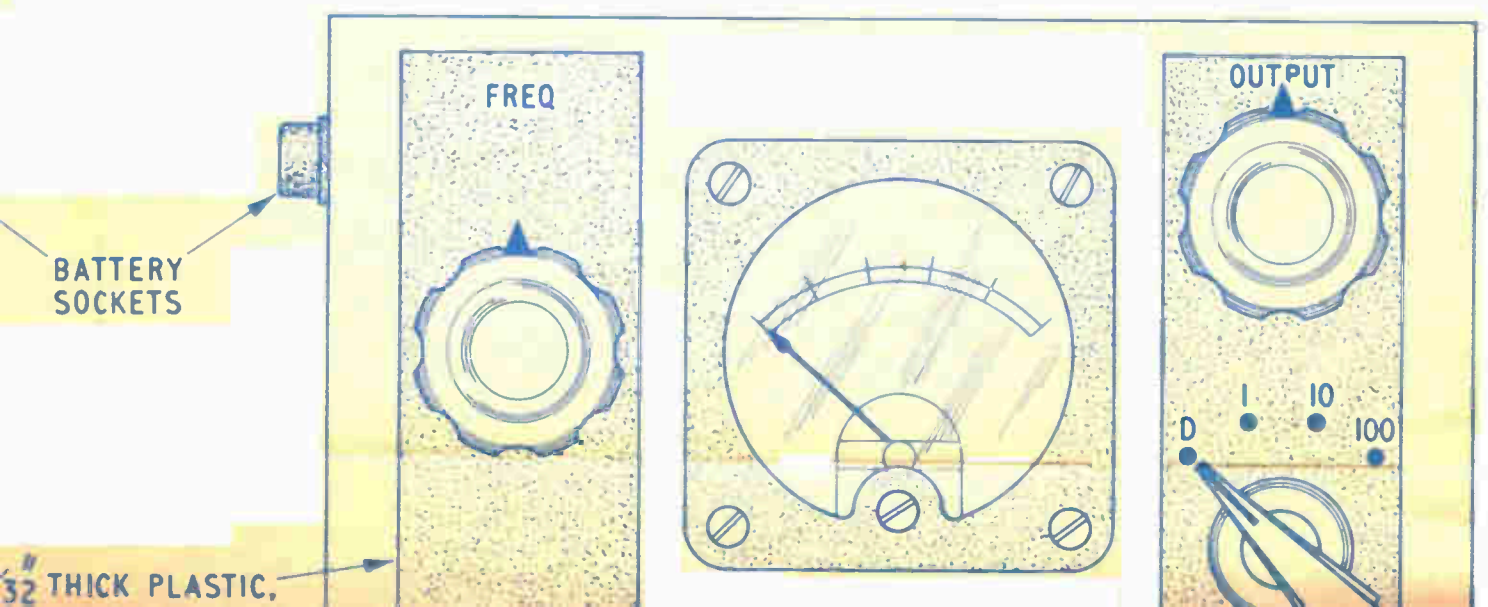
M1 Moving coil, 500 $\mu$ A f.s.d., scaled 0-10

### Switch

SI Single pole, 4 way rotary switch

### Miscellaneous

Pair of sockets, one red, one black (Radiospares). Three knobs. Two 7-tag miniature terminal strips. Aluminium sheet for case. Nuts and bolts, rivets, solder tags



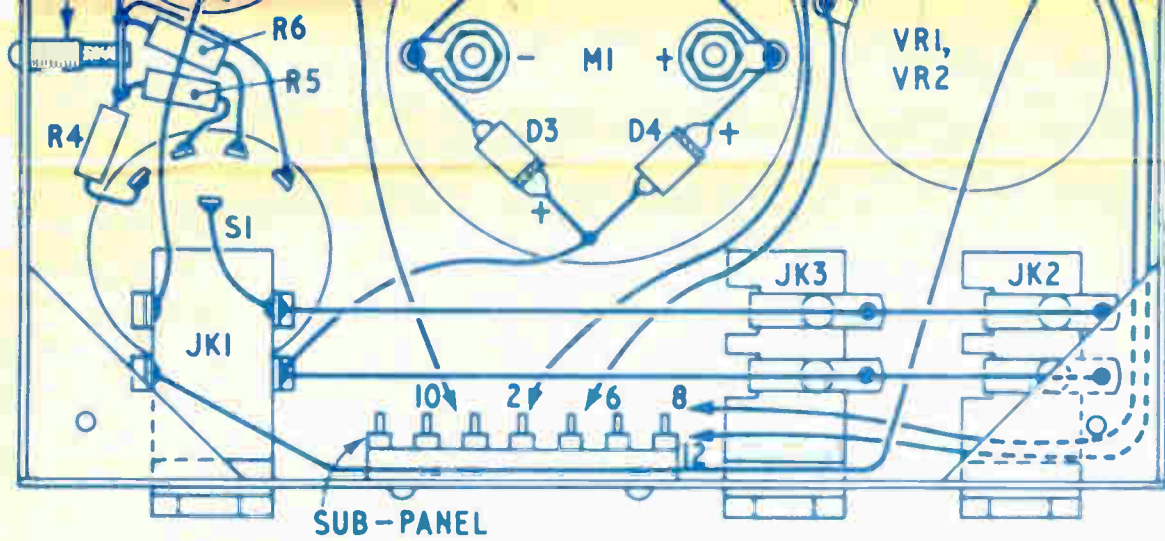


FIG. 2 - VIEW ON UNDERSIDE OF CHASSIS

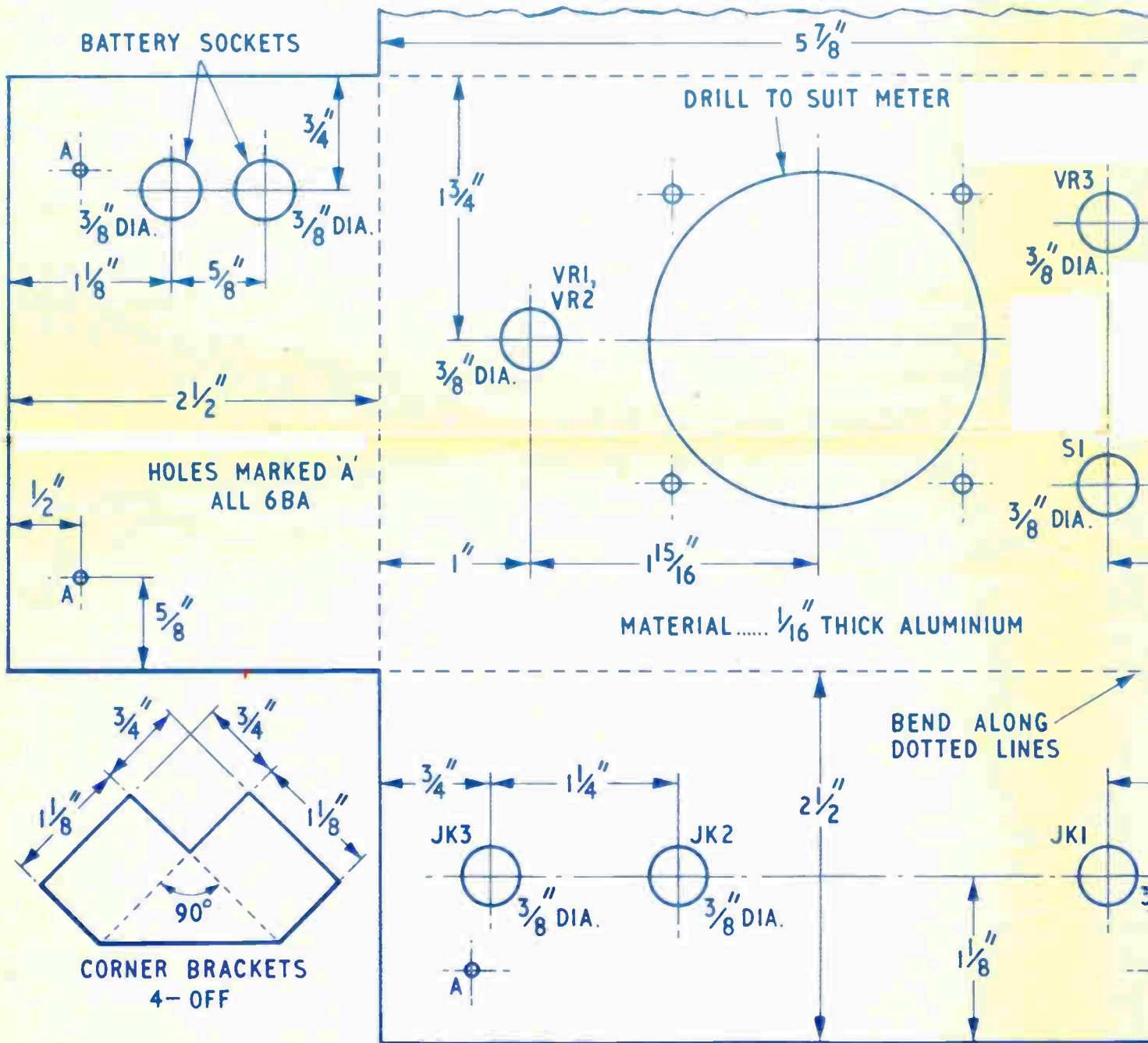


FIG. 4 - CHASSIS DRILLING DETAILS



BATTERY SOCKETS

3/32" THICK PLASTIC, DRILL TO SUIT CONTROL LAYOUT (2-OFF)

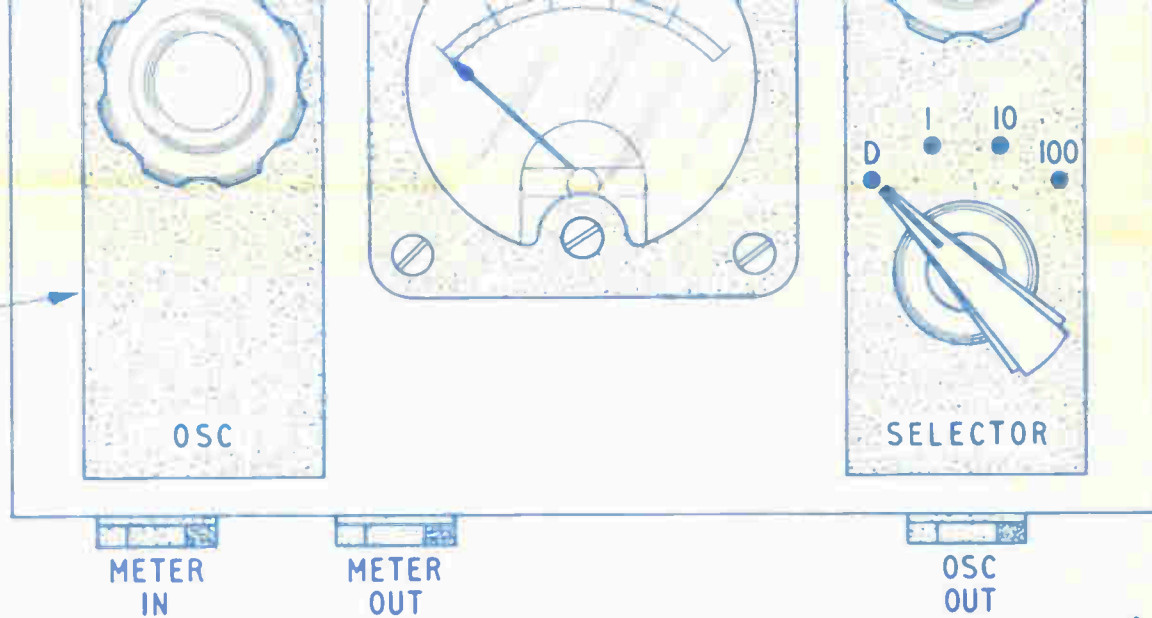


FIG. 3 - VIEW ON TOP OF CHASSIS (FULL SIZE)

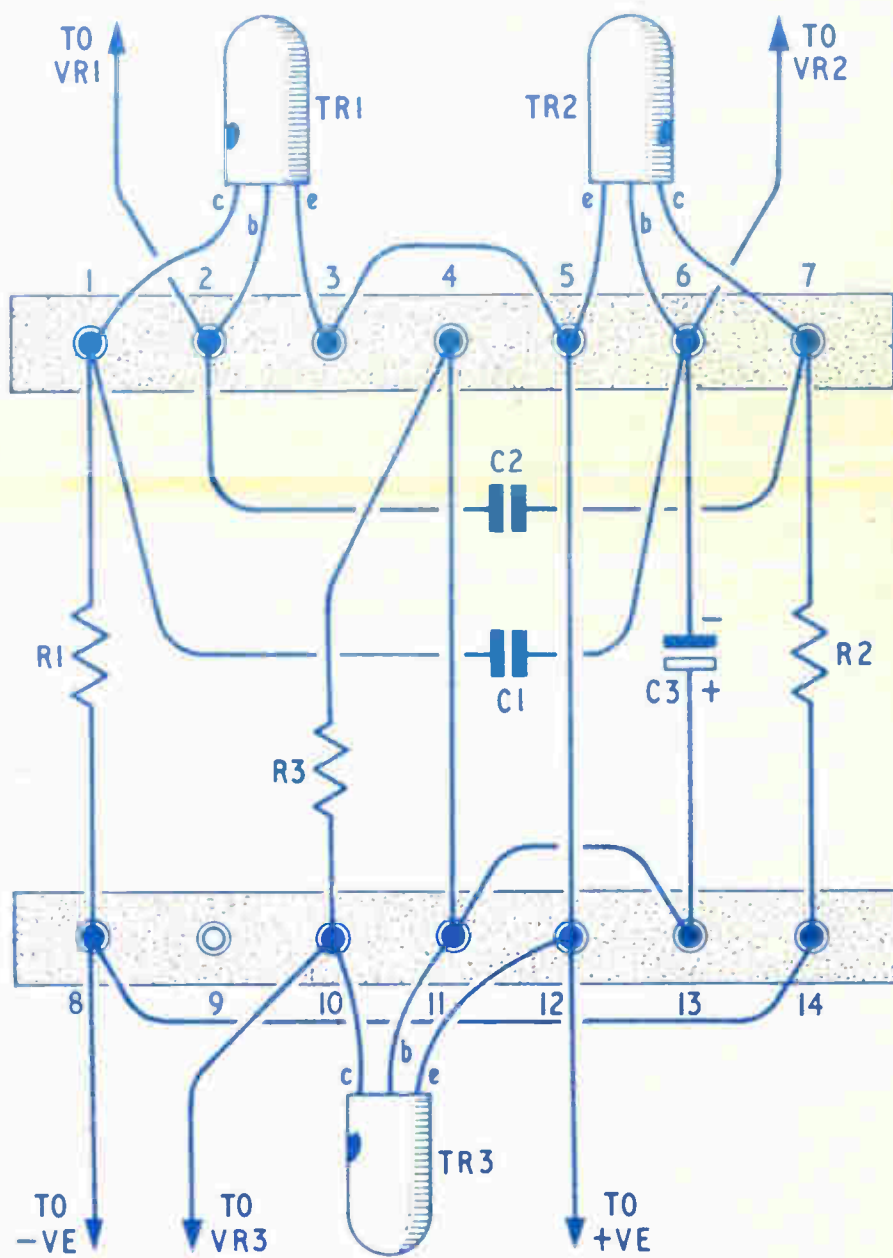
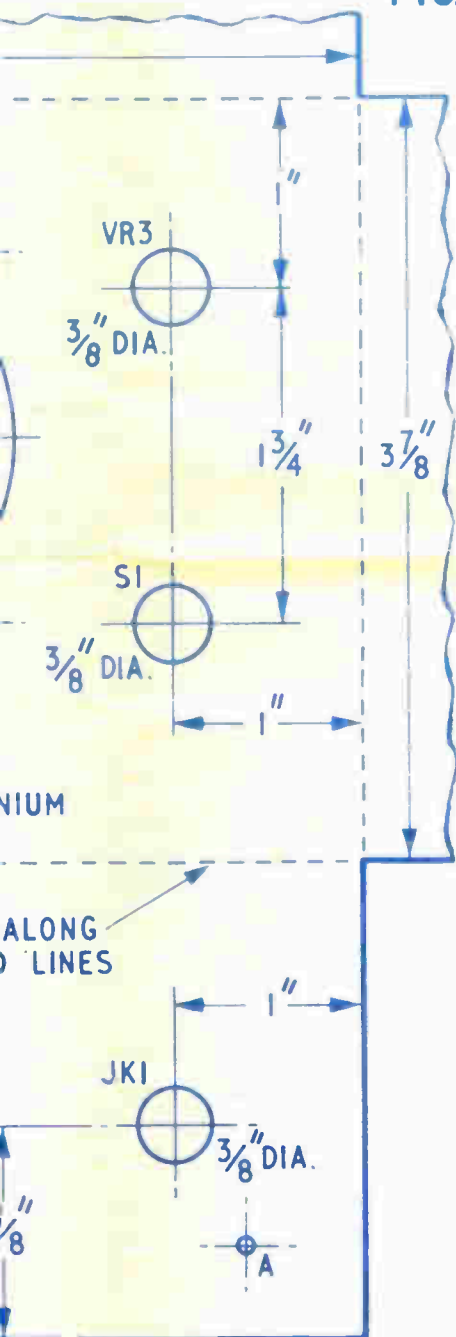


FIG. 5 - SUB-PANEL WIRING

## GLOBAL COMMUNICATIONS

THE inauguration of a transatlantic telephone service via a high altitude synchronous satellite provides a most fitting commemoration of the founding of the International Telegraph Union (later renamed the International Telecommunications Union) a hundred years ago.

When 20 countries signed the ITU agreement in Paris 17 May 1865, submarine cables already linked the U.K. with the continent, but it was not until the following year that the first transatlantic cable was successfully completed. Now the "Early Bird" satellite with its 240 two-way speech circuits will carry as much traffic as all the existing transatlantic cables can handle today.

★ ★ ★

Although "Early Bird" is going into commercial service it is a pioneer operation and still in many respects experimental. One of the questions to be answered is how objectionable will be the 0.5 second delay in speech due to the very long transmission path.

The 40-nation consortium which is planning a world satellite communications network has also to evaluate the rival claims of a system based on medium altitude non-synchronous satellites such as Telstar and Relay. With such a system there is no delay in transmission, but the earth stations require very complex equipment for tracking the rapidly moving satellites.

★ ★ ★

At the European end of the transatlantic link the British earth station at Goonhilly in Cornwall is sharing duties with its counterparts in France and West Germany.

Equipped with highly advanced devices including a super sensitive s.h.f. receiver using a ruby maser and superconducting magnet, and a computer to control the dish aerial, Goonhilly is a fine symbol of space age telecommunications. It is worth recalling that the geographical location of this station provides a link with another momentous event in the history of global communications. For it was at Poldhu but a short distance away on the remote Cornish coast that Marconi set up his primitive wireless apparatus with which in 1901 he succeeded in sending a telegraphic signal across the Atlantic for the first time.

★ ★ ★

Advancing technology increases the methods and possibilities for communication by radio, but it also creates an insatiable demand for frequency allocations. As the negotiating and regulating authority in these matters the ITU (now operating as an agency of the United Nations) has an onerous task. But its work is vital, because the success of any communications system is conditional on the co-operation and agreement of all parties concerned.

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*Our July issue will be published on  
Thursday, June 17*

# NON-DESTRUCTIVE TESTING



**BY H. POTTER**

SOLUS SCHALL INTERNATIONAL  
INSPECTION SERVICE

(Part of the Rank Organisation)

**N**ON-DESTRUCTIVE testing is the name given to a clearly defined group of physical phenomena which can be used to discover flaws in metallic or non-metallic objects without in any way altering their chemical or physical characteristics. The name is a little misleading perhaps, in that all testing must obviously be non-destructive if the tested article is to have a useful life. The term has, however, come to stay. It embraces, in order of present-day importance: X-ray and gamma radiography, ultrasonic flaw detection, crack detection by magnetic particles or penetrants, and inspection of materials by eddy-current methods.

Electronic technology plays an essential part in most of the methods just mentioned.

Almost all the world's main industries use some form of non-destructive testing. Among the biggest users are the aircraft and heavy engineering industries. Periodically military and commercial aircraft are subjected to non-destructive testing checks to ensure wing spurs are free from cracks caused by metal fatigue. All vital metals in the heavy engineering and constructional industries are tested during construction for porosity, lack of fusion and cracks.

## INTERNATIONAL INSPECTION SERVICE

Some companies provide comprehensive "on site" facilities for all kinds of non-destructive testing. For example, the Rank Organisation operates an international inspection service with specialists known in five continents.

Among the specialised equipment and techniques regularly used on all types of inspection work—from pipelines in the desert to shipbuilding on Tyneside—are: X-radiography, gamma radiography, ultrasonics, holiday detection, magnetic particle and dye penetrant crack detection. Each of these methods will now be briefly described.

## X-RAY RADIOGRAPHY

X-ray radiography is one of the most widely used methods for testing metals and welds for flaws.

X-rays are an electromagnetic-wave phenomenon exactly similar to visible light, heat rays, wireless waves, etc., and they differ from these in wavelength only. They penetrate matter and they affect photographic emulsions like ordinary light; they cause certain substances to fluoresce and they set up ionisation in air. They are used both in industry and medicine, usually in conjunction with a photograph emulsion.

These radiations are produced by electronic means in vacuum tubes called X-ray tubes.

In simple terms an X-ray tube may be likened to a diode valve. A heated filament at one end of the tube emits electrons which are attracted to an anode placed at the other end of the tube, see Fig. 1. The anode is made of heavy metal tungsten and referred to as the "target". When the electrons are stopped by the target, X-rays are generated. By arranging that the target

surface is at an angle to the axis of the tube, it is possible to produce a conical beam of X-rays whose axis is at right angles to the axis of the tube.

In common with all diodes, the tube can act as a rectifier and if connected to a source of alternating voltage, electrons and hence X-rays are only emitted during positive half cycles. This principle is used in the design of portable equipment which needs to be kept as light as possible.

With more advanced equipment of higher output, separate rectifiers, usually now of the metal types, are used additionally.

The voltages which require to be applied to the tube are far in excess of those used in normal electronics work. In industrial usage they range from approximately 100,000 volts to several million volts. Much of the electron energy produces heat in the target material and to avoid melting it special cooling systems are needed, one of which makes use of oil circulation.

An average value of tube current is five milliamperes. Increasing the tube current by a factor of two means an increase in the radiation output also by a factor of two. As the tube voltages increase, the ability of the radiation to penetrate materials also increases.

Since the radiation is emitted from the target roughly in the form of a cone, its intensity is being continuously reduced, much in the manner that the optical radiation from a lamp is reduced with distance.

For those with a mathematical inclination, the inverse square law applies. If we go twice the distance from the target, the radiation level is approximately reduced to one quarter. When a radiographer is describing his technique for radiographing a metallic object, he quotes tube voltage, the tube current, the distance of the target to the film, the film-screen combination and the exposure time.

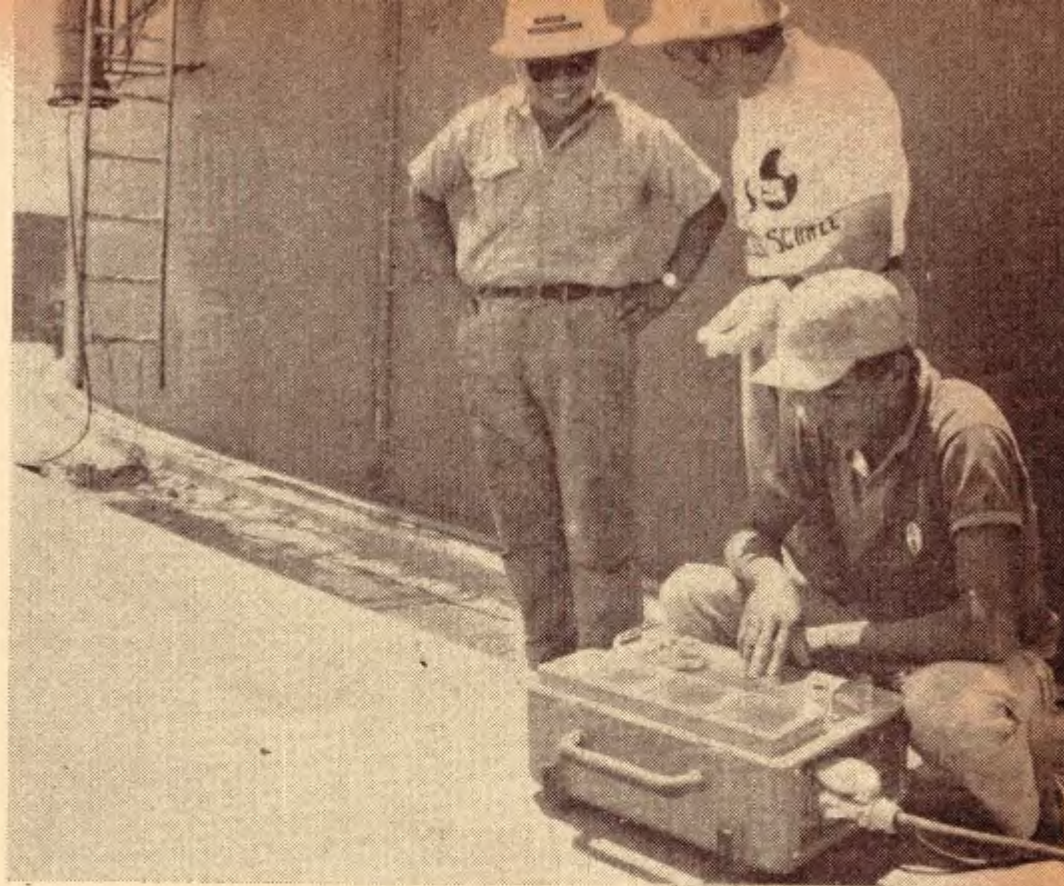
In industrial use a beam of radiation is passed through a metal plate which has been welded. The blackening of a film placed at the rear of the plate and then processed in a dark room will change where defects are present. The defects possibly include slag, lack of fusion and penetration, gas porosity or cracks.

## GAMMA RADIOGRAPHY

X-rays and gamma rays are entirely similar in their physical properties but they differ in origin.

Gamma rays are the invisible radiations given out spontaneously by certain substances. The output of radiation cannot be controlled by man. A substance can be melted, vapourised, dissolved in acid, but radiation emission still continues.

The relationship of gamma rays to X-rays may be likened to the relationship between the light emitted by the sun and that from say a sodium vapour dis-



*X-ray equipment is shown here being used to test a horizontal welded seam of an oil storage tank in North Africa*

charge lamp. On the one hand the light is emitted by a natural process and on the other it is made electronically. The laws of light, however, apply to both.

Gamma rays were first observed at the end of the 19th century. Their industrial use began between the first and second world wars, naturally occurring radium and its disintegration product radon gas being virtually the only sources of radiation available for radiography. Their radiation outputs were very small and long exposures were necessary when making radiographs.

## ARTIFICIAL GAMMA SOURCES

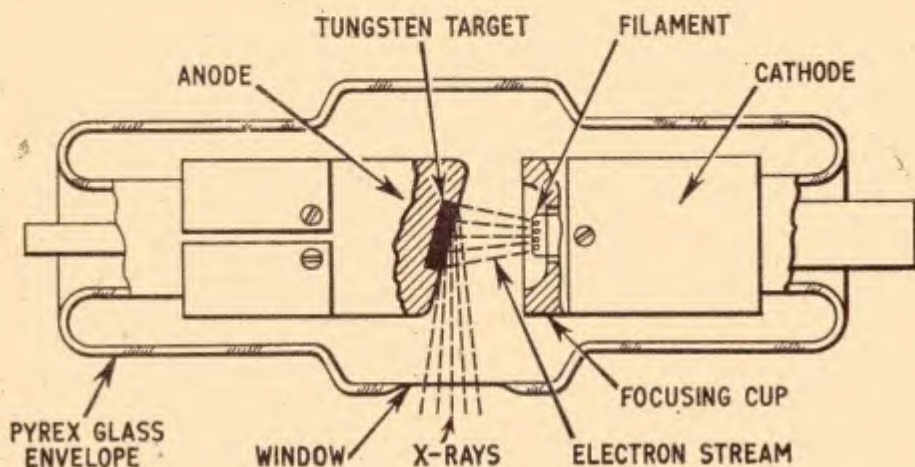
Following the second world war, when the peaceful uses of atomic energy were developed, the production of artificial sources in large quantities was initiated. Certain materials, when placed in a nuclear reactor become radioactive. The two most commonly used of this type of source are iridium 192 and cobalt 60. Sources having quite high radiation outputs are now available. These outputs, however, do not compare with that emitted from an X-ray tube and the popularity of their use depends on their extreme portability and their independence of a power supply.

Let us look at a typical application.

In the desert Kingdom of Libya in North Africa a progressive programme of oil gathering is being carried out to quench the world's increasing thirst and vast resources are being utilised to speed the work forward, and here gamma radiography is playing its part in the inspection of pipelines.

Either X-ray or Gamma ray sources can be used for the actual witnessing of a weld being made to ensure operators are up to standard. However, X-ray equipment, although technically superior, needs a power supply and this is sometimes difficult in desert regions. Therefore, gamma sources are the most practical and widely used under these conditions.

The gamma ray source used in Libya is of iridium 192, produced by the irradiation of natural iridium in a nuclear reactor. The source is in a small cylinder, 2mm diameter by 2mm long, and is ideal for giving



*Fig. 1. The general construction of an X-ray tube*



*Due to problems of accessibility it is customary to place both the film and the gamma source on the outside of the pipe diametrically opposite to each other as in this picture. Inset is the gamma source container*

good radiographic definition. It is supplied in a small protective capsule which is housed in a protective container which is also used for storage and field inspection. To set this container for exposure on main line operations, the container has only to be unlocked and an operating handle turned on.

Kodak Industrex Type "D" films are used, exposed in flexible light-proof cassettes between lead screens. All processing (i.e. developing, fixing and washing) is done in mobile darkrooms which move along with the job.

The exposure is made ideally with the source supported on the pipe centre line and the film positioned on the outside circumference of the weld.

Every 74 days the activity of a source of iridium 192 decreases to one half of its initial value and exposures are doubled. Because of this, sources are usually changed for new ones every ten weeks. Sometimes the old ones are sent to other pipelines where small diameters are being welded. New sources are flown from Britain in special containers and collected at the airport. At every stage of the journey strict safety precautions are taken.

### ULTRASONIC FLAW DETECTION

The fundamental principle of ultrasonic testing is that mechanical pulses of high frequency sound waves are transmitted into the specimen; when they reach a flaw or a boundary, the waves are thrown back as echoes to be detected by the same or a further crystal from which they emerged in the first instance.

The process is closely allied to radar, which also works with transmitted and reflected pulses.

The vibrations are set up in crystals which have the peculiar property of contracting and expanding along one axis in step with an alternating field of electrical voltage applied to an axis at right angles. The phenomenon is known as the inverse piezo electric effect. When a mechanical vibration is received by a crystal it makes the latter expand and contract along one axis and an alternating electric voltage will be set up along an axis at right angles.

The mode of application is to feed the electrical voltage to the crystal which transmits the resulting mechanical pulse to the specimen undergoing examination. The voltage is simultaneously applied to two plates of a cathode ray tube and therefore produces a peak in the trace on the fluorescent screen. The voltage which the returning echo produces in the crystal is also fed to the cathode ray tube and produces another peak in the trace.

The speed of the time base is known and if the speed of sound in the material of the specimen is known, the distance between the two peaks on the screen is an exact measure of the distance of the reflecting surface, i.e. the flaw or the back wall of the specimen, from the crystal. Better still, the screen of the c.r.t. can be provided with a scale from which the distance of flaw or back wall can be directly read.

### ULTRASONICS AND X-RAYS

Thus the ultrasonic method can detect very rapidly the presence of a flaw and give its depth below the surface. And it can do this at a distance of many feet from the crystal. What it cannot do quite so readily is to give an accurate indication of shape of the flaw.

X-rays, on the other hand, can give an accurate picture of a flaw, but they cannot penetrate more than some 4in to 6in of steel and they may only show up a flaw if their direction coincides with the plane of the flaw. When the latter is at right angles to the ray direction, and if it is a relatively thin crack, it will not show up.

Thus a negative finding by X-rays cannot imply the absence of a crack until it is supported by another negative finding at right angles. But this is an expensive process and it becomes particularly so when long lengths of welded seam or miles of railway line have to be examined.

This is where the ultrasonic method is of such great importance to save both time and money. It can be used to "beam" the specimen from more than one direction and thus to give a clean bill when no flaw echoes are found. But when such echoes do appear, X-radiography can be called in, if required, to produce a pictorial record of the shape of the defect.

Moreover, the ultrasonic beam will have shown in which direction the rays must pass through the specimen so that considerable economy in both time and money is effected.

The range of flaws and the types of specimen which can be examined are very great indeed. Thus the most common are cracks, slag inclusions, insufficient bonding, etc. in weld seams. Such seams may be in oil or gas pipelines, in the welded plates of oil tankers, in welded girders of bridges, for example.

Next perhaps in order come railway lines, where cracks from bolt holes and fissures in top and web can be detected. Axles of railway rolling stock are very suitable test objects, especially when cracks are suspected under the inaccessible wheel seating. A most useful application is the unilateral measurement of wall thicknesses of pipes to investigate the effects of corrosion, and lamination in sheet stock from rolling mills provides another fruitful field for test.

### CATHODIC PROTECTION

When a pipeline is buried in the ground it is essential that it be protected from the corrosive elements of the soil. To this end the outside of the pipe is coated with a bituminous material, either coal, tar, or petroleum products.

In addition the metal of the pipe is electrically maintained at a negative potential with respect to the surrounding soil. This corrosive preventive system is known as *cathodic protection*.

A major step forward in cathodic protection has been achieved at Blyth "B" Power Station, Northumberland, where new equipment giving even and positive distribution of current has been installed on two 350MW turbo-generators for the first time on a commercial basis.

The system involved using, in the main condenser end-boxes, copper cored platinised titanium anodes surrounded by a polypropylene mesh sheath.

These anodes are clipped direct to the cathode surfaces to give an even distribution of current over the areas where corrosion is most likely to occur. Mainly this is where the bimetallic couple exists between the cast iron of the end-box cover and the rolled naval brass tube plate.

The anode material is formed in three lengths to make a ring of anode displaced 18in from the tube plate. Titanium fittings form the electrical connection between the anode material on the inside of the box and the cable to the power unit on the outside.

The d.c. power unit comprises a transformer rectifier unit supplying current to 26 anode circuits. Each circuit is individually controlled and monitored.

*One of the most popular methods of non-destructive testing is ultrasonics. Here a small transistorised battery operated model is being used on a pipeline carrying gas*

Monitoring the effectiveness of the cathodic protection installation within the end-boxes is accomplished by means of copper/copper sulphate half-cells which are monitored from the control box. Results of adjustment to an anode or group of anodes in any one end-box are indicated by a change in the reading of these half-cells.

### HOLIDAY DETECTION

If a pipe coating is defective in places, the supply of current to maintain the necessary pipe-to-soil potential increases considerably. To prevent this the coating is inspected by a small portable high voltage instrument called a *holiday detector*. This is an American term and has no other significance than simply that the personnel responsible for applying the coating must have "taken a holiday" when voids or cracks in the coating occur.

The pipe is inspected before being lowered into the ditch. First of all the pipe is connected to earth. The detector has a trailing lead also in contact with the ground. A high voltage electrode connected to the instrument is then applied to the surface of the pipe. Where the coating is defective, a spark passes and the point of sparking can usually be recognised. Additionally, a warning bell may be incorporated.

The high voltage required, of the order of 15,000 volts, is produced by a transformer, the primary of which may be energised either by a vibrator or by an oscillatory circuit which in the latest models is transistorised.

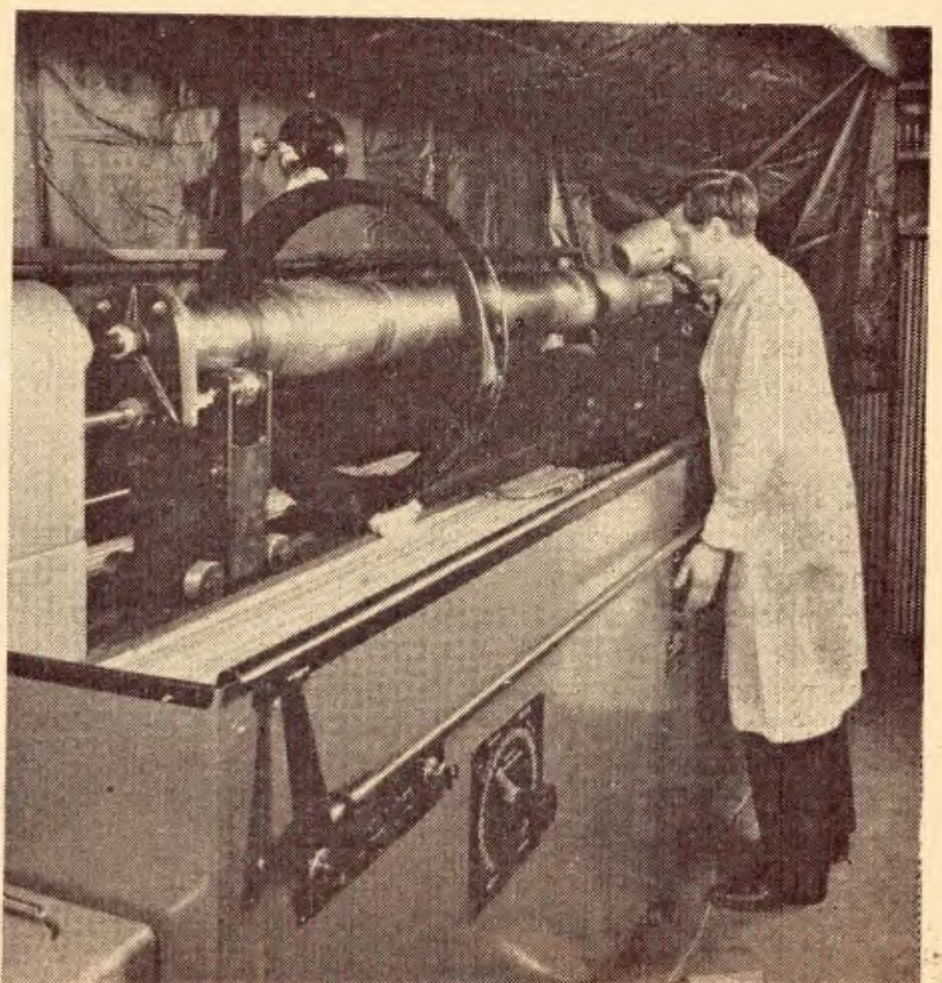
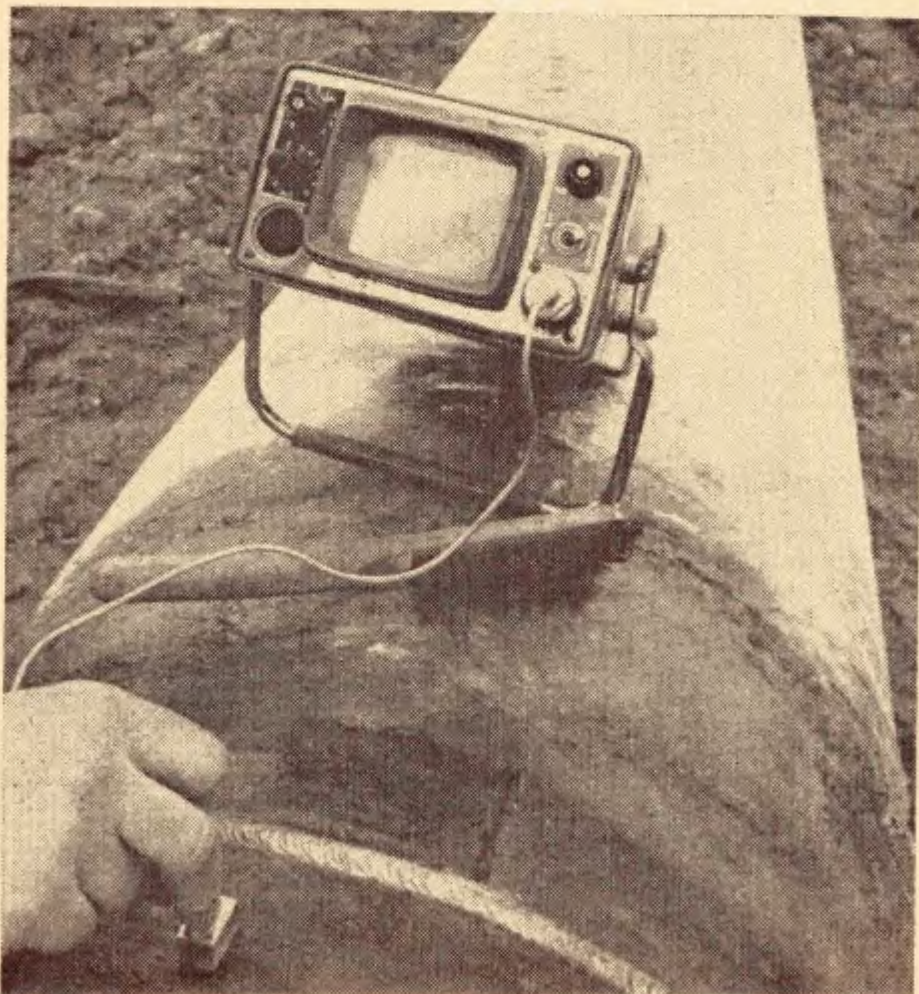
It is of course essential not to apply too high a voltage to the coating or ordinary dielectric breakdown may occur. This operation is shown in our heading photograph.

### MAGNETIC PARTICLE INSPECTION

One of the most successful methods of detecting surface defects in ferro-magnetic materials is *magnetic particle inspection*.

When an object consisting of such material is magnetised it will contain the magnetic field so long as there is no crack or other defect in the way. If a defect is

*London Transport's tube train axles are tested regularly for minute cracks invisible to the naked eye. This equipment uses the principle of magnetism*



present, the magnetic field will stray into space as shown in Fig. 2. Small particles of magnetic material such as iron dust, or iron oxide, if scattered on the surface will be attracted by the stray field and so show up the crack.

The magnetic field may be set up by passing electric current through a cable wound round the object as in Fig. 3 or by passing the current through the object as in Fig. 4. The magnetic field is always at right angles to the electric current and therefore there is so-called longitudinal magnetisation in Fig. 3 and transverse or cylindrical magnetisation in Fig. 4. In order that the defect may be clearly shown up the field must be at right angles. Therefore transverse cracks are revealed by a longitudinal field, whilst a cylindrical field finds the defects which are parallel to the flow of electric current.

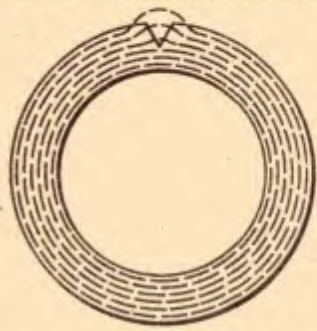


Fig. 2. Magnetic field straying round crack

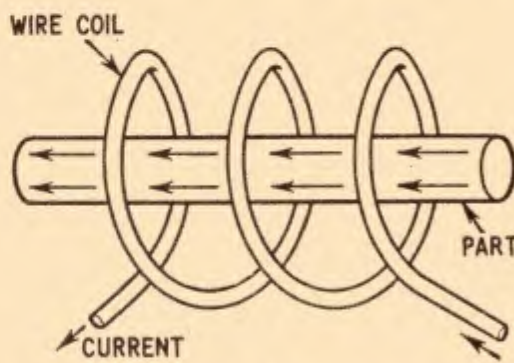


Fig. 3. Longitudinal magnetism

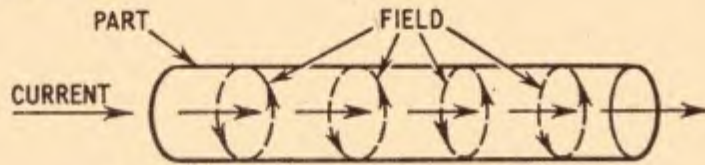


Fig. 4. Transverse magnetisation

To assist operators in the field, many types of magnetic crack-detection units ranging in current-carrying capacity from 750 amperes to 4,000 amperes—but at very low voltage—have been developed.

For such work, the magnetic particles are applied either as a dry powder or in suspension in a suitable volatile liquid which evaporates quickly. Sometimes the surface of the object is covered with a white paint coating to act as a background against which the particles are more clearly visible. And sometimes the particles are coloured red or grey or black, according to circumstances, to be more clearly visible.

For the examination of finished components such as gear wheels, turbine shafts, etc., a special ink has been produced which fluoresces when exposed to ultra-violet light. This produces a maximum contrast between the ink and the background and therefore helps greatly towards detection of defects.

Special coloured powders and water-based magnetic particle solutions have been developed for use on special structures, notably nuclear reactors, where any contamination of the surface with oil must be carefully avoided.

#### DYE PENETRANT CRACK DETECTION

Finally, mention must be made of the dye penetrant method of crack detection.

This method of non-destructive testing uses a highly penetrant oil in which is incorporated either a visible or fluorescent dye material. The penetrant soaks into any surface defects and after surplus dye on the surface has been washed away, the penetrant can be induced to come to the surface where it can be readily seen by the use of light or fluorescent radiation. ★



LET THIS

BLUEPRINT

HELP YOU TO

DETECT

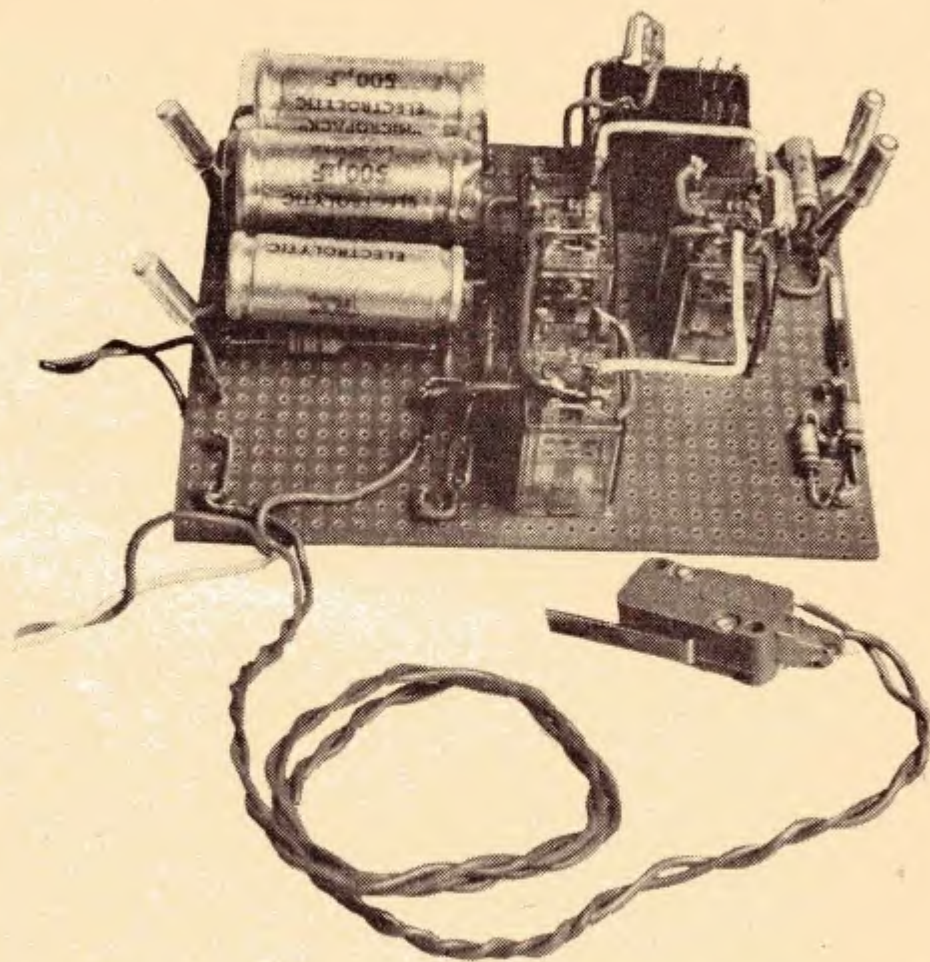
THAT UNWANTED

VISITOR

ONE of this month's blueprint articles shows how an unwanted visitor, on coming through the garden gate, can be detected by a discrete and remote form of alarm. Furthermore, the circuit will discriminate "fairly" successfully between genuine visitors and intruders. The word "fairly" is used because certain human shortcomings are inevitable; for example, if the children know about the device they may take great delight in opening the gate just to sound the alarm. If children are playing in the garden and decide to go for a stroll down the road then there is a 50 per cent chance of them opening the gate and consequently setting off the alarm. Readers may have ideas which will set off the alarm if entry or exit is made by unconventional means, i.e. other than through the gate.

The system consists basically of three interlocked timing circuits, the operation being as follows. A microswitch is fitted to the front gate, its contacts being arranged to close when the gate is opened. A few seconds after the gate is opened, provided the front door bell push is not operated, an audible warning sounds until the gate is shut. In the case where the gate is opened and immediately shut again, after the initial delay the warning will sound for a period of about 10 to 13 seconds. If after the gate is opened the front door bell push is operated the gate warning system is inhibited. In the prototype a repeating door chime system operates. If the gate is left open and the bell push is pressed, the warning system remains inhibited until either one and a half minutes have elapsed or the gate is shut.

Therefore no one can enter the garden by the gate without sounding a warning but the annoyance of continually sounding warnings is eliminated.



transistor conducts, relay RLB energises and contact RLB1 closes to maintain the negative supply to relays RLA and RLB, should S2 open, i.e. if the gate is closed. When the capacitor C3 is charged (about two seconds after S2 closed) it effectively opens the positive side of relay RLA which de-energises. Contact RLA1 changes over to operate the gate warning buzzer and disconnects the base of TR2 and capacitor C4 from the negative supply. Relay RLB remains energised, however, as capacitor C4 discharges across the base

# INTRUDER ALARM

by **B. CRANK**

## CIRCUIT

The circuit is shown in Fig. 1 on the blueprint. For the sake of clarity the multivibrator used in the circuit is shown as a box, the full multivibrator circuit being shown in Fig. 2. The detached method of relay presentation is used, i.e. the box with RLA/2 in it is relay RLA which has two sets of contacts, RLA1 and RLA2.

The multivibrator operates at very low frequency causing relay RLD to pulsate, the contacts RLD1 switch the supply to the chiming unit causing this to sound "ding-dong ding-dong" for as long as the supply is applied to the multivibrator.

The gate microswitch is S2 in the circuit diagram, when this is closed, i.e. gate open, relay RLA is energised via S2 and contact RLC1 as capacitor C3 charges. Contact RLA1 changes over and capacitor C4 charges to the full negative supply voltage. The base and collector of TR2 are now at a negative potential so the

emitter junction of TR2 via R5. As C4 discharges the collector current of TR2 falls until relay RLB de-energises, this happens about 15 seconds after the gate was opened. Contact RLB1 opens and provided the gate is shut the supply to the buzzer is broken, if the gate is open this supply is maintained by S2, although the buzzer would cease to operate as soon as the gate was shut.

The previous description covered the events that take place if the gate was opened by someone who did not press the bell push, i.e. as far as the unit is concerned an illegitimate visitor.

If after the gate is opened the bell push S1 is operated the diodes D2, D3 and D4 are forward biased, D2 conducts and the multivibrator commences to operate the chimes, capacitor C1 charges to the full negative supply via the limiting resistor R1. Diode D1 suppresses the build up of high voltages capable of



damaging the transistor TR4. D3 and D4 conduct bringing the base and collector of TR1 to a negative potential. Capacitor C2 charges up via the limiting resistor R2 and relay RLC energises. Contacts RLC1 change over disconnecting the gate warning circuit from the negative supply. When the bell push S1 is released the diodes D2, D3 and D4 become reverse biased, the chimes operate for a further two or three cycles as capacitor C1 discharges across the multivibrator, the diodes D2, D3 and D4 are now reverse biased and prevent the various circuits from interfering with each other. If the gate was open when S1 was released then the negative supply to relay RLC and TR1 is maintained via S2 and contact RLC1. Therefore relay RLC remains energised for about 12 seconds after the bell push was released as capacitor C2 discharges across the base emitter junction of TR1 via R3, the gate warning circuit remaining switched out. If during the period that capacitor C2 is discharging the gate is closed then the hold on supply to relay RLC is broken as S2 opens; relay RLC de-energises and contact RLC1 changes over so that the gate warning system is ready to operate the next time the gate is opened. In the case where the gate was left open after the bell push was pressed then relay RLC remains energised until capacitor C2 has discharged, when this happens contact RLC1 changes over to sound the buzzer after the usual delay, the buzzer would then sound until the gate was shut.

The resistor R8 is switched in by contacts RLA2 to discharge capacitor C3 ready for its next operation. The value of this resistor must be chosen to suit the relay used. It should be as small as possible but must not be so small that it prevents RLA de-energising when capacitor C3 has charged up, or so large that it prevents it operating. In the prototype the value used was 2.7 kilohms. The value of R6 should be chosen to give the required voltage drop from 18V to the rating of the buzzer.

## CONSTRUCTION AND COMPONENTS

The relays employed in the prototype were high speed relays with 700 ohm coils. RLD was a relay with heavy-duty contacts capable of carrying the chime unit current. The relays used must be capable of being operated by the supply voltage of 18 volts.

The purpose of the initial two second delay is to give the caller time to operate the bell push before the buzzer sounds. This is sufficiently high for many cases, but some constructors will require a longer delay. This can easily be obtained by using a higher resistance relay for RLA, or by increasing the value of C3. Similarly the other timing circuits can be altered at will by choosing different values for capacitor C2 and R3 or capacitor C4 and R5. The values for C3 and R4 are best found by experiment to suit the relay used.

All the diodes employed were general purpose types. It is essential to use the limiting resistors R1 and R2 as these protect the diodes from the initial surge of the capacitors during charging.

All the capacitors used should be 25 volt working or more. The chimes and relay circuits should use separate batteries. It is a good idea to fit an on/off switch in the 18 volt negative line.

Layout is not important and must be chosen to suit the components used but it should be neat and tidy. A suggested layout and wiring are shown in Figs. 3 and 4 on the blueprint.

## TESTING THE UNIT

After completion the wiring of the unit should be given a thorough check before the batteries are connected. Connect a bell push and a switch to act as the gate microswitch to the unit. Connect the batteries, care being taken to ensure correct polarity.

(1) Operate the gate switch on and off; after the chosen delay the buzzer should sound for about 13 seconds and then cease.

(2) Allow a few seconds for capacitor C3 to discharge. Operate the gate switch on and off and press the bell push. The buzzer should not sound. The chimes should operate and continue to operate two or three times after the bell push is released.

(3) Immediately repeat item (1).

(4) Switch on the gate switch and leave it on. Press the bell push; the chimes should operate as before. After about one and a half minutes a click should be heard as relay RLC de-energises and relays RLA and RLB energise. After the chosen few seconds' time delay the buzzer should sound until the gate switch is opened. The buzzer will remain on for about 13 seconds whilst relay RLB is energised.

If the unit fails any of the tests outlined above locate and cure the trouble before proceeding to the next stage of testing.

## MODIFICATIONS

If wished the buzzer may be omitted and the chimes arranged to run at two different speeds, fast for the gate and slow for the bell push. The necessary alterations are shown in Fig. 5. It will be seen that the buzzer is replaced by a relay RLE and one side of contact RLA1 is taken to the multivibrator negative line at Y via the diode D5. The multivibrator capacitor C6 is replaced by two capacitors, C6a and C6b. C6b is kept in circuit by the normally closed contact RLE1. Operation is simple, when the gate warning system is operated and when contact RLA1 is in its de-energised state, the multivibrator receives its negative supply from contact RLA1 and the chimes operate. Relay RLE is energised and contact RLE1 opens making the total capacitance of C6 lower so that the chimes run faster. When the chimes are operated from the bell push, RLE remains de-energised (RLC energised) and the chimes run at their normal rate. D5 prevents interaction between the various circuits. The chiming circuit can be replaced by a bell. With reference to Fig. 1 on the blueprint, omit all of the components to the left of diode D2, including D2, R1, C1, multivibrator, D1, and relay RLD. Connect the bell from one side of bell push to earth. Operation of the unit remains unaltered. ★

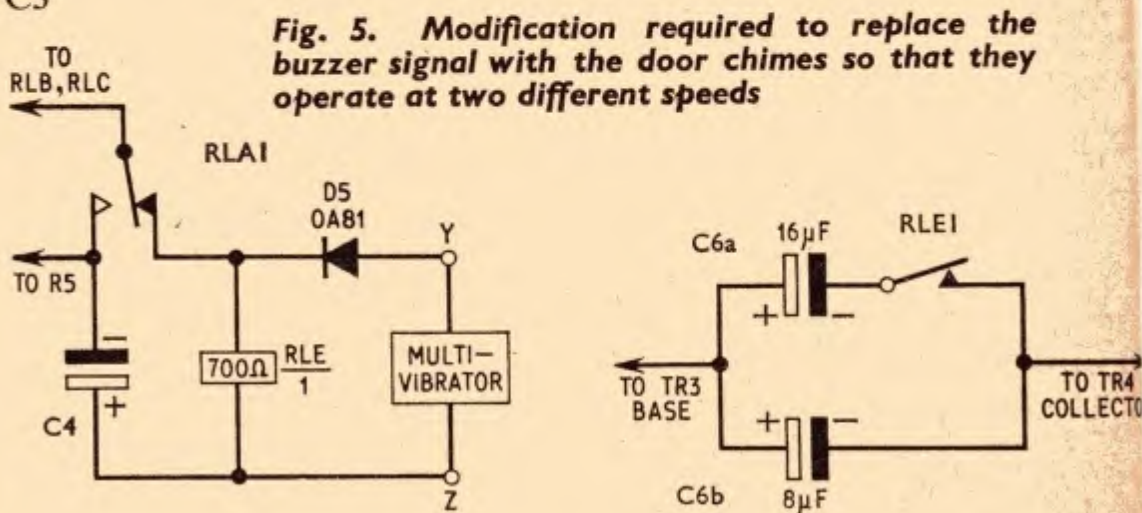
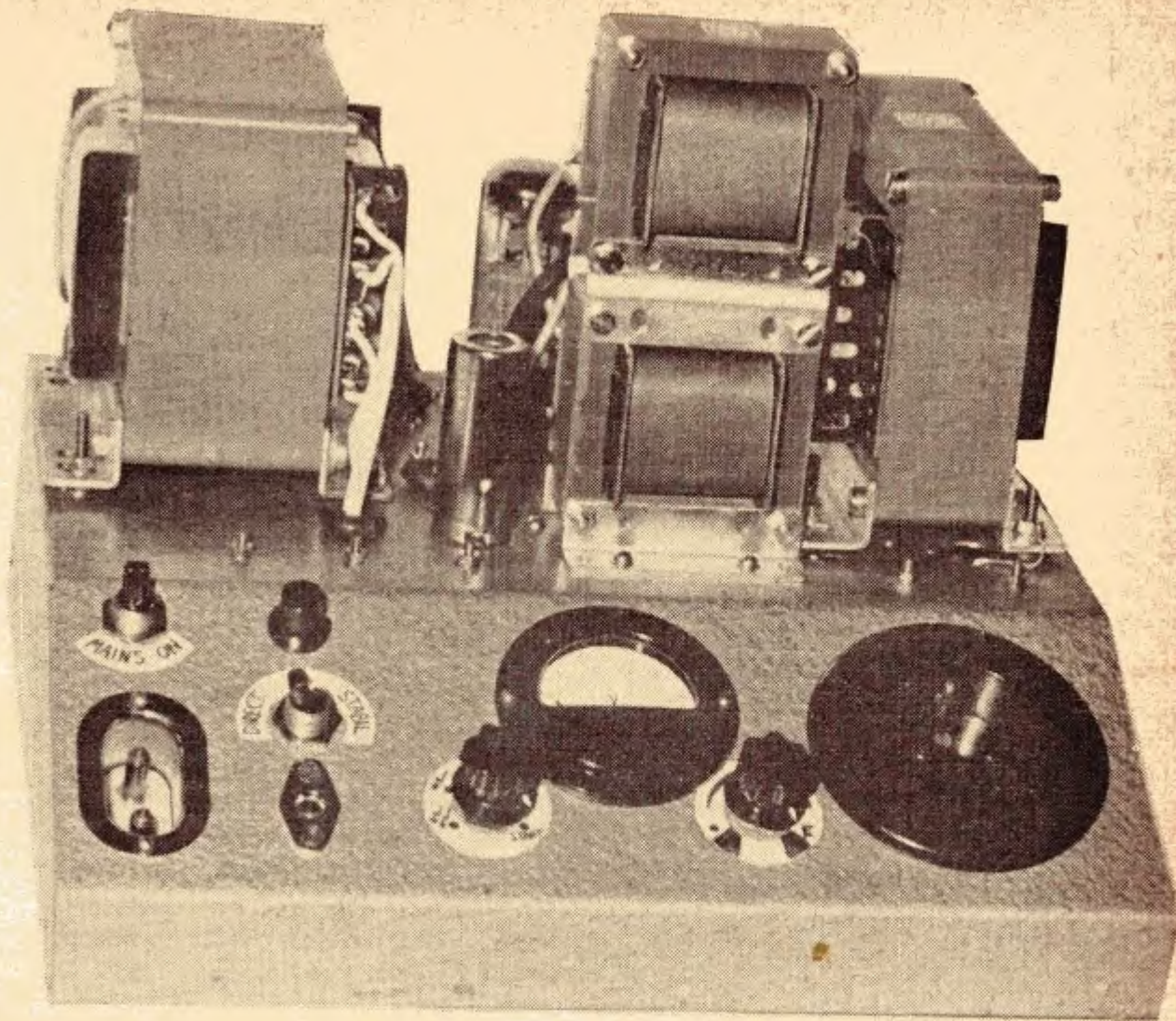


Fig. 5. Modification required to replace the buzzer signal with the door chimes so that they operate at two different speeds

A practical discussion of the principles and requirements of voltage stabilising systems, leading to a specific and versatile a.c. mains voltage stabiliser unit capable of loading up to 250 watts.

By M. L. Michaelis, M.A.



## A.C. MAINS VOLTAGE STABILISER

ANY DEVICE which is to function as a voltage stabiliser is always required to fulfil one or both of two basic functions. Firstly, it is called upon to keep the output voltage applied across the consumer load constant in the face of fluctuations of the input voltage. Secondly, it is also often required to keep the voltage applied across the consumer load connected to its output constant over a wide range of resistances, i.e. power drains, of that load.

This second requirement may be summed up by the stipulation that the output impedance of a high class stabiliser must approach zero, so that the regulation is, ideally, infinitely good.

It is at this stage not yet necessary to distinguish between stabilisers for a.c. and d.c. voltage outputs respectively; these introductory remarks apply quite generally.

There are, however, two classes of stabiliser systems which must be distinguished at once.

### STABILISERS AND REGULATORS

Fig. 1a shows a primary stabiliser in the strict sense of the word. The input voltage subject to fluctuation is applied via a suitable resistor to some component which functions as an *inherent* constant voltage device, i.e. which produces a more or less fixed voltage drop across itself, largely independent of the current flowing through it within the intended operating range. It is clear that any fluctuations of the input voltage will therewith appear entirely across the series resistor and will therefore no longer be felt at the consumer load connected in parallel with the stabiliser component.

Some simple constant voltage devices are shown in Fig. 2. These basic arrangements are discussed later.

Fig. 1b shows the type of stabiliser circuit which should, more correctly, be called a *regulator* circuit. In a way, this arrangement is a further development of Fig. 1a, for it makes use of a stabiliser circuit of the same type in the section labelled "fixed reference

voltage". This primarily stabilised fixed reference voltage is now not used to deliver the output power to the consumer load, but is merely used for purposes of comparison with a sample of the output voltage actually applied to the consumer load.

This comparison takes place at negligible power drain in the comparator, which delivers an output voltage proportional to the detected error, i.e. to the discrepancy between the actual output voltage and its intended value.

The input voltage subject to fluctuation is fed straight through to the stabilised output via a regulator device which, whatever its detailed nature, always functions as a variable resistor which, through appropriate adjustment following every fluctuation of the output voltage, keeps the output voltage constant.

The detected error voltage is amplified any required amount in the error amplifier, whose large output is then employed for rigid and immediate automatic control of the instantaneous effective resistance of the main regulator device.

### POWER RATING

A *regulator* after the fashion of Fig. 1b is always greatly superior in performance to a simple stabiliser of the type sketched in Fig. 1a, for several reasons.

The available output power from a constant voltage device is generally severely limited and equal to the maximum permissible power dissipation of the device itself, obtained when the power drawn by the output load approaches zero.

It is not in general possible to operate such constant voltage devices in parallel to obtain more total available power, at least not for the common neon tubes and Zener diodes falling in this class. This is because slight inevitable differences of characteristics lead to gross inequality of current sharing, unless individual series resistors are included which, however, cause serious deterioration of the degree of stabilisation.

In the case of regulators, any number of similar regulator devices may be connected in parallel in the main branch to obtain any desired output power rating. Moreover, since such regulator devices generally employ valves, power transistors or saturable reactors, all of which are readily available in high power ratings, even a single suitably chosen item can here lead to very high power rating.

### ERROR AMPLIFIER

The second aspect of the superiority of a regulator compared to a stabiliser lies in the error amplifier. Apart from surmountable problems of gain and phase stability of the system, this amplifier can readily be given a very high gain, so that even *minute* discrepancies of the output voltage of the regulator produce enormous correcting control voltages applied to the regulator device. In other words, the output voltage regulation can be made extremely rigid in such systems.

Since the actual output voltage is sensed and compared with a fixed reference voltage, it is immaterial for what reason the output voltage would have changed in the absence of the regulation. In other words, this type of system inherently stabilises the output voltage both against input voltage fluctuations and in the face of output load fluctuations or deliberate load changes.

The stabilisers of the type shown in Fig. 1a are quite good in the face of fluctuating input voltage with constant or negligible output load—they are therefore eminently suitable for constituting the fixed reference voltage of a regulator system according to Fig. 1b—but their degree of stabilisation is generally inferior in the face of fluctuations of output load, i.e. their output impedance is appreciable and consequently their regulation relatively poor.

### STABILITY CONSIDERATIONS

Apart from the obvious requirement of constant output voltage in the face of input voltage and loading fluctuations as the primary function of any stabiliser system (we shall now continue to employ the more familiar term "stabilisers" for all systems, including regulators), there are a number of other demands imposed upon such equipments, according to the particular application.

In the case of a d.c. voltage stabiliser, matters are generally simple, since the additional problems of potential instability so acute in a.c. voltage stabiliser systems are here seldom manifest to the same degree.

### PHASE SHIFT

The basic reason for this difference lies in the fact that the output of an a.c. stabiliser generally has to be rectified and smoothed for comparison with the fixed reference voltage, which leads to a phase shift in the control loop. The error amplifier may need damping, which is a source of a second phase shift within the control loop. Thirdly, the regulator device itself in an a.c. system can lead to a further phase shift.

The total phase shift may be 180 degrees with respect to the desired negative feedback of the regulating action at some frequency (generally very low, only a few c/s or a fraction of a c/s) considered as being injected into the loop. If the loop gain exceeds unity at this frequency, then oscillation will generally take place and the circuit will "hunt".

The number of sources of unwanted phase shift in a d.c. system is less, since no rectification and smoothing of comparison signals is necessary and the regulator device itself is normally a valve or transistor (Fig. 4) free of phase shift. The damping capacitor can lead to a theoretical maximum phase shift of 90 degrees, insufficient to produce instability.

### TIME DELAY

Another way of looking at this question of phase shift in relation to measures to prevent hunting is to consider the time delay between the appearance of a supposed error in the output voltage and completed correction thereof on the part of the series regulator device.

This time delay consists of two individual intervals; (a) the response time of the comparator, and (b) the response time of the series regulator device. Both are negligible in a d.c. system of the kind shown in Fig. 4. However, both can be appreciated in an a.c. system.

The response time of the comparator is appreciable because of the need for rectification and smoothing to obtain a sample of the output voltage for comparison with the reference voltage. The response time of the

Fig. 1a (right). A basic voltage stabiliser

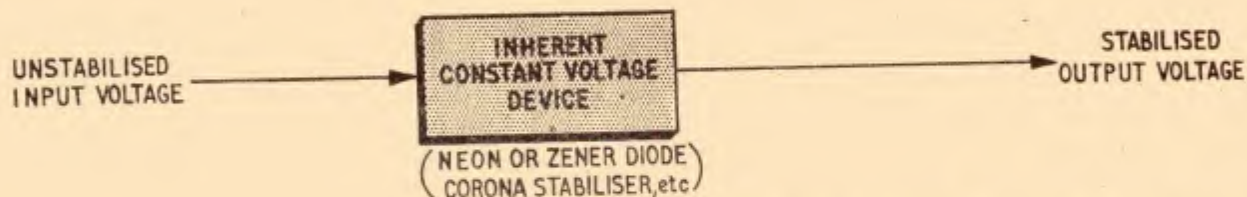
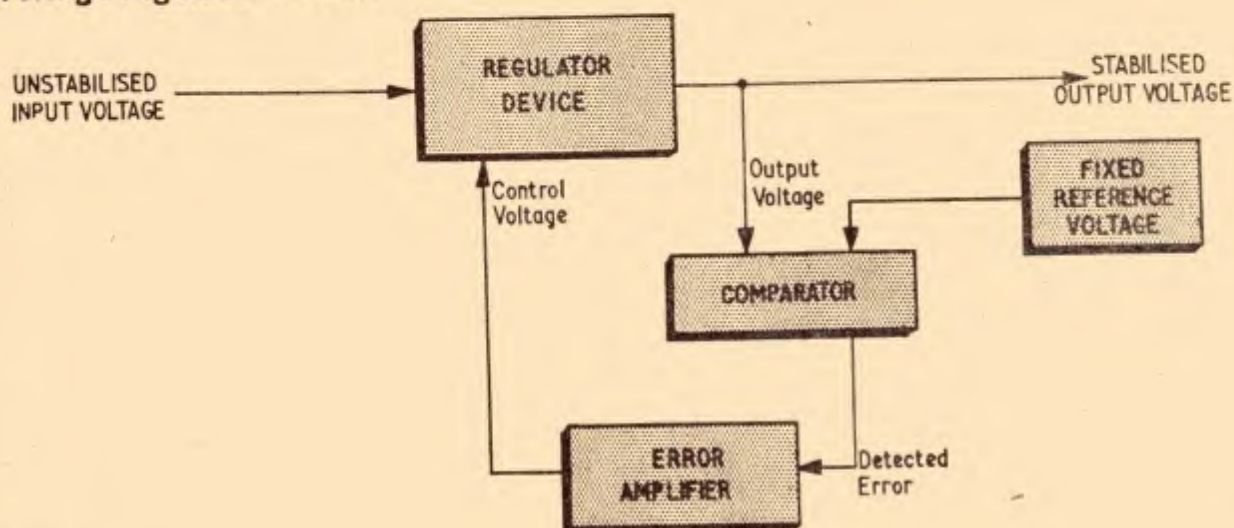


Fig. 1b (below). A basic voltage regulator circuit



series regulator device can also be appreciable in an a.c. system if the detailed structure again requires rectification or employs inductive circuitry, as is usually the case.

The system is, in general, particularly prone to instability and consequent hunting if the response of the series regulator device is much slower than that of the comparator. This is because the comparator and error amplifier will automatically react under such circumstances to supply an unduly large control

signal to the sluggish series regulator so that, when the latter finally does respond, the output voltage of the equipment is left with a new error of opposite sense to the original one. The whole process is then repeated in the other direction, in an attempt to correct this new error.

It is easily seen that the circuit therewith hunts back and forth, settling down after many successively smaller oscillations, or oscillating continuously, as the case may be.

The opposite case, where the comparator is much slower than the series regulator device, improves the stability of the whole circuit, since overshoot of the regulation is then obviously impossible. But this state of affairs brings a new disadvantage, namely that the time required to correct an error in the output voltage is appreciable.

The correct design compromise to aim at in a practical circuit is to make the series regulator device operate as fast as possible with due regard to other requirements, and then to choose the rectification and smoothing time constant for the output voltage sample such as to make the comparator slightly slower than the series regulator. Careful attention to these points can make a practical circuit dead-beat over its intended range of operating voltages and loads.

## OUTPUT WAVEFORM

An important further consideration in the design of a.c. voltage stabilisers is the question of output waveform of the system, and the decision, in case the output waveform cannot be held constant over the entire working range, whether the peak or the r.m.s. output voltage is to be stabilised by the system. Such questions do not arise for d.c. voltage stabilisers and they therefore represent an additional factor complicating the design of a.c. voltage stabilisers.

## SATURABLE REACTORS

It should naturally be the aim of a good a.c. voltage stabiliser to maintain the output waveform constant and as accurately a sine wave as possible. This can be difficult to achieve, since it is tantamount to the requirement that the series regulator device—usually a saturable reactor—should strictly obey Ohm's law over the entire working range, which can obviously only be true in a limited sense in actual practice on account of the impedance variation due to saturation by the current.

The very function of such variable reactors is thus opposed to Ohm's law which states that the resistance (ratio of voltage to current) must be independent of the current itself!

A number of tricks aiming to introduce mutually compensatory waveform distortions are thus required in any practical circuit with good output waveform. The only alternative would be to use saturable inductors with really massive cores, so that the d.c. control current used in the primary for variable saturation of the core is such as to produce a very much greater magnetic flux than the controlled a.c. current in the secondary, so that the latter always swings on a small incremental part of the magnetic characteristic which is approximately linear at all saturation levels.

This manner of approach is uneconomical, both in the size of components in relation to the controlled power and on account of the large d.c. control power required from the error amplifier system.

## WAVEFORM REQUIREMENTS

Since the nature of any waveform distortion is very often such as to accentuate the peaks and suppress the lower part of the input sine wave, i.e. to make the output voltage dwell unduly long at low values during each half-cycle, rising to only a brief peak, stabilisation onto the peak voltage would mean that the r.m.s. output voltage gradually drops as the output current loading is increased and the waveform distortion thereby causes progressively greater departure from a sine wave.

Consumer devices dependent upon constant r.m.s. voltage (lamps, valve heaters) would thus run progressively dimmer the greater the total loading connected to the output of the stabiliser, even though a moving coil meter, connected to the peak rectifier supplying the output voltage sample to the peak voltage comparator, indicates an absolutely constant output voltage.

If the output voltage sample rectifier is designed to give a d.c. voltage proportional to the r.m.s. level of the a.c. output voltage, the peak voltage is left free to "run away". This can lead to serious endangerment of the apparatus connected as load to the output of such a stabiliser unit, quite apart from the considerable difficulty of designing a sample rectifier giving a d.c. output strictly proportional to the r.m.s. level of an arbitrary input waveform.

## OVERLOAD DANGERS

If such a stabiliser is overloaded (partial short circuit in one of the consumer units connected, or inadvertent connection of too many consumer units), when waveform distortion will be aggravated, the actual peak voltage can reach tremendous values, several times the stabilised r.m.s. level of the highly distorted waveform. This can lead to insulation breakdown in the mains transformers or other components in electronic equipment being fed from such a supply.

Furthermore, electronic equipment frequently makes use of low loading peak rectifiers to establish e.h.t. voltages for c.r.t.'s or Geiger counter tubes, etc.

For example, peak rectification of 250V r.m.s. sine wave a.c. from a transformer winding, in a voltage doubler circuit, establishes about 700V. If the equipment is being fed from an r.m.s. stabilised supply with distorted waveform showing excessive peaks, the e.h.t. peak rectifiers will obviously develop excessive voltages much greater than those normally arising on a sine wave mains input. This can destroy the equipment being operated.

## SWITCHING SURGE

Even if the loading and distortion are not excessive during normal operation, one must consider the effects of the switching surge when a further piece of electronic equipment is switched on in addition to those already running off the stabilised supply.

When all the valve heaters and the h.t. and e.h.t. reservoir capacitors are cold and discharged, upon first switching such an item of equipment into circuit, the initial current surge can be up to ten times normal values, which will temporarily overload the stabiliser. The transient output waveform distortion will then produce transient excessive voltages in all sections of other equipments employing peak rectification, which can lead to flashover and breakdown.

This discussion has made it quite clear that r.m.s. rectification in the establishment of the sample output voltage for the comparator in an a.c. stabiliser system

may lead to highly dangerous conditions, so that peak rectification is here demanded for reasons of safety.

This is also fortunate, too, from design considerations, since any rectifier with reservoir capacitor acts as peak rectifier on a virtually arbitrary waveform, whereas a rectifier with r.m.s. response to an arbitrary waveform is difficult to realise (special square law diode followed by suitable RC integrator or miller integrator amplifier).

Even the principal h.t. rectifiers in the average piece of electronic equipment tend to develop d.c. voltages above the r.m.s. a.c. voltage of the h.t. winding on the mains transformer.

When such equipment is operated off an a.c. mains stabiliser without peak voltage stabilisation, the h.t. voltages will be abnormal, usually unduly high. This is generally far more serious than the slight drop of r.m.s. heater voltage in the equipment if peak stabilisation is used, and slight waveform distortion should arise.

### TRANSISTORISED CONVERTERS

The practical design described later in this article has been trimmed to satisfy these four requirements.

In passing, a word with regard to the transistor converters now becoming increasingly popular for deriving a 50c/s voltage supply from a car battery, for operating normal mains equipment in the field.

Many such converters deliver a pure square wave output, this being most economical to achieve with a simple transistor oscillator and power amplifier.

Peak and r.m.s. levels on a square wave are identical, so that the peak level of the square wave must equal the r.m.s. voltage of the mains sine wave for correct operation of the valve heaters on either power source. This could mean that the h.t. voltage developed on the square wave supply will be lower than on a mains sine wave supply.

Equipment employing peak rectification to derive an internal e.h.t. voltage will not function off the transistor converter supply, since insufficient e.h.t. voltage will be developed. Thus, whilst radios, amplifiers, tape recorders, etc., will normally operate more or less correctly, oscilloscopes and much other more refined electronic equipment may give trouble. For this reason, transistor converter models are now appearing with an approximate sine wave output.

### SIMPLE STABILISERS USING INHERENT CONSTANT VOLTAGE DEVICES

Having now completed the general discussion essential for proper comprehension of the basic requirements of voltage stabiliser systems, we can proceed to discuss various specific circuit designs leading up to a fully developed a.c. voltage stabiliser as constructional topic for this article.

Fig. 2 shows four practical versions of the type of voltage stabiliser using an inherent constant voltage device (Fig. 1a). The diagrams Fig. 2a and Fig. 2b show arrangements for stabilising a d.c. voltage; Fig. 2c and Fig. 2d show the respectively equivalent circuits for stabilising an a.c. voltage.

In the latter two circuits, the stabilised a.c. output voltage is always a square wave. It is not possible to obtain a stabilised sine wave with such simple arrangements.

In all four circuits, the resistor R should be chosen such that the maximum encountered input voltage just leads to the maximum current through the constant voltage device as specified by the makers, in the absence of any load connected across the stabilised output.

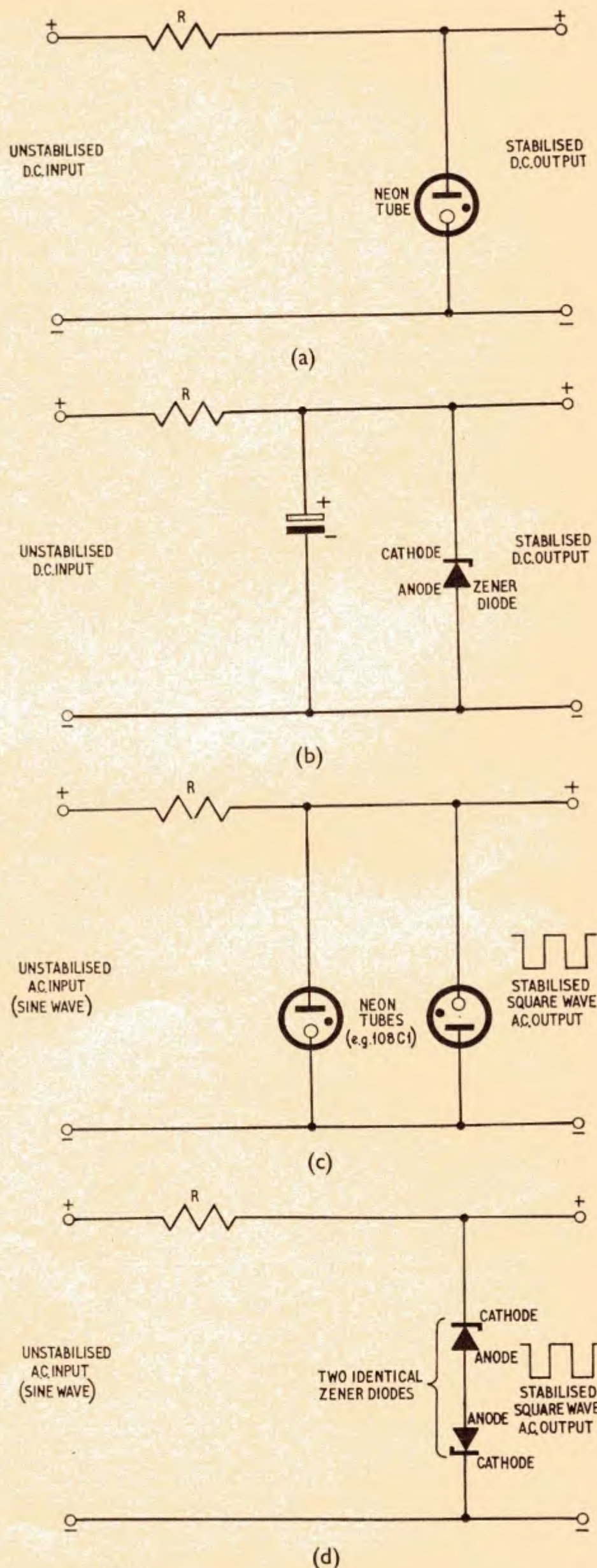


Fig. 2. Simple stabilisers of the type outlined in Fig. 1a. a and b are suitable for stabilising d.c. supplies, c and d are suitable for a.c. supplies

## NEONS AND ZENER DIODES COMPARED

In the case of neon tubes as constant voltage devices (Fig. 2a and Fig. 2c), the minimum input voltage must be at least as great as the maximum striking voltage specified by the makers.

In the case of Zener diodes as constant voltage devices (Fig. 2b and Fig. 2d), this restriction is not necessary, since all Zener diodes draw current immediately the reverse voltage exceeds the Zener voltage.

Thus, whilst a capacitor across the neon tube (unless small, e.g. up to  $0.1\mu\text{F}$  maximum) would cause overload of the tube due to the heavy initial surge upon discharging back to the operating voltage from the striking voltage, there is no such danger in the case of Zener diodes, which consequently tolerate very large parallel capacitors improving the permissible surge loading capacity of the stabilised output.

Zener diodes are now available with constant voltage ratings from about one volt up to 180 volts, so that, apart from the price of the higher voltage types, they are superior in every way to neon tubes and will probably replace the latter almost entirely in the future. The only slight drawback lies in somewhat greater temperature coefficients of the stabilised voltage.

Not all neon tubes are suitable for operation in an a.c. stabiliser circuit of the type shown in Fig. 2c. Only those types with activated cathodes such that the striking voltage with anode positive is very much lower than the striking voltage with anode negative (e.g. type 108 C 1) are suitable. The particular tube with positive anode then strikes on each half cycle, and the other one remains extinguished, so that neither tube ever draws reverse current which would lead to drift of the stabilised voltage.

On the other hand, all Zener diodes without exception are suitable for use in an a.c. voltage stabiliser of the kind shown in Fig. 2d.

There is no objection whatsoever to drawing current through a Zener diode in both directions; in the forward direction it behaves as a normal diode, passing current as soon as the anode is positive to the cathode. In the inverse direction, no current is drawn until the cathode is positive to the anode by an amount equal to the Zener voltage, whereafter any further attempt to make the cathode more positive still results in heavy current being drawn.

## BACK-TO-BACK ZENERS

It is clear from this behaviour that the two Zener diodes must be connected back-to-back in series for a.c. stabilisation, not in parallel as in the case of neon tubes. One Zener diode is connected in the forward direction on each half cycle, so that parallel connection would represent a total short circuit and give zero output. It is unimportant whether the anodes or the cathodes of the pair are connected together.

Zener diodes are available for low voltages, e.g. 6.3 volts, for which neon tubes do not exist. Furthermore, such low voltage Zener diodes are available with current ratings up to several amps. The arrangement of Fig. 2d is therefore convenient and economical for stabilising the heater supply for valves in sensitive circuits which may require such measures.

Circuits of the type shown in Fig. 2a and Fig. 2b are used in virtually all stabilisers of the error amplifier and regulator type, whether for a.c. or for d.c. stabilisation, where they furnish the fixed reference voltage.

## CONSTANT VOLTAGE TRANSFORMER

Fig. 3 shows the principle of the popular constant voltage transformer offered by several suppliers as simple a.c. mains voltage stabiliser. This is fundamentally of the simple "inherent constant voltage device" type, using a tuned circuit employing a saturable reactor operated on the low frequency side resonance flank as a constant voltage device.

The principle is illustrated in Fig. 3a.  $L_1$  and  $C_1$  draw respective currents 180 degrees out of phase with each other, with that through  $L_1$  greater than that through  $C_1$ , because the mains frequency is below the resonant frequency of the combination. The inductive difference current is drawn externally through  $L_2$ .

If the input mains voltage should increase, the currents in both  $L_1$  and  $C_1$  will increase, but in  $L_1$  the more so, because of resulting increased saturation of the core. Consequently the inductive difference current will increase and the voltage drop across  $L_2$  rise to counteract the increased input voltage.

Conversely, if the input voltage decreases, the inductance of  $L_1$  will rise due to the decreased saturation at the lower current, the difference current through  $L_2$  will fall and the voltage drop across  $L_2$  decrease to compensate the fall of input voltage.

The purpose of  $C_1$  is seen to be that of subtracting a large relatively constant amount from the current through  $L_1$ , as far as the drain through  $L_2$  is concerned, so that the relatively small saturation variations in  $L_1$  alone are amplified in their effect by a factor roughly equal to the  $Q$  of the tuned circuit represented.

## WAVEFORM DISTORTION

The circuit is somewhat frequency dependent, but since it operates on the resonance flank and not at resonance, careful design will certainly give some degree of frequency tolerance.

A more serious disadvantage is the considerable waveform distortion produced. This can be corrected in the better quality units functioning on this principle by connecting series resonant circuits for the respective harmonics of the mains frequency ( $C_3, L_3$  and  $C_4, L_4$ ) across the output, as shown in Fig. 3b. Since such traps operate at resonance, the frequency tolerance is necessarily narrower as soon as such items are included, though a nearly perfect sine wave can certainly be restored thereby.

There are numerous variations in the number and disposition of the saturable and unsaturable inductors and capacitors in such circuits as commonly found in practice, and the performance of some well-designed versions approaches that of much more refined electronic regulator circuits. The design of the necessary chokes is difficult if a wide range of control and loading is required.

## STABILISERS WITH ERROR AMPLIFIER AND REGULATOR

Fig. 4 shows the popular conventional electronic d.c. stabiliser circuit for an h.t. voltage supply.

The bleeder  $R_1, VR_1, R_2$  furnishes a sample of the output voltage such that (neglecting the grid base of  $V_3$ ) the voltage at  $VR_1$  slider is equal to the operating voltage of the reference voltage neon tube  $V_4$  when the output voltage has the desired value. The comparator is the grid/cathode section of  $V_3$ .

Any error in the output voltage is amplified by  $V_3$  and applied as a d.c. control voltage to the control

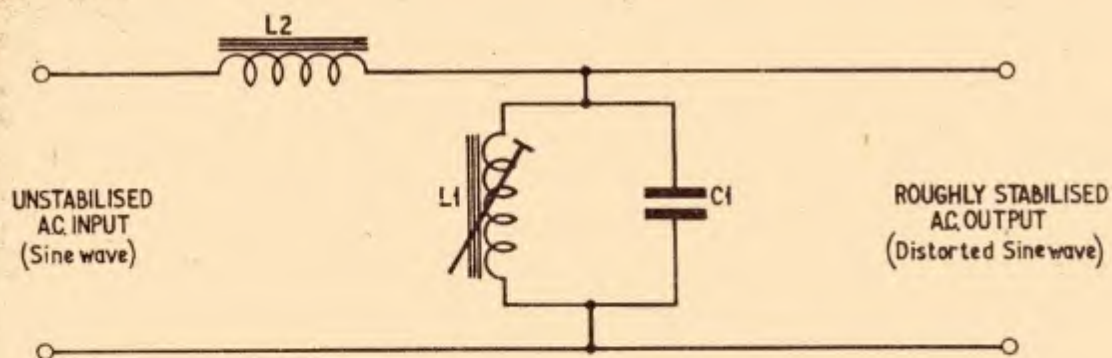


Fig. 3a. The principle of constant voltage transformers is given in this simple arrangement

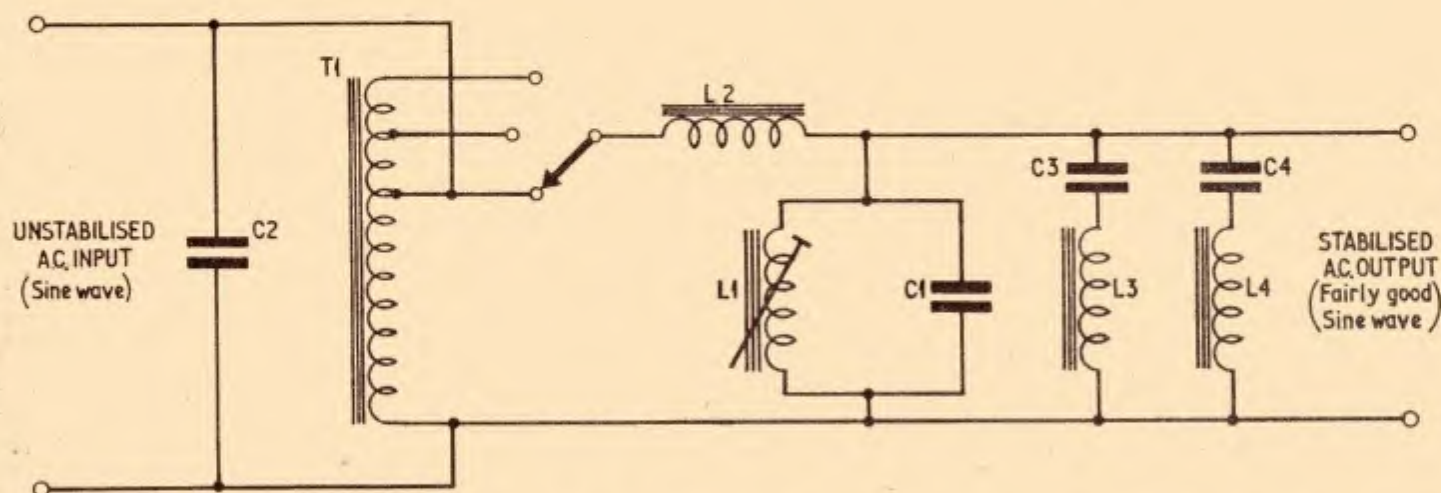


Fig. 3b. This shows an improved arrangement for a constant voltage transformer with waveform correction

grid of the series regulator valve V2 in such a sense as to correct the error of the output voltage.

It is seen that there is no component in the circuit to produce any time delay or phase shift in the regulating action, so that the latter is instantaneous, stable and dead-beat under all circumstances.

The circuit is extremely reliable and uncritical, which accounts for its great popularity. Even if a capacitor of a few microfarads is shunted across the output to remove residual r.f. which may come in from the consumer device, no phase shift greater than 90 degrees can be produced at any frequency in the control loop, so that instability is even then impossible.

The author has built numerous versions of this circuit in all types of electronic equipment, and knows

of no case of instability except upon omission of R4, or failure to place R4 very close to the grid pin of V2, when parasitic v.h.f. oscillation of V2 with the stray inductances and capacitances of the wiring can take place. But this is easy to prevent.

If V2 is a pentode, a screen stopper (100 ohms to 1 kilohm) is required for the same reason, and if V3 is a high-slope valve, it may also require a grid stopper resistor between its grid pin and the slider of VR1 (try 10 kilohm to 47 kilohm). R5 is chosen to give V4 the standing current specified by the makers, R3 and R4 are normally about 100 kilohm. V3 may be any small audio triode or r.f. pentode. V2 may be any normal output valve capable of withstanding a continuous anode current equal to the maximum desired output current.

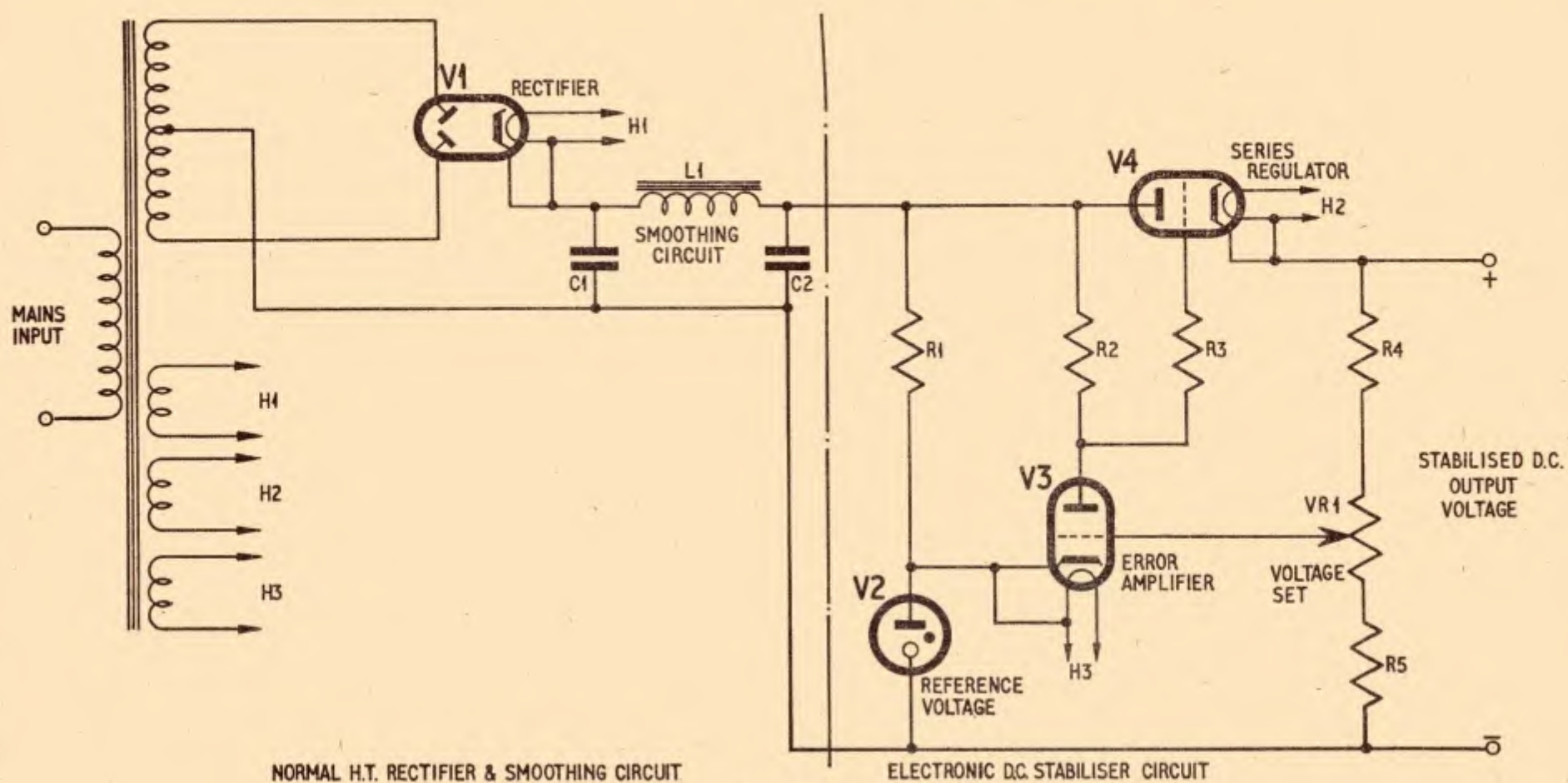


Fig. 4. The conventional d.c. stabiliser circuit

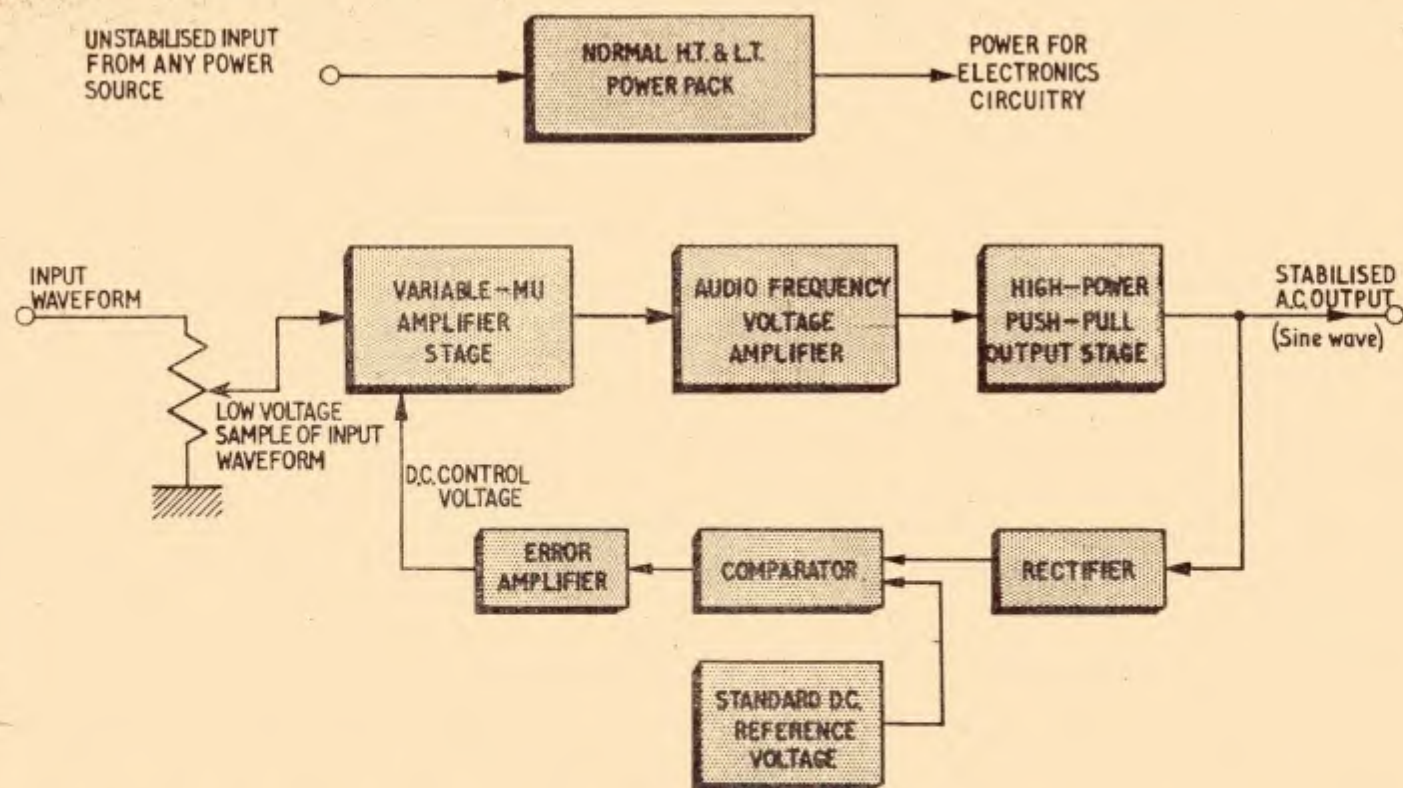


Fig. 5. This illustrates the principle of the power amplifier type of a.c. stabiliser

### POWER AMPLIFIER TYPE A.C. STABILISER

In a first mental attempt to translate the popular d.c. stabiliser circuit of Fig. 4 into a form suitable for stabilising an a.c. voltage, consider the arrangement sketched in Fig. 5.

The problem is simply that of finding a suitable series regulator to replace V2 in Fig. 4 in such a manner that it can control a sine wave on both half cycles without distortion. One conceivable solution is to apply the control voltage from the error amplifier to a low level variable  $\mu$  audio amplifier fed with a few hundred millivolts (maximum) of the mains sine wave, and using the output thereof to drive a conventional high-power audio amplifier. This results in Fig. 5.

required from the unit, not merely acting as a variable sluice to power drawn directly from the mains. Nevertheless, the author built up an experimental circuit according to Fig. 5, using a 100 watt power amplifier with two EL34 valves, in order to test the stability.

Unless complicated auxiliary feedback circuits are employed to constitute phase balanced bridges at principal frequencies of self-excitation, the circuit was found to be violently unstable to an extent amounting to real danger on account of transient output voltage surges of up to several thousand volts arising under some conditions.

This behaviour is not surprising, when one considers the large number of stages and their many sources of

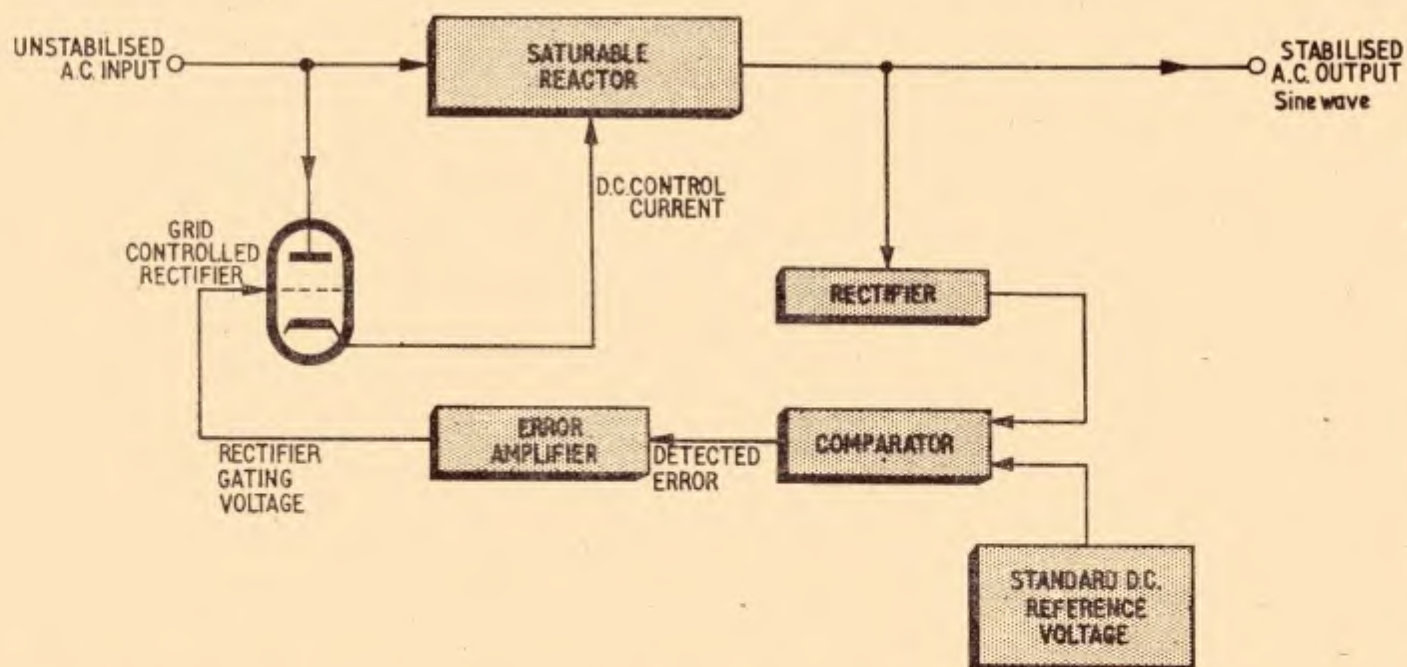


Fig. 6. A block diagram of the a.c. stabiliser finally evolved by the author and which will be described in detail in the second part of this article

This circuit arrangement has one important advantage which may be of great interest for certain electronics applications, namely that the input power feed and the input frequency (and waveform) feed can be from different sources.

Whilst drawing primary power from the mains via the h.t. power pack of the unit, the input waveform, for example, may be obtained from a crystal controlled oscillator and divider circuit, so that the output frequency is stabilised as well as the output voltage.

A drawback of the arrangement is its low efficiency and uneconomical design, since the output valves must be capable of delivering the full maximum power

possible phase shift within the control loop. The final conclusion reached at this stage of experiments was that, although commercial units of excellent performance and using this type of circuit exist, its construction is not to be recommended for our present purposes, since simpler, more economical and more reliable arrangements are available.

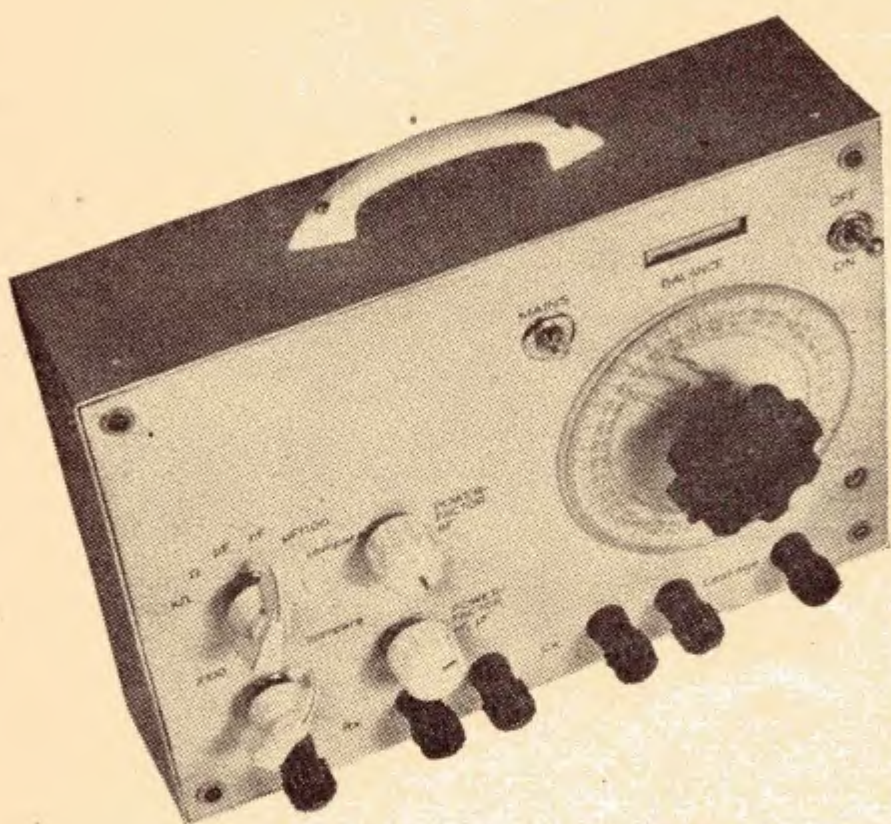
This brings us to Fig. 6, showing the basic principle of the arrangement finally adopted and developed to a satisfactory design. A discussion on this design and constructional details will be given in the second part of this article.



# RESISTANCE CAPACITANCE BRIDGE



BY R. E. F. STREET



**M**OST amateur constructors have felt the need for a resistance-capacitance bridge at one time or another. Of course, for the amateur, the measurement of resistance is not so great a problem as the measurement of capacitance, for even the simplest multirange test meters feature one or more resistance ranges whose accuracy is generally sufficient for "go, no-go" testing.

## LINEAR SCALE

The bridge described here has a number of features not normally found in home-constructed units and one of these is the use of a linear scale on which the readings are taken.

Most home-built bridges are calibrated in ratios, and the scales are cramped at the ends with resultant loss of accuracy when readings are taken at points removed from the centre of the scales.

Since there are a number of permissible variations in the main components of this bridge, the procedure used for deriving their values will be of interest to most readers. The diagrams concerned with this explanation are Figs. 6 to 9 and are given here—Figs. 1 to 5, concerned with the physical construction of the unit,

are on the blueprint given free with this issue of PRACTICAL ELECTRONICS.

Fig. 6 shows the basic Wheatstone bridge network. The bridge is said to be balanced when the potentials at the junctions of R1/R3 and R2/R4 are equal—when the meter M shows no deflection. In this condition,

$$\frac{R_1}{R_3} = \frac{R_2}{R_4}$$

Fig. 7 shows the usual form of the Wheatstone bridge employed in home-built resistance bridges. In this case, R1 and R3 are part of a variable resistor VR1, R<sub>s</sub> is a standard resistor, of which the value is known, and R<sub>x</sub> is the unknown resistor whose value it is desired to determine. When the bridge is balanced,

$$\frac{R_1}{R_3} = \frac{R_s}{R_x}$$

from which

$$R_x = \frac{R_3 \cdot R_s}{R_1}$$

The value of R<sub>s</sub> is known and the ratio R3/R1 is read on the scale of VR1, so that R<sub>x</sub> may be determined without knowing the actual values of R3 and R1.

Fig. 6 (below). The basic Wheatstone bridge network

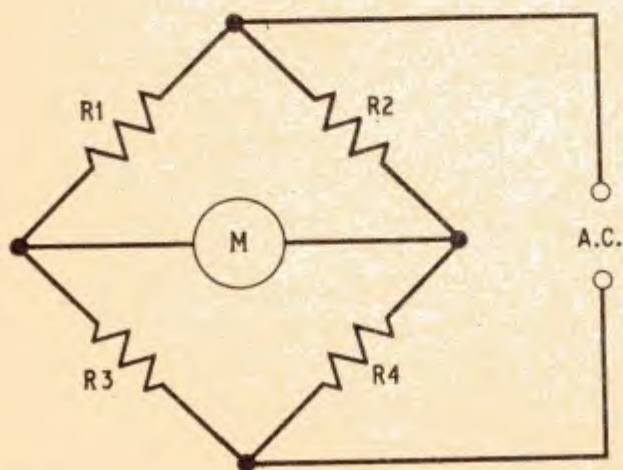
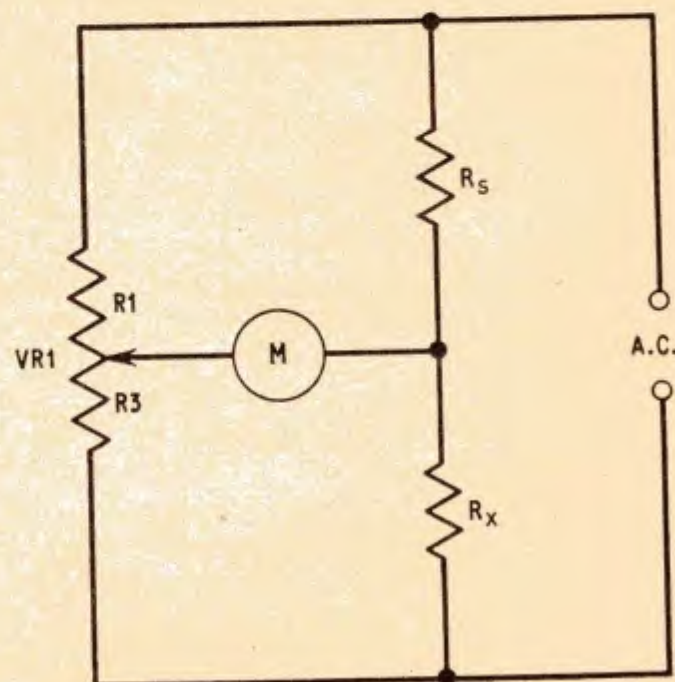


Fig. 7 (right). An alternative form of the Wheatstone bridge, employed in home-built resistance bridges, where a balance can be obtained by VR1 adjustment



## BASIC CIRCUIT

The basic configuration of the bridge described in this article is shown in Fig. 8. A variable resistor is used for R3 and a fixed resistor for R1. At balance, as before,

$$R_x = \frac{R_3 R_s}{R_1}$$

$$\therefore R_3 \propto R_x$$

As may now be seen, a linear scale may be employed on R3 for reading off the value of  $R_x$ , the unknown resistor. An easy scale to obtain for a home-built instrument of this nature is a 360 degree protractor; it remains therefore to calculate the circuit conditions necessary to ensure that this linear scale (of degrees) which we have chosen applies.

Suppose the "unknown" resistor is  $e$  ohms and that the variable resistor VR1 being used for R3 has a maximum value of  $b$  ohms and a total rotation of  $x$  degrees for a variation in its resistance of 0 to  $b$  ohms. Suppose, too, that when  $R_x$  is  $e$  ohms, the resistance of VR1 is  $c$  ohms when the bridge is balanced. These conditions are illustrated in Fig. 9.

Since the bridge is balanced,

$$\frac{a}{c} = \frac{d}{e} \quad (1)$$

Now VR1 alters in resistance by  $(b/x)$  ohms per degree of rotation, and, at balance, the pointer of VR1 must be at  $e$  degrees to indicate that  $R_x$  is  $e$  ohms.

$$\therefore c = \frac{e \cdot b}{x}$$

$$\therefore \text{from (1), } \frac{a \cdot x}{e \cdot b} = \frac{d}{e} \quad (2)$$

$$d = \frac{a \cdot x}{b} \quad (3)$$

## SCALE-MULTIPLYING FACTORS

From (3), the value of  $R_s$  for given values of VR1 and R1 may be calculated. Now, it would be a useful feature of the unit if it had several ranges with a factor of 10 between them. Thus, if  $e$  degrees on the scale is to represent when  $R_x$  is  $10e$  ohms, then R1 will have to be  $(a/10)$  ohms, from (2). If  $e$  degrees on the scale is to represent when  $R_x$  is  $100e$  ohms, then R1 will have to be  $(a/100)$  ohms, also from (2). Thus, R1 may be switched to provide  $\times 1$ ,  $\times 10$ , and  $\times 100$  factors for the indications on the scale of the instrument.

In this bridge, the value of R1 corresponding to  $a$  ohms is 18,000 ohms, and  $(a/10)$  ohms and  $(a/100)$  ohms are therefore 1,800 ohms and 180 ohms respectively.

In the  $\times 1$  position, therefore, R1 is 18 kilohms, and if a 10 kilohm potentiometer, having a rotation of 300 degrees is used for VR1, then the value of  $R_s$  ( $d$ ), the internal standard resistor, is given by

$$d = \frac{a \cdot x}{b} \quad (3)$$

$$= \frac{18000 \times 300}{10000}$$

$$= 540$$

$$\therefore R_s = 540 \Omega$$

Now, suppose that when the bridge is balanced,  $e$  degrees on the scale is to represent a value of  $e$  kilohms for  $R_x$  instead of  $e$  ohms. Then,

$$R_x = (1000) e \text{ ohms.}$$

Now, at balance,

$$\frac{a}{c} = \frac{d}{e} \quad (1)$$

$$\therefore d = \frac{a \cdot e}{c}$$

To preserve this relationship, if  $R_x$  is now  $(1000e)$  ohms,  $d$  must also be multiplied by 1000, and  $R_s$  will thus be  $(1000d)$  ohms.

From the above, it will be seen that by appropriate choice of the value of  $R_s$ , the basic indication of the bridge may be changed from ohms to kilohms.

## READINGS

In this bridge, a resistor of  $(10b/x)$  ohms is placed in series with VR1 and the effect of this is to change the limits of the scale from 0 and  $x$  degrees to 10 and  $(x + 10)$  degrees, which are more convenient.

There are two resistance ranges in the unit, corresponding to ohms and kilohms, and by using the multiplying factors mentioned above, readings may be taken from 10 ohms to 30 megohms.

Three capacitance ranges are provided—pF, nF and  $\mu\text{F}/100$ —and these require some explanation. Their derivation is similar to that of the resistance ranges and there is no point in going through the procedure again. However, the unit "nF" may be new to some readers; it stands for "nanofarad" and 1nF is equal to 1,000pF or  $0.001\mu\text{F}$ . This abbreviation is often

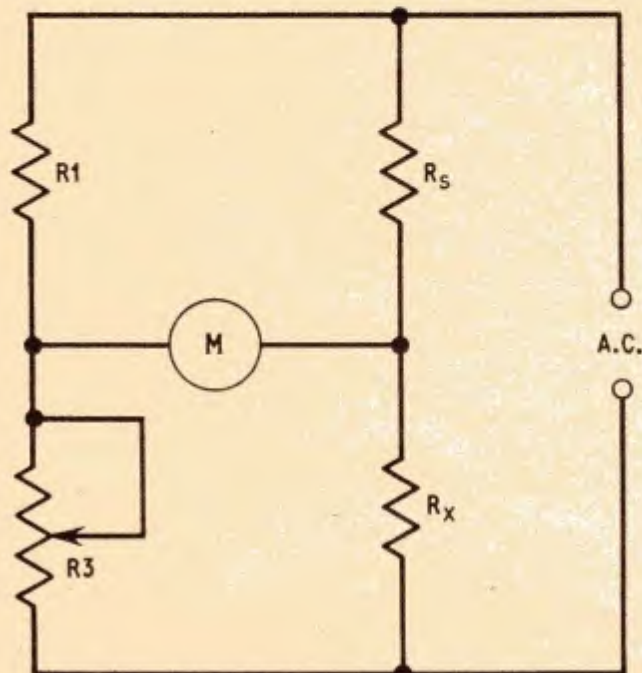
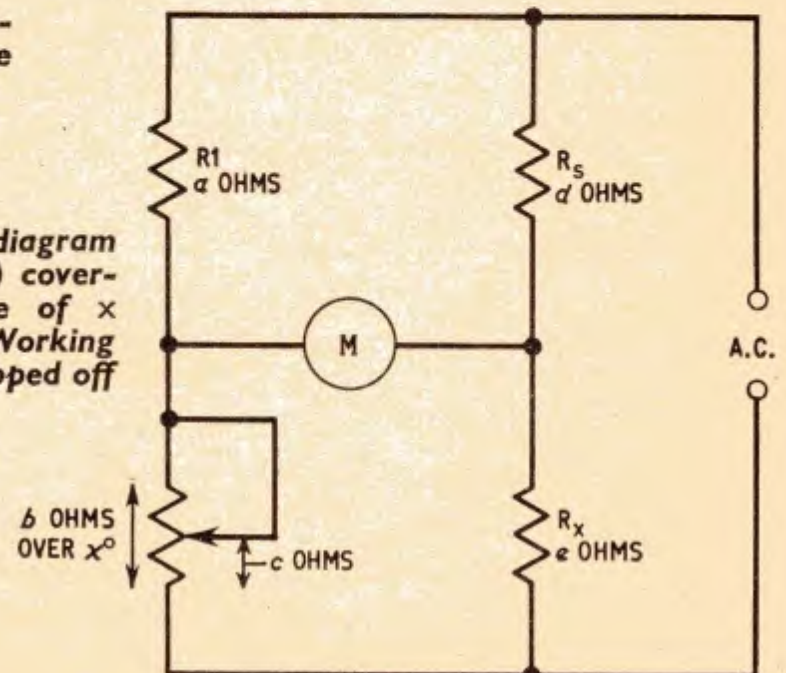


Fig. 8 (left). The basic configuration of the bridge constructed by the author

Fig. 9 (right). Circuit diagram with R3  $b$  ohms (max) covering the whole scale of  $x$  degrees of rotation. Working values of  $c$  ohms is tapped off by the wiper



useful and gives a unit intermediate between pF and  $\mu\text{F}$ , thus preventing otherwise knowledgeable people from using the nonsensical abbreviation "kpF".

The " $\mu\text{F}/100$ " range also needs some comment. The basic scale of the instrument is from 10 to about 300 degrees and if there were a " $\mu\text{F}$ " range, and the factor  $\times 100$  were in use, then the readings would be  $1,000\mu\text{F}$  to  $30,000\mu\text{F}$ , which would not be a great deal of use. There is also the point that the internal standard required would be  $540\mu\text{F}$ —scarcely practical!

With a " $\mu\text{F}/100$ " range, the internal standard is a manageable  $5.4\mu\text{F}$  and the  $\times 100$  range therefore corresponds to  $10\mu\text{F}$  to  $300\mu\text{F}$ ; the  $\times 10$  to  $1\mu\text{F}$  to  $30\mu\text{F}$ ; and the  $\times 1$  to  $0.1\mu\text{F}$  to  $3\mu\text{F}$ . The three capacitance ranges thus give a total coverage of some  $10\text{pF}$  to  $300\mu\text{F}$ , which is adequate for normal uses. The ranges of the instrument are set out in the Table below.

## CIRCUIT

Fig. 1 on the blueprint gives the actual circuit of the bridge. The range switch is S2 and the five ranges mentioned earlier are shown. The switch S1 selects appropriate resistors—R1, R2, and R3—to give multiplying factors of  $\times 100$ ,  $\times 10$ , and  $\times 1$  respectively for the readings on the scale of the instrument.

When resistance measurements are being made, the unknown is connected to the Rx terminals, and when capacitance measurements are being made, the unknown is connected to the Cx terminals. It will be seen that the disposition of the Rx and Cx terminals is such that the same scale may be employed on VR1 for reading resistance and capacitance.

The fourth position on S1, and the sixth position on S2 are marked "compare". When S2 is switched to position 6, no internal standards are in circuit, and when S1 is switched to position 4, R4, R6 and VR2 are brought into circuit. The purpose of the "compare" facility is to enable close matching of components—two resistors or capacitors—to be carried out.

The two (similar) components to be matched are connected one to the Rx terminals and one to the Cx terminals. Since VR1 rotates from about 10 degrees to about 310 degrees, the point of half-rotation is about 160 degrees, depending upon the component actually employed for VR1. Thus, if, during matching, a reading of 165 degrees were obtained, it would mean that the two parts were not exactly matched. The appropriate adjustment would then be made to one of them to give a reading on VR1 closer to 160 degrees to give closer matching.

TABLE

RANGES		
k $\Omega$	$\times 1$	10k $\Omega$ to 300k $\Omega$
	$\times 10$	100k $\Omega$ to 3M $\Omega$
	$\times 100$	1M $\Omega$ to 30M $\Omega$
$\Omega$	$\times 1$	10 $\Omega$ to 300 $\Omega$
	$\times 10$	100 $\Omega$ to 3k $\Omega$
	$\times 100$	1k $\Omega$ to 30k $\Omega$
pF	$\times 1$	10pF to 300pF
	$\times 10$	100pF to 3nF
	$\times 100$	1nF to 30nF
nF	$\times 1$	10nF to 300nF
	$\times 10$	0.1 $\mu\text{F}$ to 3 $\mu\text{F}$
	$\times 100$	1 $\mu\text{F}$ to 30 $\mu\text{F}$
$\mu\text{F}/100$	$\times 1$	0.1 $\mu\text{F}$ to 3 $\mu\text{F}$
	$\times 10$	1 $\mu\text{F}$ to 30 $\mu\text{F}$
	$\times 100$	10 $\mu\text{F}$ to 300 $\mu\text{F}$

## NULL-INDICATOR

The null-indicator used is a "magic-eye" valve—an EM87—and the circuitry of the bridge enables one "side" of the null-indicator to be earthed and connected to chassis. The other "side" of the indicator is the control grid of the valve and this is fed via C1 from the junction of the Rx and Cx terminals. The circuit thus corresponds basically with Fig. 9.

The a.c. for energising the bridge is at 50c/s and derived from the mains supply via T2 and T1. T1 is an output transformer connected to give a step-up ratio of about 1 : 8 and is wired to the 6.3V heater winding on T2. Resistor R12 is connected in series with the output from T1 to the bridge circuit to limit the current flowing when it would otherwise tend to rise excessively.

## LEAKAGE TEST

The h.t. supply for V1 is derived from a simple half-wave circuit and this supply also feeds two terminals on the bridge, marked "leakage". One terminal is connected to chassis—the negative—and the other to a neon lamp V2, the other side of which is wired to the h.t. supply via R11.

Connecting a paper or mica capacitor to the "leakage" terminals provides a rough and ready method of assessing leakage; a good capacitor will cause the neon to light for a shorter or longer period, depending upon its capacity, while a leaky capacitor will give a continual glow in V2.

The normal leakage currents of electrolytic capacitors will give rise to a continual glow, so that it is difficult to assess their condition by this means.

R11 limits the maximum current which may flow between the "leakage" terminals, but capacitors of low working voltage should not be tested for leakage.

The neon V3 is present simply to indicate that the instrument is switched on; it contains its own current-limiting resistor in its holder, unlike V2, which is a neon having an M.E.S. base.

## CONSTRUCTION

Full details of the method of construction adopted in the prototype are given in Figs. 2 to 5 on the blueprint. The aluminium chassis used for the case is 10in  $\times$  7in  $\times$  2½in approximately. The size is not too critical, but certainly the chassis should not be smaller than the one specified or difficulty will be experienced in housing all of the components used.

The front panel should be cut out, marked out and drilled as shown by the layout in Fig. 2. To preserve the good appearance of the front panel, only four bolts or screws have been allowed to show on the face and these are the four which fasten the panel to the case. For mounting parts on the reverse of the front panel, brackets are necessary and these are shown in Fig. 3.

Bracket A is held in position by the fixing-bushes of VR1 and VR6 (as shown in Fig. 4) and is used for VR2, VR3, and VR4.

Bracket B, in conjunction with a spring clip, is used for V1 and is fastened under the mains switch S3. (Incidentally, it is necessary to reduce the length of the "prongs" of the spring clip in order to position V1 close to the slot in the front panel.)

Bracket C is clamped under the negative "leakage" terminal and is used for the clip-on M.E.S. lampholder required for V2.

The fourth bracket, Bracket D, is flat and held by

the fixing-bush of VR5; it is used for the tag-strip associated with C3 and C4 which is held to the bracket by two countersunk bolts positioned with their heads against the front panel.

## COMPONENTS IN THE CASE

When the front panel has been completed and the major parts mounted, it can be used to determine the exact positions required for the components to be mounted in the case. The layout of these is shown in Fig. 5, and it will be seen that there is not much room to spare when the front panel is in position.

It is therefore best to position the components, such as T1 and T2, by placing them in about the right locations and then seeing if the front panel will fit, rather than following the layout slavishly.

When the parts have been mounted in the case, the wiring proper may be carried out. Owing to the compact layout of the instrument, it will be found helpful to work from the circuit (Fig. 1) as well as the wiring diagrams (Figs. 4 and 5).

It is advisable to place a small piece of insulating material on the rear of the front panel beneath the valveholder of V1 to prevent accidental short circuits between the pins and the metal panel. Insulation is also needed over the tags of T2.

## SCALE

On the prototype, the 360 degree protractor for the scale was fixed to the control knob of VR1, but, if desired, it may be fitted to the front panel and a pointer fitted to the knob of VR1. However, if this is done, it will be necessary to transpose the connections to VR1 to give readings which increase in magnitude in a clockwise direction.

Of the two methods, fixing the scale to the knob makes the taking of readings much easier since the figures are then always horizontal and immediately below the magic-eye indicator. (Normally, protractors have two series of figures which run clockwise and anticlockwise—one set will have to be disregarded when taking readings, or may be painted out.)

The control knob must be fitted to the spindle of VR1 in such a way that when VR1 is fully clockwise (scale fitted to knob) or fully anticlockwise (scale fitted to front panel), the reading is 10 degrees.

It should be noted that potentiometers normally have tracks which do not extend over the whole range of their rotation, and the reading must be 10 degrees at the start of the *track*, not the start of the rotation. The required point may normally be determined by the "feel" of the control, or by listening to the sounds made by the control during rotation (although very quiet surroundings are needed for this method).

The datum for readings should be a line on the front panel immediately under the balance-indicator—see Fig. 2—if the scale is fixed to the control knob.

## POTENTIOMETER FOR VR1

The potentiometer used for VR1 should preferably be of the precision type and 10 kilohms total resistance. A "linear" type is obviously essential and the better the linearity, the more scope there is for making the accuracy of the completed instrument high.

Suitable components for VR1 are the Colvern CLR5001 (10 kilohm), and the CLR6010 (10 kilohm). Large potentiometers of higher accuracy could be accommodated by altering Bracket A to allow VR2 to be positioned nearer to VR3, VR4 and VR6, perhaps

arranging for the spindles of VR2, VR3 and VR4 to be at the vertices of an equilateral triangle. A potentiometer of, say, 3in diameter could then be used, such as the Colvern CLR7001 (10 kilohm.) In the larger type of potentiometer, the Painton CV25SHL would also be suitable.

It should be noted, however, that the large, heavy-duty, potentiometer normally has three-hole fixing, not a  $\frac{3}{8}$ in bush, and holes would then have to be made in the front panel at the appropriate points. It would then be advisable to use a large control knob, to ensure that the fixing-bolts are hidden from view.

## OTHER TYPES

It may be difficult for some readers to obtain potentiometers of the precision or heavy-duty type without waiting an inordinate time for an order to be fulfilled. In these circumstances, there is no reason why an ordinary type of large wire-wound potentiometer should not be used for VR1, although accuracy will tend to be less, obviously.

The resistance tolerance in readily available components is often 20% and to avoid difficulty, it would be advisable to ask the dealer from whom the unit is purchased to select a potentiometer in which the resistance is as close to the nominal 10 kilohms as possible.

From equation (3) given on page 565, it will be seen that the value of  $R_s$  is proportional to the resistor in use for R1 (Fig. 9) and to the total rotation (in degrees) of VR1. Also, the value of  $R_s$  is inversely proportional to the total resistance of VR1. All of this means that if, say, a 5 kilohm potentiometer were used for VR1, it would be necessary to multiply the standard resistors by a factor of two. For the ohms range, the standard would therefore be 1,080 ohms (1 kilohm 2% + 200 ohms variable) and for the kilohms range, the standard would be 1,080 kilohms (1 megohm 2% + 200 kilohm or 250 kilohm variable).

With a 5 kilohm component for VR1, the capacity standards would also have to be multiplied by a factor of two.

## CHANGES IN COMPONENTS

There is also the point that if a potentiometer different in value from 10 kilohm were used, R4, R5, R6 and VR2 would have to be altered. R5 would be about 166 ohms, R4 about 22 kilohms and R6 18 kilohms, if VR1 were a 5 kilohm type. VR2 would in this instance remain at 3 kilohms.

It is easy to calculate the values required for R4, R5, R6 and VR2 if VR1 is different from 10 kilohm. When using the "compare" facility, with identical components connected to the Rx and Cx terminals, the potentiometer VR1 must be at half-rotation for balance. Using the same symbols as before, if the potentiometer has a total resistance of  $b$  ohms over  $x$  degrees of rotation, the value of R5 is given by  $(10b/x)$  ohms.

For the conditions set out above VR1 is set to  $(b/2)$  ohms. Thus,  $R4 = (b/2) + R5 + (f/2)$  where  $f$  ohms is the resistance of VR2. Suitable values for the resistors and potentiometers may thus be worked out if a value is agreed for R4. The value of VR2 would be chosen to give a useful range of adjustment.

From the above explanations, readers should be able to work out values of components if the unit they use for VR1 is not 10 kilohm but, say, 5 kilohm or 20 kilohm.

## CALIBRATION

The first step in calibrating the instrument is to check the scale to see that it has been accurately positioned as described earlier, so that a reading of 10 degrees is obtained when VR1 is at its minimum setting. The "ohms" range may then be calibrated, on the "×1" position of S1, by connecting a close tolerance resistor of known value (in the range 10 ohms to 300 ohms) across the Rx terminals and adjusting VR4 to give balance of the bridge with VR1 indicating the value of the resistor on the scale. A similar procedure is followed with the "kilohm" range by connecting a known resistor of between 10 kilohms and 300 kilohms to the Rx terminals.

The capacitance ranges are more difficult, but the "pF" range may be calibrated in a manner similar to that used for the "ohm" and "kilohm" ranges, by employing a capacitor of close tolerance in the range 10pF to 300pF (these are readily available today with a tolerance of 1 per cent).

The "nF" and " $\mu\text{F}/100$ " ranges can be calibrated by measuring appropriately valued capacitors on a bridge which has already been calibrated, and then measuring them on the bridge. If great care is taken in construction and calibration, and a close tolerance potentiometer of accurate linearity is used for VR1, then the bridge may be made very accurate.

## ALTERNATIVE METHOD

Another method would be on the following lines. Suppose it is required to calibrate the " $\mu\text{F}/100$ " range; two capacitors would be employed—say  $1\mu\text{F}$  each, nominally. Both would be measured on the bridge and the readings noted—perhaps 1.21 and 0.96. The next step would be to connect the two in parallel and measure the combination. The reading should, of course, be  $(1.21 + 0.96)$  or 2.17. If this reading did not result, then the value of C4 would have to be altered accordingly—an increase in value if the reading were too low, and a decrease if it were too high.

The need for paralleling capacitors to obtain the required values for the internal standards explains why, in Fig. 4 on the blueprint, the capacitors C3 and C4 are shown as several components.

## COMPARISON

The "compare" position can be calibrated by determining the centre of rotation of VR1—so many degrees on the scale—remembering that it is the centre of the track which must be determined.

Suppose that this works out to be 155 degrees on the scale. Then, if two nominally identical components are connected to the Rx and Cx terminals (say, two 1 per cent resistors), and the bridge is balanced, a reading of 150 degrees might be obtained. The next step would be to transpose the two components and again adjust the bridge for balance. It is obvious that if the adjustment of VR2 is correct, the reading obtained should now be 160 degrees—if not, VR2 should be adjusted and the procedure repeated until the differences between the two readings and centre reading are equal.

It is best to carry out the calibration of the five ranges of the instrument with the multiplier switch S1 at the "×1" position. Then, the tolerances of the multiplier resistors R2 and R1 do not come into play. From the circuit, it is obvious that the closer the tolerances of R3, R2, and R1, the more accurate the multiplying factors will be.

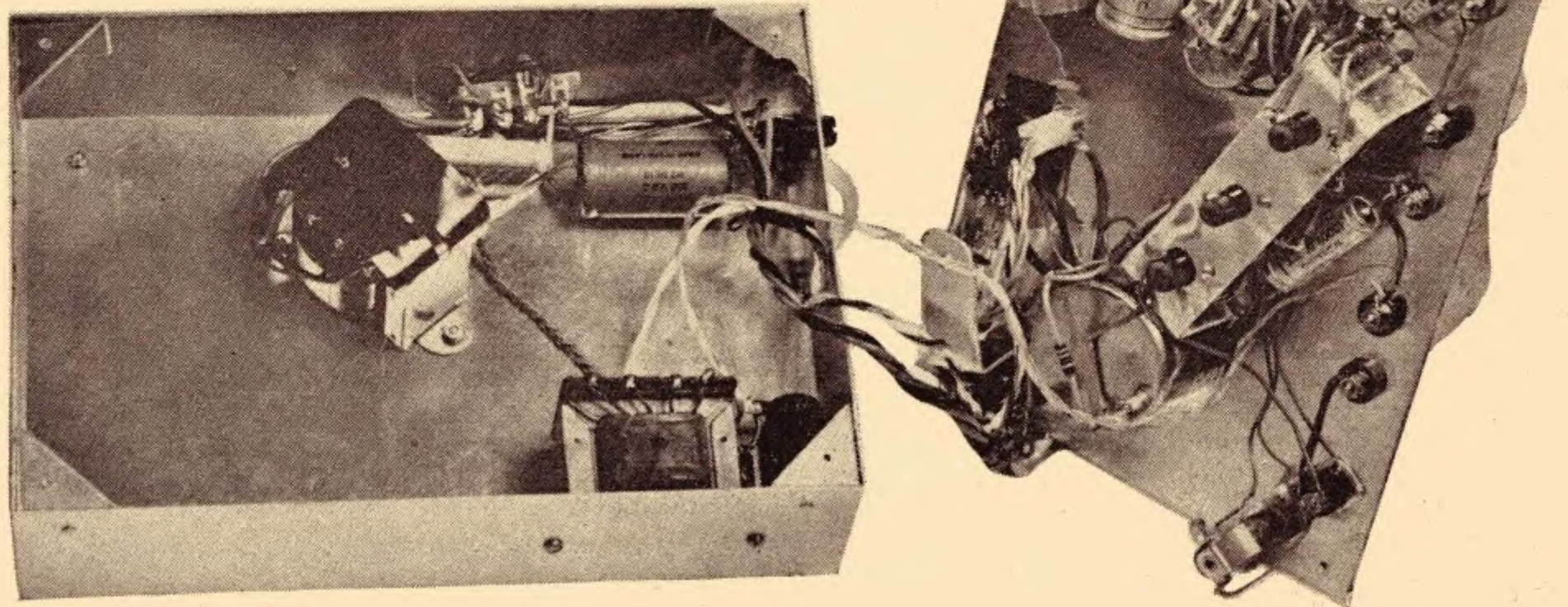
## MEASURING LOW VALUES

As it stands, the unit does not measure below 10 ohms nor 10pF—to extend the ranges to do this directly would be difficult, but components of less than 10 ohms or 10pF may be measured by measuring components of higher values and connecting the unknown in series (for resistors) or parallel (for capacitors).

Thus, if it were suspected that a resistor were about 4 ohms, a "12 ohm" resistor could be measured on the bridge and might be found to be 14 ohms. The "4 ohm" resistor would then be wired in series with the "12 ohm" resistor, and, if the reading were then 19 ohms, the nominally 4 ohm resistor would be seen to have a value of 5 ohms.

High-value electrolytic capacitors—over  $300\mu\text{F}$ —cannot be checked with the instrument as it is shown on the blueprint. However, if desired, another position may be added to S1 using a resistor (R1a) of 18 ohms.

Two-pole five-way switches are not common, but if a two-pole, six-way Radiospares "Maka-Switch" wafer is employed, the movable "stop" may be used to give five ways on S1. ★



# ELECTRONIC BUILDING BLOCKS



## PART THREE

by R. A. DARLEY

LAST month we discussed the simple form of CR network and the effect of CR values on square wave inputs. In this month's article we shall see how a diode can be used to clip part of a waveform and, when applied to a CR circuit, how it can "clamp" the waveform to any given voltage reference.

### CLAMPING DIODE

Consider now the action of the circuit shown in Fig. 3.1a in which a diode is wired in parallel with a resistor; the circuit has a long time constant and is fed from a square pulse generator.

So far the action of the differentiating circuit has been described on the assumption that a *perfect* square pulse is used, i.e. one in which the rise time is zero. In practice the rise time *must* be finite; it may be only a fraction of a microsecond, but nevertheless it must exist. The voltage appearing across the resistor will not reach the full value of the applied voltage; the longer the rise time, the less nearly will this voltage be reached.

Referring to Fig. 3.1a, assuming that the input pulse is all positive, the arriving pulse will bias the diode in the forward direction and it will conduct, effectively short-circuiting the resistor and resulting in a very short time constant. This very short time constant, combined with the finite rise time of the input square pulse, will result in only a brief positive going "spike" of very limited amplitude across R. The capacitor will have charged to the full applied voltage by the end of the input pulse, as shown in Fig. 3.1b. At the end of the pulse there will be zero volts at the input and a discharge path through the generator.

The diode is thus biased in reverse and is effectively open-circuit, and as it is no longer shunting the resistor, the full CR time constant is available. The voltage across R goes fully negative, and then starts to decay towards zero, but as the time constant is now long, only

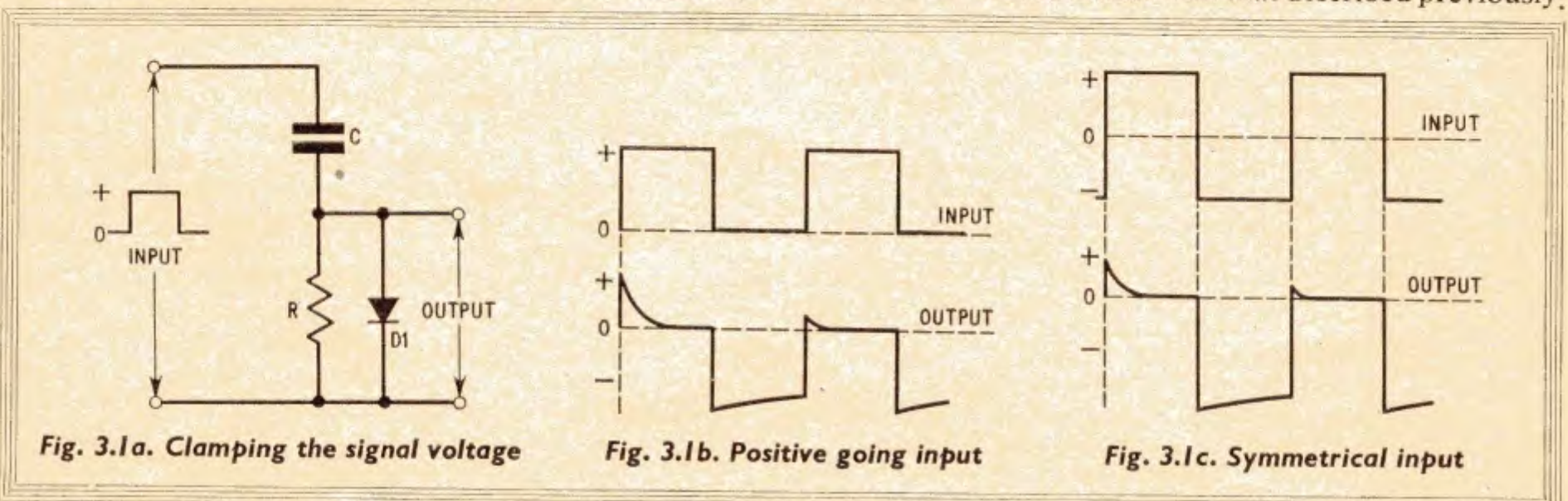
a small amount of decay takes place before the input pulse again arrives. A new arriving pulse will result in an even smaller positive going spike, in this case, of the same amplitude as the amount of decay just considered. This spike rapidly falls to zero volts. When the input pulse cuts off the voltage across the resistor again goes fully negative. The cycle repeats for each following pulse. The effect of the diode, therefore, is to "clamp" the output voltage to zero reference and cause the all positive input to become an all negative output of similar form. If the diode were reversed the output would be all positive going instead.

This circuit may not at first sight seem to be of great value, but if its action resulting from a square pulse input varying symmetrically about the zero point is considered, it can be seen to be very useful indeed. The action is almost identical with that described above, the relative waveforms resulting from this application being shown in Fig. 3.1c. Note that if the input varies, for example, between 20 volts positive and 20 volts negative, the output will vary between approximately zero volts and 40 volts negative. If the diode were reversed, the output would again be all positive.

The above circuit is sometimes referred to as a "d.c. restoration circuit". It should be borne in mind when referring to circuits that transistors have a "built in" diode between base and emitter and between base and collector, and that this "built in" diode may be used to give d.c. restoration, although no diode clamp is shown in the circuit diagram as such.

### BIASED DIODE

The "clamp" point of the above circuit may be set to any desired level by biasing the diode to the level which is required. The circuit of Fig. 3.2a shows one way of doing this, using a battery, and Fig. 3.2b illustrates the resulting waveforms. The action of the circuit is almost identical with that described previously.



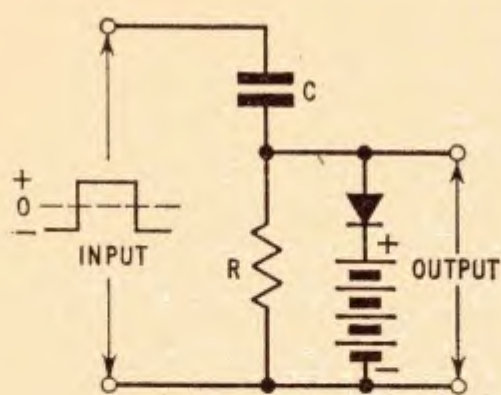
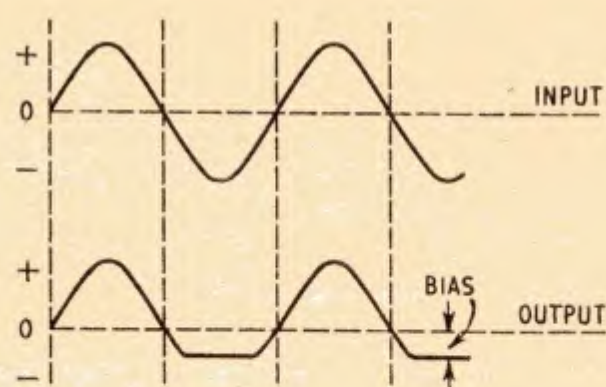


Fig. 3.2a. (left) Predetermined clamping voltage supplied by a battery

Fig. 3.2b. (right) Resulting waveforms. Notice the bias effect on the negative part of the output waveform



## DIODE LIMITING AND CLIPPING

Fig. 3.3a shows a simple diode limiting device. The diode is wired in series with a resistor, with input and output as shown, thus forming a potential divider network. The only stipulation in the choice of components is that the resistance value is high compared with the forward resistance of the diode, and low compared with the reverse resistance. If a sine wave, which varies symmetrically about the zero point, is applied to the input, the following action takes place.

With the arrival of the positive half of the waveform, the diode is biased in a forward direction; its resistance is therefore small compared with that of  $R_1$  and, due to the potential divider action, almost the full applied positive voltage is developed across the load resistor. With the arrival of the negative portion of the sine wave, however, the diode will be biased in reverse, so that its resistance is very high compared with that of the load resistor; only a very small part of the negative signal is therefore developed across the load resistor  $R_1$ . The resulting waveforms are shown in Fig. 3.3b, and it can be seen that the action of the circuit is to "limit" the amplitude of the negative half cycles down to almost zero volts. Alternatively, it can be said that the circuit "rectifies" the input waveform, or again, that it "discriminates" between positive and negative voltages. Thus, the circuit may be referred to as a "limiter", "rectifier", or "discriminator".

If the diode were reversed, as in Fig. 3.3c, the output would be mainly negative, or alternatively, if the resistor were placed above the diode, as in Fig. 3.3d, the output would again be mainly negative. A fourth configuration, shown in Fig. 3.3e, would also result in a mainly positive output.

If a battery or some other voltage source were placed in series with the diode, as shown in Fig. 3.3f, the limiting point of the circuit would be altered, as illustrated.

A very important and basic point that must be realised about these circuits is that, while the circuits shown here are assumed to be deliberately designed, all valve and transistor circuits of this type will exhibit one or other of the characteristics mentioned (either non-biased or biased limiting) under certain circumstances, i.e., when the input is sufficiently large.

## APPLICATIONS

Two particularly useful applications of the principles outlined are worth further mention. The first of these is the conversion of a sine wave to a square wave. The circuit is shown in Fig. 3.4, and can be seen to consist simply of two biased diodes wired in parallel, one in the forward and the other in the reverse direction;

one diode "clips" the positive half cycles and the other the negative ones.

Within certain limitations the circuit is very effective. They are:

1. The peak-to-peak value of the sine wave input should be large compared with the peak-to-peak value of the output. The greater the input to output ratio, the more nearly will a true square wave be produced, and a minimum ratio of 5:1 should be employed for good results.

2. The frequency of operation; the diodes have a fairly high value of internal capacitance, and thus act as differentiating circuits. The inherent positive and negative "peaks" of the differentiating circuit are thus present in the output, but to only an insignificant degree at low frequencies. At the higher frequencies, however, these peaks become quite prominent in the output waveform, and limit the usefulness of the circuit. The circuit should thus be limited to the audio frequency range for the best results.

The second circuit is shown in Fig. 3.5. This circuit may be used as the basis of an accurate direct reading frequency meter.

The CR values are chosen to give a short time constant compared with the highest frequency used. Thus the resulting output across the resistor is composed of short positive and negative pulses with a short rise time. Diode  $D_1$  acts as a discriminator, eliminating (for all practical purposes) the negative pulses. Now, within certain limitations, the mean value of this final positive pulse will be directly proportional to frequency. If the frequency is doubled, so will be this mean value; if frequency is halved, so also is the mean value, and so on.

Moving-coil meters almost invariably read mean values of input (mean is taken as the average) so if the meter is wired in the circuit as shown it will give a direct and linear reading of the input frequency.

Of the limitations mentioned above, the most important is that the amplitude of the square wave input *must* be held at a constant level, otherwise the meter readings will be quite meaningless. Secondly, the rise time of the positive pulse from the diode must be very short. Thirdly, the length of the square wave input pulse must be sufficient to allow full decay of the differentiated pulses.

To meet all three of the above requirements a true electronics circuit is normally required. A useful car speedometer can, however, be made using the diode circuits described in this article, i.e., contact breaker waveform can be fed to the input via a diode limiter.

**Next month we will discuss bridge circuits.**

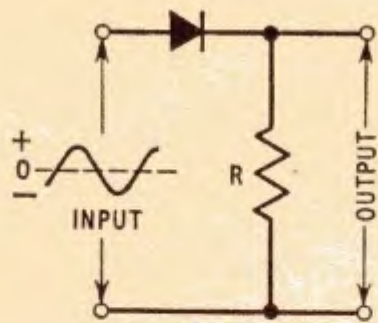


Fig. 3.3a. Simple diode limiting circuit giving positive going half cycles only. A sine wave centred on zero volts is applied to the input

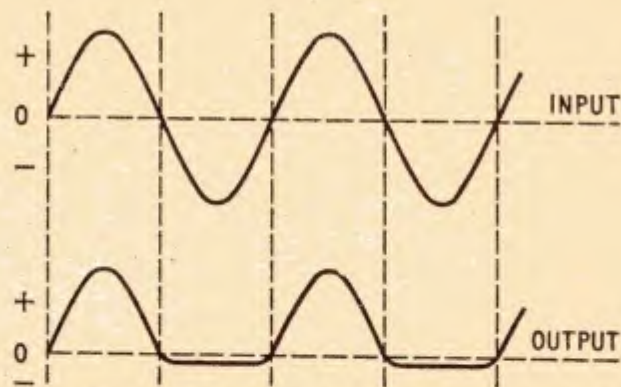


Fig. 3.3b. Input and output waveforms. The small amount of negative voltage on the output is due to the leakage current through the diode when reverse biased

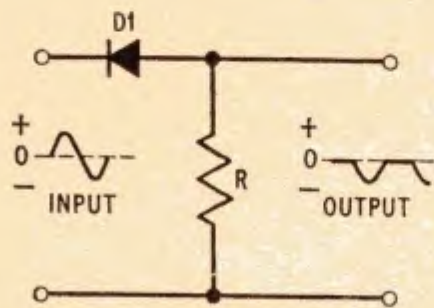


Fig. 3.3c. The effect of reversing the diode under the same input conditions as in Fig. 3.3a

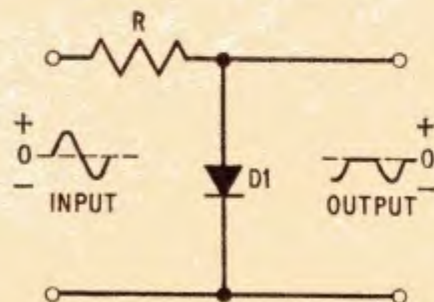


Fig. 3.3d. The diode and resistor are interchanged to give the same effect as in Fig. 3.3c

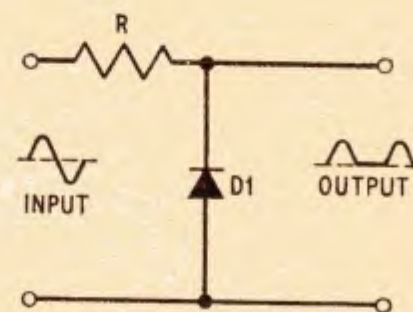


Fig. 3.3e. The effect of reversing the diode under the same input conditions as in the previous cases

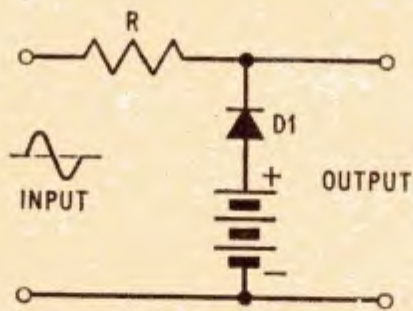


Fig. 3.3f. A battery is inserted in the circuit of Fig. 3.3e to bias the diode, and effectively centre the waveforms at a point other than zero

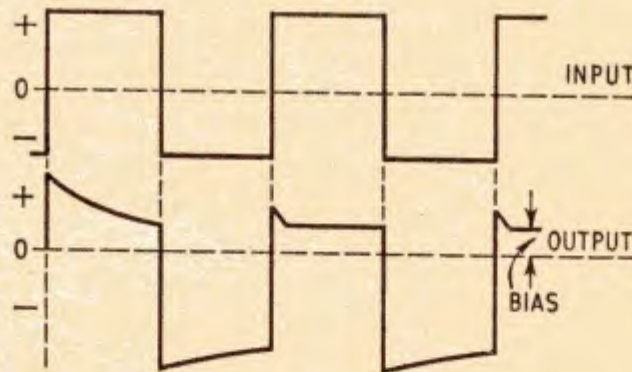


Fig. 3.3g. The input and output waveforms applicable to the kind of circuit shown in Fig. 3.3f. Note the bias determined by the battery voltage

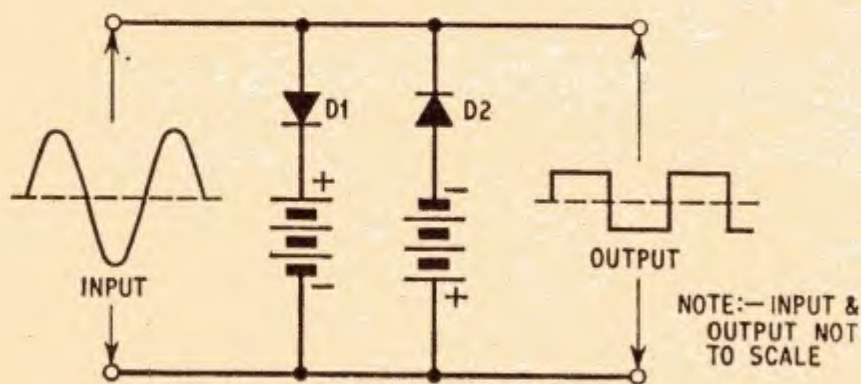


Fig. 3.4. By using two diodes in opposition a sine wave is biased, clipped and clamped to provide a square wave output

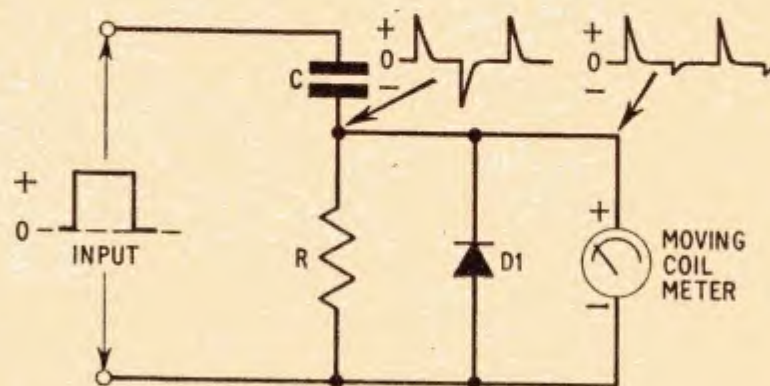


Fig. 3.5. Direct reading frequency meter principle using a diode and differentiating circuit



# ELECTRONI



THE REALM of electronic musical instruments is sadly lacking in catering for the amateur musician requiring a cheap, easy-to-play device to pick out a popular melody. It was to meet this need that the electronic trumpet was conceived.

Being fully transistorised and extremely portable, it can be used in any location since it requires no mains supply for its operation. Half a watt of output power is available from two OC81 transistors in push-pull, this being more than adequate for even a large room under normal listening conditions. However, additional amplification can easily be arranged if required either by feeding into an alternative amplifier or by simply playing into a public address microphone.

The fingering technique simulates that of the orthodox trumpet, the three rear push-buttons performing the same role as the trumpet's valves. This method of keying was chosen because of its simplicity over the more conventional piano-type keyboard. For those conversant with the established keyboard layout and who are capable of tackling the extra mechanical work involved, a miniature piano keyboard might be preferable as no other fingering techniques would need to be learned. In this event, a separate resistor would be necessary for each note of the keyboard together with an associated contact. Also the sub-octave capacitors would need to be selected to lower the pitch a whole octave in order to keep the denomination of the keyboard notes the same. With the simpler trumpet keying to be described, this need for uniformity does not arise.

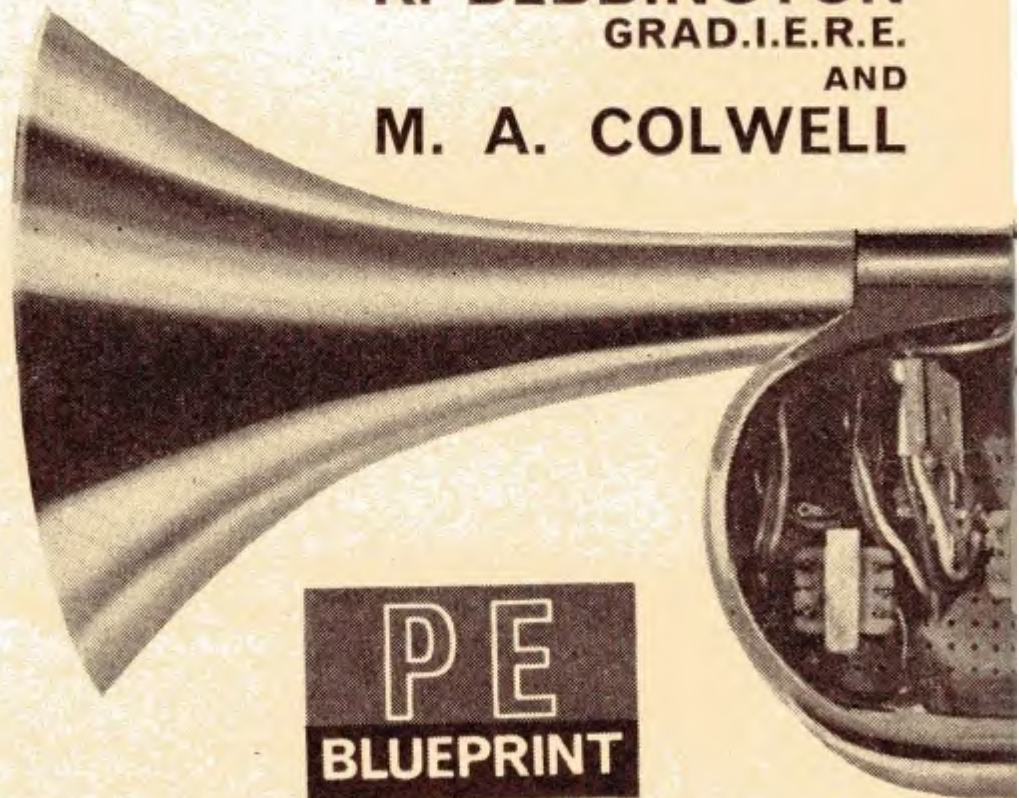
## BASIC REQUIREMENTS

A simple electronic melody instrument must have the following basic requirements:

- (a) an oscillator for producing the notes,
- (b) an amplifier to supply sufficient power output,
- (c) a loudspeaker.

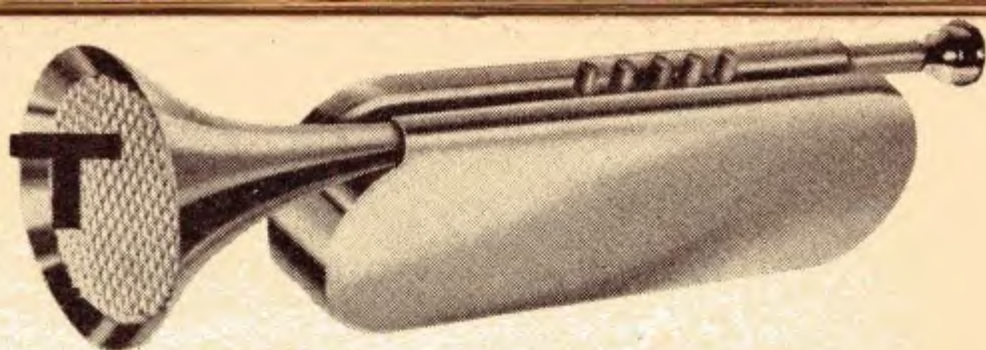
In addition, some method must be found for varying the pitch or frequency of the oscillator accurately over the range of the musical notes required. Some method

BY  
**R. BEBBINGTON**  
GRAD.I.E.R.E.  
AND  
**M. A. COLWELL**



PE  
BLUEPRINT

# C TRUMPET



of starting and stopping the notes is a necessity. Variation both in tonal colouring and volume is desirable if monotony is to be avoided.

## NOTE GENERATOR

Several oscillator circuits were tried before settling for the one shown in Fig. 1 on the blueprint. Its waveforms are rich in harmonics so it is ideally suitable for simulating many of the instruments of the orchestra. An approximate square wave is available from the collector of TR2, whilst its emitter yields a triangular waveform not unlike that of a trumpet. A 4:1 frequency ratio can be obtained with a resistance chain of about 10 kilohms in TR1 collector which is useful if a piano-type keyboard is envisaged.

The music stave Fig. 4 shows the trumpet fingering employed. Musicians use the term "valves" for the mechanical pistons of a brass instrument but because of the conflicting electronic variety our equivalents will be termed push-buttons to avoid confusion. On the prototype the standard trumpet technique was adhered to, in that the first button (S1) lowers the pitch a full tone, the second button (S2) a semitone and the third a tone and a half. It will be apparent therefore that different combinations of these three buttons may control the pitch over seven semitones or half an octave.

Whereas the trumpeter can by varying lip pressure produce a harmonic series on each of these valve combinations it is necessary for us to press the sub-octave buttons (S4 and S5) to continue our series down the scale. As this is essentially a melody instrument its range should roughly correspond to the human voice. Most melodies do not exceed G above the treble stave so this is a convenient note from which to start our descending scale. Fig. 4 illustrates the fingering for each note down to "D flat" below the stave.

Further extension may be produced either by adding a further switch and capacitor or by switching both the existing capacitors in together. The latter method produced E flat without any of the three push-buttons depressed, so to continue the chromatic series a bottom C could be produced on 1st and 2nd buttons with both sub-octave contacts made. This would extend the range to the low A using the fingering 123. Whilst the fingering down to D flat would produce the same notes on a trumpet there are a number of alternative, easier combinations available for the brass instrument

because of the many harmonics that can be produced by the lips.

The four variable resistors are series connected, one is used for the initial tuning, i.e. G with no push-buttons depressed, the other three individually tune with the three push-buttons.

## MOUTHPIECE CONTACT

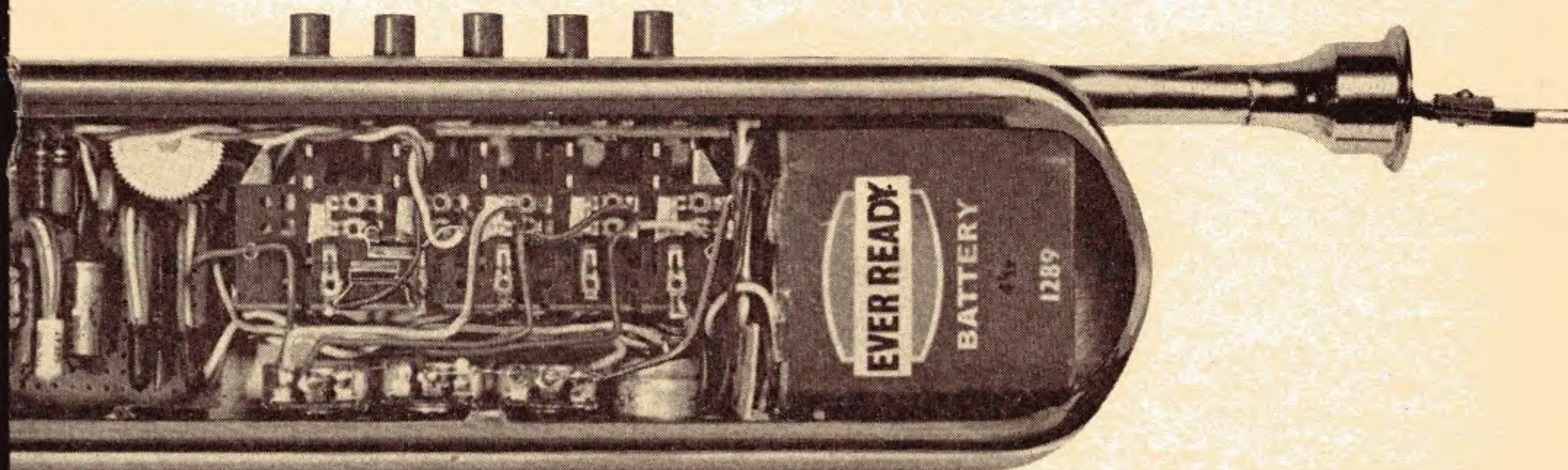
Whilst the sound could be initiated by another finger control, it was thought that having adopted the trumpet fingering technique, a mouthpiece to start and stop the sound would be more appealing. This merely consists of a "make" contact with a rubber sleeve which can be gripped by the lips to start the note; relaxing the grip will stop the sound. With a little practice the action becomes quite easy and fairly rapid passages of music can be attempted. To eliminate excessive clicks when the notes are initiated it was found that it was better to leave the oscillator running continuously and to switch the collector of the driver stage of the amplifier. To obtain a smooth transition from one note to the next, the finger movements must be synchronised with the lip action.

## AMPLIFIER

The amplifier uses three transistors, an OC81D driving two OC81's in push-pull which feed a 3 $\frac{3}{8}$ in loudspeaker. Transformer coupling is used throughout and as the components are mounted on a perforated wiring panel no soldering tags are required. To facilitate wiring, the positive and negative rails run the whole length of the amplifier panel. Care must be taken to see that the positive and negative 4.5 volt leads from the battery are not reversed or the transistors may suffer.

In order to prevent damage to these when soldering it is safer to leave the lead-out wires long. A well-tinned hot iron will obviate the need for prolonged heating and a heat shunt is a worthwhile precaution especially for the beginner who has not learnt the art of soldering quickly. The layout of components is given as a guide, but final dimensions will be dictated by the physical size of the components to hand.

There is plenty of output from the oscillator to fully load the amplifier and the constructor may experiment



with different tone filters interposed to find tone-colours to suit his own taste. The expression control (VR5) is merely a volume control to give volume changes such as crescendos, diminuendos and forte-piano effects. This is best controlled by the third finger of the left hand as the first three fingers of the right hand are employed with the manipulation of the rear three push-buttons. For the sub-octave notes the first and second fingers of the left hand are brought into play, so this will obviously limit the choice of positions for these contacts as they will need to be within easy reach of these fingers.

## CONSTRUCTION

The construction of the instrument is quite straightforward and, if made to the full size drawing given in Fig. 3 of the blueprint, it should resemble, as far as is practicable, an orthodox full-sized trumpet.

It is probably best to tackle the circuit first, building the note generator and amplifier on a piece of laminated wiring board (Veroboard) 3.75in × 2.5in with holes spaced 0.15in square. Before assembling any of the components on the board cut the corners at one end as shown in Fig. 2 on the blueprint. The amount to be cut off can be determined by counting the number of holes in the two directions and marking off with a sharp pointed scribe. With copper strips facing uppermost, carefully saw the unwanted piece off with a junior hacksaw. Remove any rough edges with a fine file. The board can be accommodated in the body of the instrument as shown in Fig. 3 on the blueprint.

Now with the copper strips uppermost cut the strips at positions 22C, 22E, 6I, 8K, 8J, and 3L (see Fig. 2) using the special cutting tool or a sharp knife.

## PANEL WIRING

Component assembly can be started now. It will be noticed that the layout of components on the plain surface follows a pattern very similar to the layout in the circuit diagram (Fig. 1). This is a worthwhile procedure which will help in circuit tracing.

Little more need be said about the wiring of the board except that care should be exercised in observing the polarity of the batteries, the connections of the transistors, transformers and electrolytic capacitors, otherwise irreparable damage may be caused to these components. Transistors TR4 and TR5 are fitted with copper cooling clips, obtainable from many component specialists for a few pence.

The connecting wires are passed through the holes and soldered to the appropriate strips. Some of the wires on the transformers will pass through the appropriate holes without bending and are shown on Fig. 2 as thick black dots on the transformer bobbins. Note the connections of switch S6a and S6b. These wires and those to VR5 (ganged in the same housing) should be stiff 18 or 20 s.w.g. and of such a length that the component is self supporting in the position shown in Fig. 3 on the blueprint. The plastic "tyre" is essential in order to project through the slot in the top of the instrument.

The rest of the wiring is straightforward and can be left until the main body of the instrument is completed. Nevertheless it is appropriate to clarify a few points at this stage. Make the lead-out wires from the board long enough to reach their various destinations and leave them attached to the board. The wires to the loudspeaker and mouthpiece contacts (S7) should be flexible; all others are single strand p.v.c. covered.

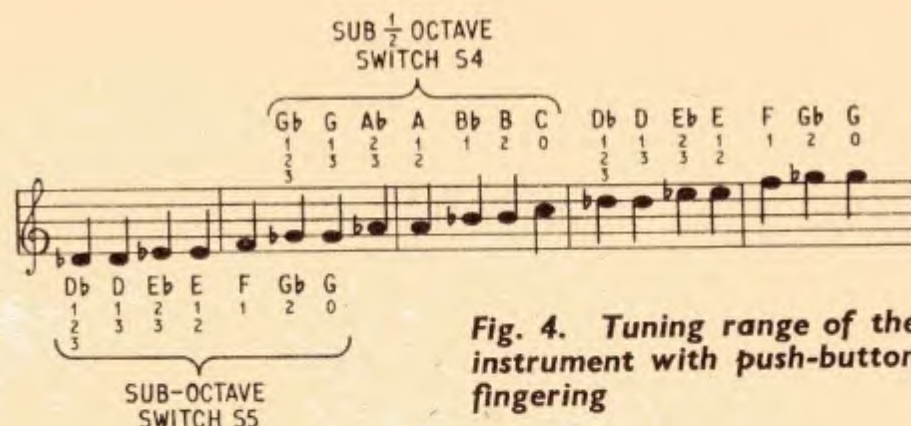


Fig. 4. Tuning range of the instrument with push-button fingering

Leave sufficient length of the flexible wires so that the loudspeaker and mouthpiece contacts can be pulled out of position for soldering.

## TRUMPET BODY

The body is made from wood, obechi and balsa being chosen from the point of view of lightness of weight and availability. Some care is necessary in handling the wood because it is fragile, but when the instrument is completed it is quite strong.

The two side plates are cut from 3in × 1/8in obechi to the size of those in Fig. 3, i.e. 2 7/8in × 11 7/8in overall, the ends being round to simulate the shape of a real trumpet. The top and bottom pieces are 9 1/8in × 1 5/8in and are glued in the positions shown. If one of the modern impact adhesives is used the glueing operation can be completed quickly and easily without the risk of the parts subsequently moving out of position.

The curved end pieces are made from balsa which, when soaked in water, can be bent to the required shape. Although these are specified as 1/8in thick, the prototype end pieces were made from two pairs of 1/16in thick balsa lapped and glued with balsa cement to form stronger pieces. Note that the direction of the grain of the balsa is across the width so that bending is made easier. These end pieces are butted and glued to the side plate also with balsa cement, which sets hard and forms a strong fillet. Notice the wood stiffeners round the inside of the body to strengthen the structure and, in some cases, acting as location guides for some of the components.

## COMPONENTS . . .

### TRUMPET HOUSING

#### Wood

- 3in × 0.125in × 2ft obechi
- 2in × 0.125in × 2ft obechi
- 2in × 0.125in × 1ft balsa (see text)
- 1/16in square obechi
- 0.25in × 0.0625in obechi
- 0.75in × 4ft half round ramin

#### Bell

- 4in diameter funnel
- Small plastic flower vase (Woolworth)

#### Mouthpiece

- 0.5in o.d. × 5in aluminium tube (thin wall)
- Water tap anti-splash nozzle (Woolworth)

#### Miscellaneous

- Paper backed gold foil, Evo-stik impact adhesive and balsa cement.

Electronic components are on the blueprint

## TUBES

The half round wood ( $\frac{3}{4}$ in wide) is cut and shaped to simulate the tubes of an orthodox trumpet. Note the grooves filed out to accommodate the push button knobs (see Fig. 3). Similarly four larger grooves are filed out to accommodate the potentiometers nuts on the underside. One end of one of the top "tubes" is hollowed out to leave a shell about  $\frac{1}{16}$ in thick or less, so that it can be fitted over the narrow end of the bell.

When the glue on the body work is firmly set, cut-outs are made with a sharp knife in the curved ends so that the bell fits firmly in the end as shown in Fig. 3. Fig. 5 shows the details of cutting the slot in the plastic vase; the top plate of the body fits into it. A hole is drilled through the top plate for the loudspeaker wires.

The vase is fitted over the narrow tube of a 4in plastic funnel and fixed with impact adhesive as shown in Fig. 5. The bell should now be complete and ready to be fitted in the end of the trumpet. It should be glued in position so that the half-round wooden "tube" fits over it (also by glueing) as shown in Fig. 3.

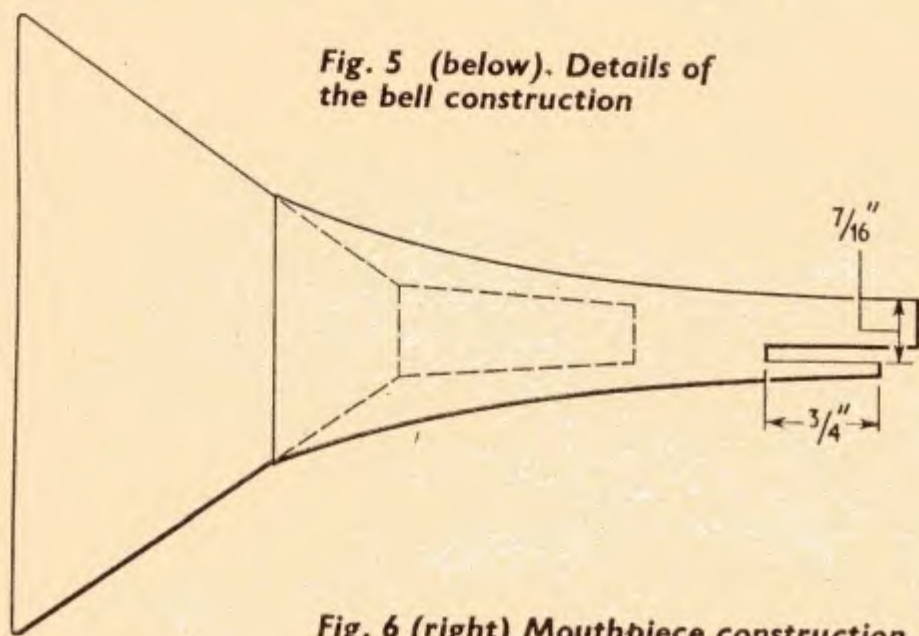


Fig. 5 (below). Details of the bell construction

Fig. 6 (right) Mouthpiece construction.

The half-round wood should project beyond the side edge by  $\frac{1}{8}$ in to allow the cover plate to be fitted underneath it. The other top half-round tube is shaped and the aluminium mouthpiece tube cut to fit the end (see Fig. 6). The other end of the aluminium tube is slotted as shown so that it can be force fitted in the mouthpiece nozzle. This is, in fact, an anti-splash water tap nozzle with the inner wire gauze removed.

Holes  $\frac{3}{8}$ in diameter should be cut in the bottom plate to take the potentiometers VR1 to 4 in the positions shown in Fig. 3 on the blueprint. Similarly the holes and slots in the top plate are cut to accommodate the push-button switch and volume control VR5. This is quite a simple operation if a small drill and sharp knife are used, but be careful not to split the wood, otherwise the structure will be weakened. The stiffener strips are worthwhile and should not be omitted if the strength of the instrument is to be maintained. A wood separator is glued to insulate the battery strips from the switch assembly.

Having completed the main body construction the cover plate can be fitted with two lengths of half-round wood (each  $2\frac{5}{8}$ in) glued in the positions shown in Fig. 3 on the blueprint. When the cover plate is mounted in position on the body the half-round pieces should fit firmly between the top and bottom plates, giving a strong instrument, with support to the top plate when the buttons are pressed.

## ASSEMBLY

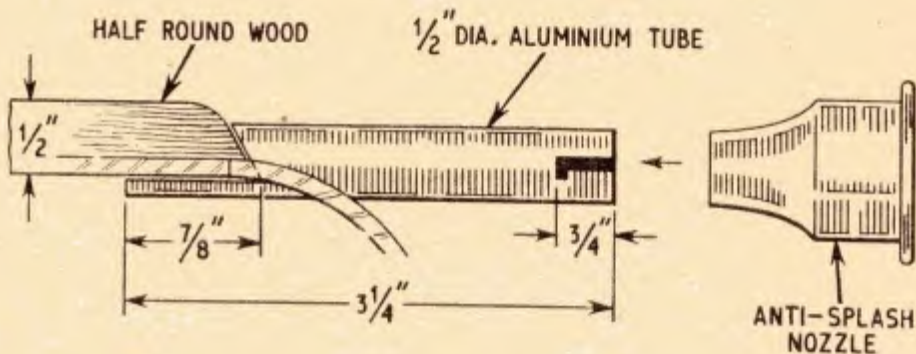
All that remains now is to assemble the components in the body and wire them up. In the circuit diagram (Fig. 1) on the blueprint, switches S1, S2 and S3 are shown "normal open". In fact they should be closed so that when no push-buttons are pressed VR4 should be connected to the collector of TR1, shorting out VR1, VR2 and VR3. The spindles of these potentiometers should be cut short and slotted for screwdriver adjustment. Make sure when wiring the push-button switch and VR4 that there is sufficient room to take the half-round supports on the cover plates.

The mouthpiece contacts were taken from a small relay and insulated from the metal nozzle with a rubber sleeve. The loudspeaker is fitted in the funnel and covered with a small piece of loudspeaker grille. Both of these can be held in position by glueing small pieces of rubber to the inside of the funnel.

The finished instrument can be painted or, as in the prototype, it can be covered with paper backed gold foil for a realistic effect.

## TUNING

Because the notes generated by this electronic trumpet have a complex waveform with harmonics, it is not easy to tune the instrument by ear, unless you have very sensitive hearing and are accustomed to such an operation. It is recommended that a "standard", such as a known tuned instrument or tuning fork, be used for the job.



Care should be exercised in adjusting the potentiometers one at a time, then cross check by referring to the scale shown in Fig. 4 and operating the appropriate combinations of push-buttons as indicated. Against each note shown is the operation sequence of the switches S1, S2 and S3. Switch S4 will lower the whole register by half an octave and S5 by a whole octave. With both S4 and S5 pressed together the register can be lowered by  $1\frac{1}{2}$  octaves so extending the whole range of the instrument to a total of two octaves. The values of C2 and C3 are fairly critical and a certain amount of experiment may be necessary to achieve the exact pitch required by selecting a suitable component from the approximate range shown in the components list.

Although some musicians find it easier to commence tuning from middle G or A, you should start on this instrument at top G. With all push-buttons in the non-operated condition adjust VR4 for top G. Next with S1 depressed tune for F, one tone below. Adjust VR2 with S2 only depressed. Now cross check by pressing S1 and S2 together; the result should be E, two tones below top G. VR3 is now adjusted to achieve D by pressing S1 and S3. By referring to Fig. 4 each note can be obtained to some degree of accuracy, but if adjustment of the potentiometers is critical they can be shunted with a resistor connected across each one of about 3.3 kilohms.



# the 73 page

by Jack Hum  
G5UM

## It's on the Record

On this page last time we discussed how the QSL card may be profitably used by the short-wave listening enthusiast as a means for sending reports to distant stations.

What we did not get around to covering was the important question: Where does the information come from that is to be written on the outgoing QSL card?

The answer: From the station log.

No doubt there *are* in existence, somewhere or other, enthusiasts who reach for a blank QSL card to send off even while they are still tuning in that exotic DX station. One would hardly number them among the *practical electronicians*. The methodical man keeps a station log both as a record of his activities and as good training for the time when he aspires to a transmitting licence—for then logkeeping will be obligatory.

Whatever the area of his interest—short-wave broadcast listening, reception on the amateur bands, even DX television (and there are more people that go in for this than you may think)—the enthusiast will see to it that his performance is put down on paper at the time it happens.

“At the time it happens”: this is important, too. Memory, like the sound of a signal, fades: that is one thing. Another is that a stipulation in the G.P.O. transmitting licence requires this to be done, requires the log to be entered there and then, not made up afterwards from odd jottings on scraps of paper.

## Essential Data

And what form should the log take? There are the basic “musts” of date, time (always in G.M.T.) and station received. These are the bedrock foundations of logkeeping. But it is necessary to build upon them if the record is to be an informative one—and “building” involves rather more than adding simply signal strength (in RST code, meaning

Readability, Strength, Tone), and a word or two about conditions prevailing at the time. For a glance back at a log entry a year or two afterwards can be a bald and unconvincing pastime if no more than the bare essentials are recorded.

Now it does not do to go to the other extreme of making every session with a communication receiver a trial-by-paper. After all, we are (most of us) in practical electronics for the pleasure we get out of it and too much documentation can detract from that pleasure. Even so, to get into the habit of embellishing the log with additional worthwhile information that will be pleasurable and instructive to read at a later date is to make one's radio reception sessions yield the fullest value.

To develop this point, the writer recommends the keeping of what he calls a narrative log. In this, dates, times and similar basics are included, together with frequency in use: but in addition a few notes are added by way of record of what the other man has to say over the air. These notes while naturally covering such things as the technical details of the equipment he is using will extend beyond them to the point of including news of local happenings (how his radio club is faring, perhaps, and what sort of lectures are being given there) and even embracing any personal information (family status, job and the like) he may feel inclined to give.

## “The Handle”

Then of course there is “the handle”—American slang for the forename.

To many older-time radio amateurs the current insistence on asking for “the name” is a thoroughly irritating habit. There are hundreds of Jims, Ivans and Fritzes among the world's radio amateurs, but only one G5XX or G8LM: “the name” is of little value as identification, the callsign everything. No-one else in the world has your callsign: thousands (probably) have your forename.

“I didn't catch the name” is often heard during the course of an amateur's “over”. His correspondent is nearly always too polite to reply:

“You didn't catch it because I didn't give it”.

We have some sympathy for the operator who, pestered by an Iron Curtain station to give his name,

rapped out “Montmorency” at about 25 words a minute in morse. Silence from the other side of the Iron Curtain.

A brusque brush-off, no doubt: and no doubt deserved.

No apology is made for this “nomenclative” digression: every tilt at the more fatiguing cliches of amateur radio is in the interests of saner operating.

## “Spotlighting” Entries

Back to the log: if “the name” must go in, the narrative record should include it.

To the transmitting amateur there is some merit in so organising the log that completed contacts are thrown up by underlining, while abortive calls are not. This facilitates totalling up the number of contacts made during the course of a month or a year, if a statistical analysis is required of activity on

1726	Called G2BIA						
1736	Called & worked G5FK	599012	HF	599031			
1740	Called & worked G3SHZ	599040		599032			
1748	Called G2BIA						
1750	Called & worked G2BIA	599017	HF	599033			
1800	Called & worked G3EVV	599064	Kent	599034			
1805	Called & worked G3TIB	599036	34	589035			
1808	Called G4CVR						
1811	Called G8DY						
1820	" G3IUF						
1825	" "						
1826	" "					145	1
1827	CP					144	7
1833	Called G3DY					146	1
1838	" "					144	7

A transmitting amateur's log showing how contacts made can be underlined to distinguish them from abortive calls. The columns, self-prepared, cover date and time, then station worked, with signal strength and location details, thirdly frequency used, followed by power input and mode (c.w. or telephony)

various bands. How this may be done is shown in the accompanying illustration.

Further information may be provided by the log if new stations worked for the first time are spotlighted by making a coloured pencil mark in the margin alongside the entry.

# the 73 page

by Ja

# THE PHYSICS EXHIBITION

MANCHESTER was the venue for this year's exhibition of the Institute of Physics And The Physical Society. This was the first occasion the exhibition has been held outside London. The choice of Manchester was an appropriate one. This city, with its world famous University (birthplace of the first electronic binary computer) and College of Science and Technology, is one of the foremost centres of scientific research and teaching in the country.

As on previous years, each item offered for display was considered by a panel of referees. Selection was on the basis of those instruments, pieces of apparatus or materials which were likely to be of special interest or use to physicists in the practice of their profession.

The exhibitors included 18 universities and colleges, 19 government departments and 90 manufacturers.

The recent advances in laser techniques was evidenced by a large number of exhibits in this field. One instance of a practical application was the miniature ruby laser used in eye surgery.

Electronics was naturally very well represented. A few examples are given below.

**High voltage acoustic telemeter.** In connection with the introduction of 25kV a.c. overhead traction on certain main lines, studies are being made of the dynamic behaviour of the overhead system and the locomotive pantographs. For this purpose, a high voltage acoustic telemeter has been developed by British Railways. Signals from a measuring transducer fitted to the pantograph or to part of the overhead system are amplified and then converted to sound waves by a crystal. The sound signal is transmitted down an 11in glass rod which acts as the electrical insulator, and is then reconverted to an electrical signal by a further piezo-electric transducer at earth potential. All circuits use transistors throughout. The carrier frequencies range from 3.9 to 7.2 kc/s, and the frequency response is d.c. to 50 c/s.

**Self-powered light sources.** Beta emissions from tritium gas are used to produce light from the phosphor-covered walls of glass tubes. The energy of these beta emissions is contained within the glass envelope. It is anticipated that these light sources will have a useful life of from 15 to 20 years. The principal use for these devices seems to be in illuminated signs and instrument panels. One considerable advantage compared with electroluminescence is that no polarising voltage is required with these Betalights.

**Thermionic triode converter.** A gas filled triode converter now in the development stage was shown by Fairey Engineering Ltd. This company has for some time been collaborating with the Imperial College of Science and Technology in design study work on static devices in which heat energy could be converted directly into electrical energy.

**Ultrasonic communication.** The possibilities of coding ultrasonic transmission by modulation techniques have hitherto been rather neglected. Gulston Industries Ltd. demonstrated tone telemetry with selective calling permitting multi-channel control. Modulation of the ultrasonic wave by speech frequencies was also demonstrated. This seems likely to have a future as a "licence free" communication system requiring no wires.

# GOLDEN JUBILEE OF PUBLIC ADDRESS

P.A. IS FLOURISHING! This was the impression given at the Golden Jubilee Public Address Exhibition held at Harrow-on-the-Hill by the Association of Public Address Engineers. There was a congenial atmosphere, a friendliness and an efficiency of organisation which is seldom experienced to such a degree as it was on this occasion.

Perhaps it was due to the environment of the King's Head Hotel on top of the hill; perhaps it was the fact that we were celebrating 50 years of public address. But deep down one gets a feeling that this was more than just another exhibition, more than just a group of manufacturers trying to sell their wares.

Indeed nostalgia played a great part as the occasion was honoured by the presence of His Excellency, Albert Kønigfeldt, Chargé d'Affaires of the Danish Embassy in London. In opening the exhibition His Excellency acknowledged the consideration given by the A.P.A.E. in associating the name of Paul Jensen with the exhibition. Paul Jensen founded the "Commercial Wireless and Development Company" with Edwin Pridham in 1913. Under the changed name of "The Magnavox Company" they discovered the characteristics of the moving coil principle, and in 1915 built a dynamic loudspeaker using a one-inch voice coil and a three-inch corrugated diaphragm coupled to a horn about 34 inches long. They connected a heavy duty carbon microphone and 12 volt battery to the system and set up a violent acoustical feedback—the first case of P.A. howl. With the loudspeaker set up on the roof clear speech was heard one mile away.

After further experiments the "Magnavox" system was officially presented as a working system to 100,000 people who heard carols and speeches on Christmas Eve 1915. So P.A. was born and, although both Jensen and Pridham have since died, their early pioneering will long be remembered by P.A. engineers.

One of the most up-to-date developments in P.A. is the installation of sound reinforcement in the Royal Festival Hall. The type of equipment used in the Hall was exhibited together with the latest designs in equipment used for many indoor and outdoor functions.

In one of the lower rooms there was a display of equipment used many years ago including very early telephone sets and an original Magnavox horn loudspeaker as used by Jensen and Pridham for their pioneering effort. The sheer size and weight of some of the older gear would make one's eyes boggle!

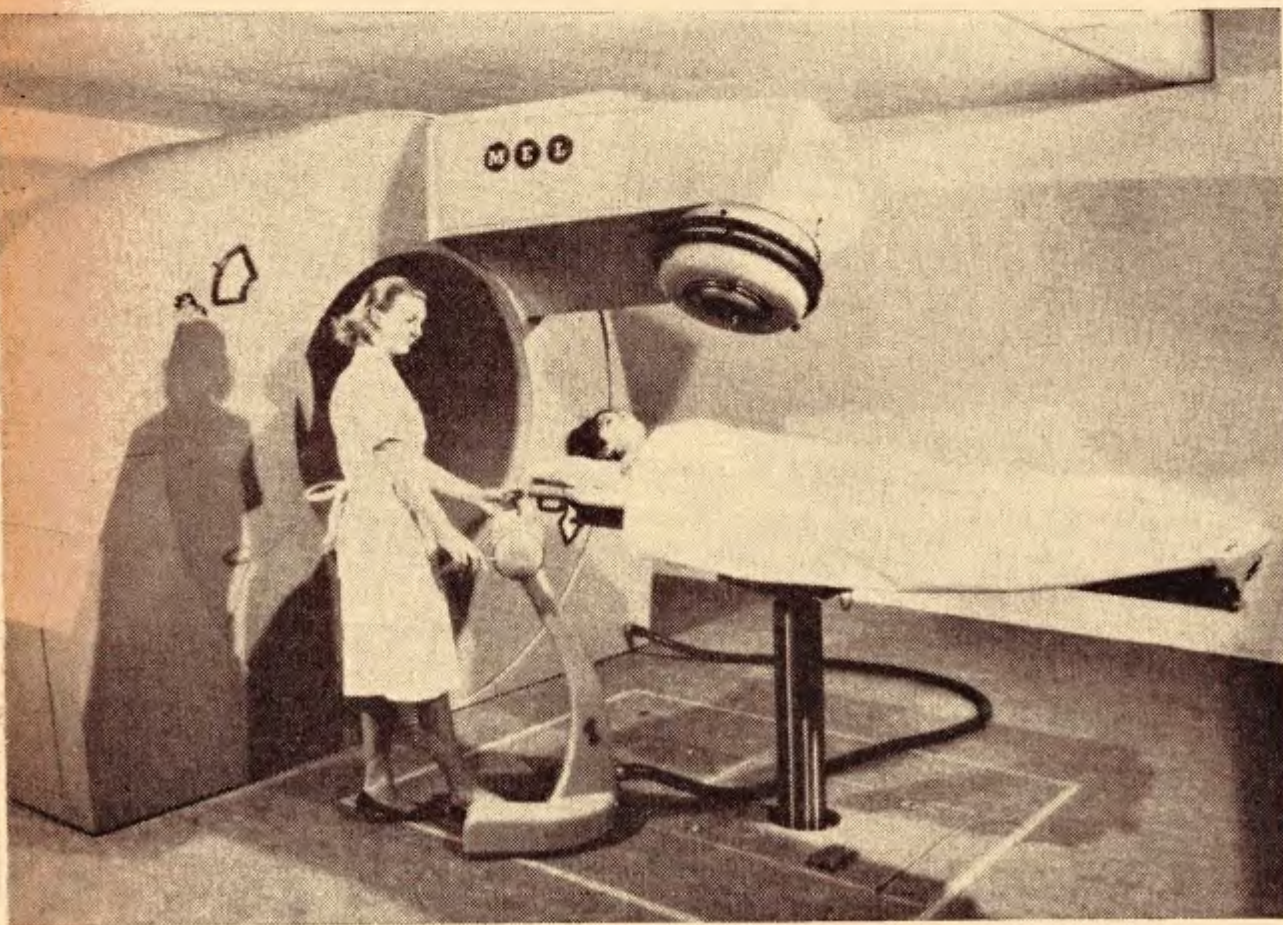
A special feature at the exhibition was the two way link with P.A. engineers in the U.S.A. during which reminiscences of the early days were exchanged.

The retiring President's Dinner in the evening of the first day was well attended. Mr. Frank Poperwell made reference to the very happy and successful year he had enjoyed as President. The newly elected President is Mr. Robert Owen, proprietor of Reosound Engineering and Electrical Company.

One final note which we quote from the Association's Journal: "A town in France decided to do something about the menace of NOISE, and trying the usual methods of trying to get things quieter without success, decided to engage a local P.A. man—to go round the streets with mobile P.A. telling the inhabitants to be quiet. Well it's one way of getting over a problem!"

# ELECTRONORAMA

## HIGHLIGHTS FROM THE CONTEMPORARY SCENE



### Life Saver

**A** NEW British machine, a medical linear accelerator designed and manufactured by The M.E.L. Equipment Company, for the x-ray treatment of cancer is being installed for the Rotterdam Radiotherapy Institute at the Daniel den Hoed Hospital in Holland.

The accelerator and x-ray head extend from an annular drum and rotate in a complete circle about the treatment table.

Earlier machines, which were of different construction, were restricted to 220 degrees rotation. Now, the x-ray beam can be directed from any angle, so enabling the patient to be treated while lying in one position.

The new machine has an x-ray beam energy of 6MeV (6 million electron volts). A "super" version is also made with an energy of 8MeV. These energies are considerably higher than the 4.3MeV of earlier models, and give increased percentage doses to deep seated malignancies. In consequence, the entrance dose given to healthy tissue is reduced and at the same time the exit dose is still sufficiently small to avoid the skin reaction induced by higher x-ray energies. The maximum electron energies are 8 and 10MeV for the standard and "Super" models respectively.

The electron beam is magnetically deflected through 90 degrees to strike a transmission type gold target. The resulting x-ray output after collimation and flattening is 400 rads per minute at one metre in air. The waveguide system is virtually sealed off and a high degree of vacuum is maintained by ion pumps.

The picture shows the radiotherapist setting up the machine prior to treatment.

### Bump in the Night

**S**CIENTISTS working at Downey, California, are trying to find out the effects of severe drops and jolts on airborne astronauts. To aid this research, special dummies called ANDY have been created to simulate human beings.

Sensitive electronic instruments inside the dummies record the tensions that spacemen would be subjected to when flying through space. This project is part of the "Apollo" programme designed to place man on the moon.

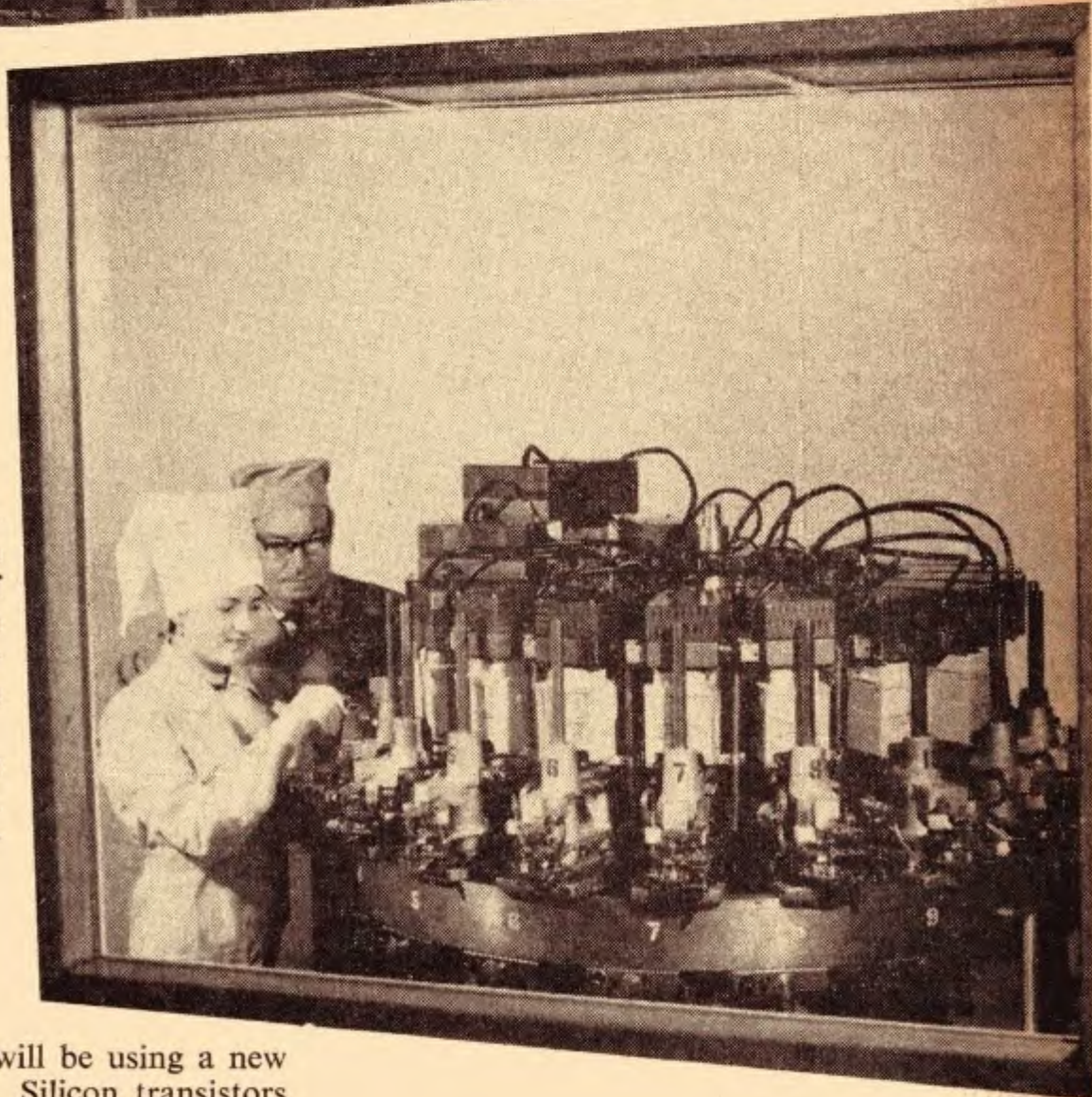




### Clean Air Zone

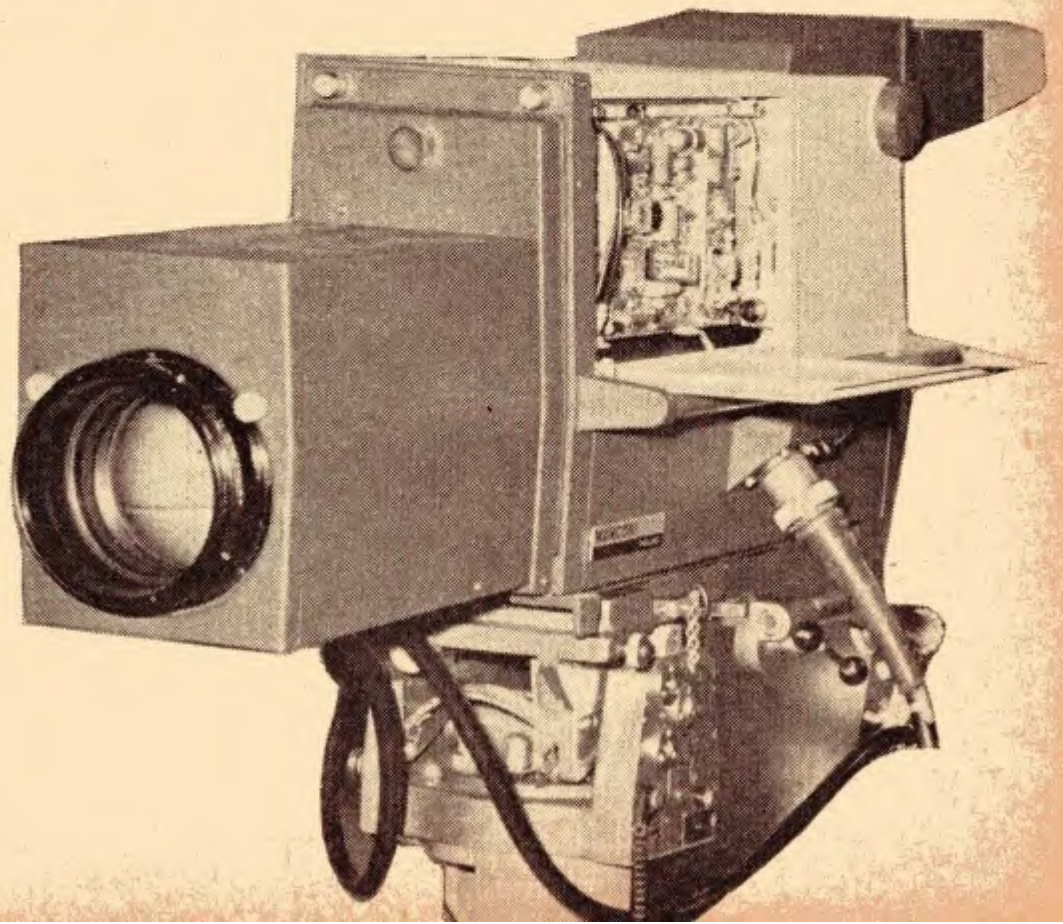
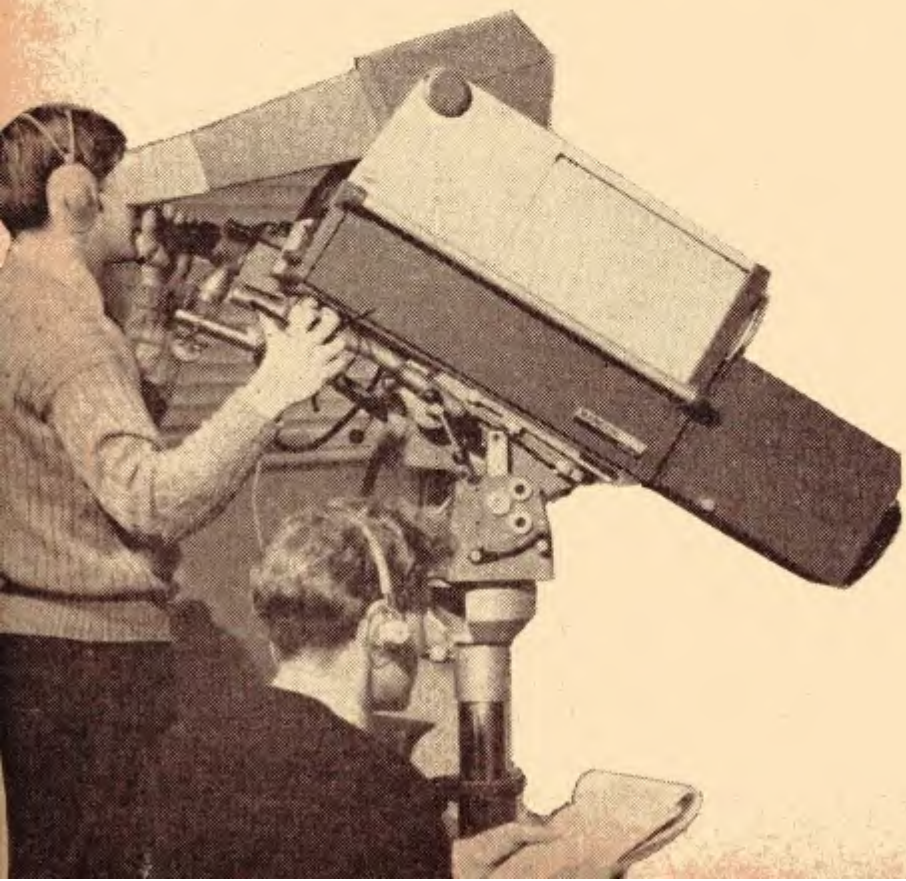
**D**RY-REED relays and sealed relays have to be manufactured in conditions of extreme cleanliness. In fact, if you were to be invited to the Relay Division of Elliott-Automation's Willesden factory you would have to wear special clothing to enter this inspection and assembly room where Clare-Elliott mercury-wetted contact capsules and relay assemblies are produced by the millions.

The machine shown on the right produces three million dry-reed capsules a year also in stringent air conditions. Elliott's claim that these types will never be entirely superseded by transistors.



### Zoom!

**S**OME OF the largest independent television companies will be using a new type of camera developed by The Marconi Company. Silicon transistors have been used providing greater stability and reliability. This model (Mark V) incorporates a tilting viewfinder with greater luminance, integrated zoom lens with variable adjustment of focal length, 4½in image orthicon tube, and plug-in modular circuitry.

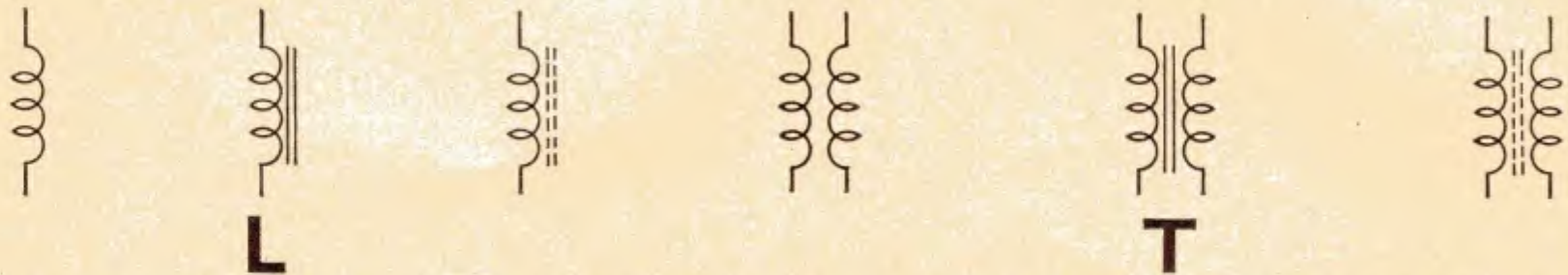




# BEGINNERS start here...

8

## An Instructional Series for the Newcomer to Electronics



Circuit symbols for inductors (L) and transformers (T). The three variations of each symbol indicate the type of core (if any). The basic symbol denotes no core or "air core", the second symbol denotes laminated iron, and the third an iron dust core.

WE come now to a rather subtle point in this electromagnetic induction business, which has quite a few consequences. This is the fact that induced currents made to flow by a changing field are set up in the same coil that produced the magnetic field in the first place, see Fig. 8.1.

### SELF-INDUCTION

It is important to remember that induced currents always flow in a direction which opposes the changes in the main current. In other words, if a voltage is suddenly switched across a large coil, the current is sluggish in building up. But once the current is flowing, then at the switch-off it tends to carry on flowing.

This effect is known as *self-induction*, and is the property used in inductance coils, chokes and so on. Components made especially to produce this effect are known as *inductors*.

Some inductors are simply coils of wire, but others are wound on iron cores. The presence of an iron or ferrite core concentrates the magnetic effect and therefore increases the self-inductance of the coil.

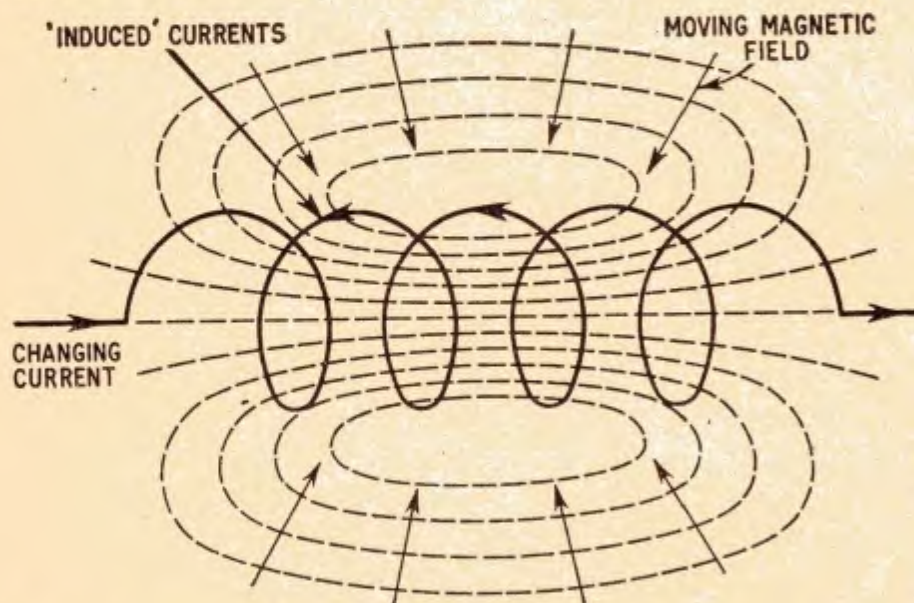


Fig. 8.1. As the field moves, the induced currents tend to flow against the changing current, and thus tend to prevent the change. Self inductors are often called "chokes" when arranged to do this job

### THE UNIT OF INDUCTANCE

Inductance, both *mutual* and *self*, is measured in terms of a unit called the Henry—symbol *L*.

A coil has a self-inductance of one henry if the applied voltage is one volt when the current is changing at the rate of one ampere per second.

For many of the applications in electronics, the henry is inconveniently large, and inductance is usually given in submultiple units such as

1 millihenry (mH) = one thousandth of a henry

1 microhenry ( $\mu$ H) = one millionth of a henry

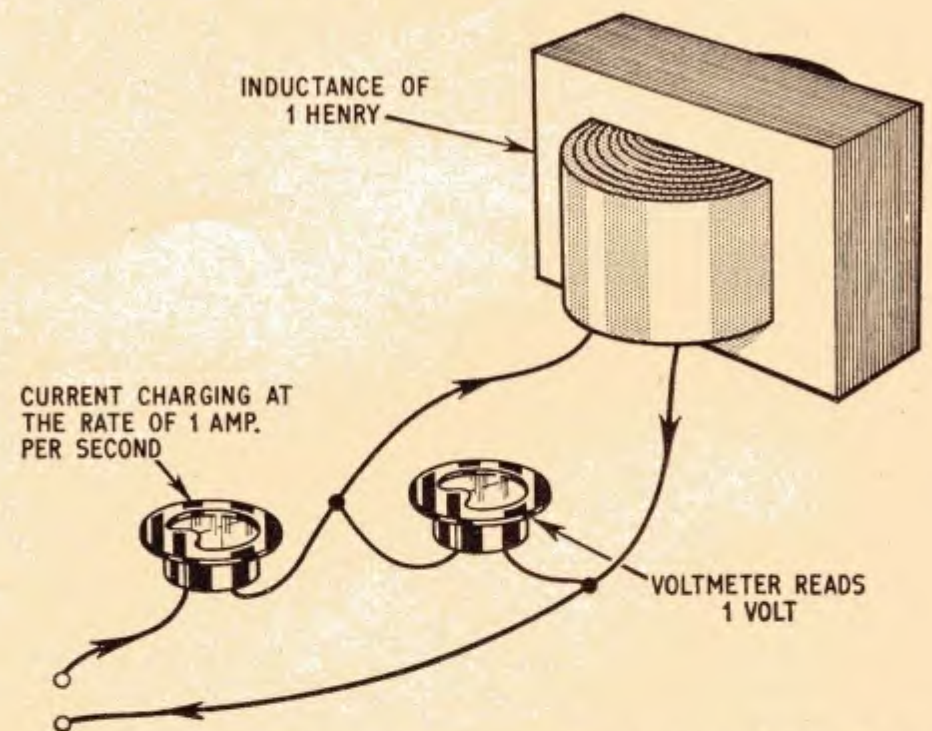


Fig. 8.2. An inductance of one Henry is a fairly large value. Notice that it is the change in current which produces the change in the field, which then induces the one volt e.m.f. across the coil

Fortunately, it is easy to add up separate inductors in series—it is the same as resistors—i.e.

$$L_T = L_1 + L_2 + L_3 + \dots$$

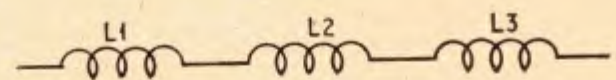


Fig. 8.3. Inductors in series

and in parallel,

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \dots$$

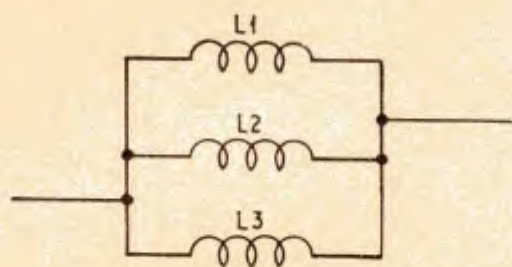


Fig. 8.4. Inductors in parallel

but note that the separate magnetic fields must not link together for these formulae to work with accuracy. Remember that capacitors add in the opposite way.

### PRACTICAL WORK

For our experiments with electromagnetism and induction, a fairly large coil is required, together with an iron core. The core can be salvaged from a mains transformer, which can be obtained by a search in the local junk shops such as those stocking secondhand radio chassis or ex-government units. It should not cost more than a few shillings. There may be a suitable transformer lying in your electronic "odds and ends" box, or in the bits cupboard of the school science room.

The iron laminations that make up the transformer core are shaped either "T"s with "U"s, or "E"s with "I"s. Both types can be put to use in the experimental work here described.

Ideally, the windings on the transformer can be put to immediate use, if you are lucky enough to obtain an old type in which the separate coils are wound in sections which can be slid off one at a time. Otherwise the coil from an old "mains energised" loudspeaker magnet could be put to use.

Failing these methods, a coil can be wound on a home-made bobbin as shown in Fig. 8.5. Make the bobbin out of very stiff cardboard or "paxolin". The centre should fit comfortably (not tightly) over the laminations and its length should be about half the length of the centre limb of the core. The end cheeks can be glued onto the centre piece, and their size should be such as to allow the "E"s or "U"s to go over the coil. Fill up the bobbin with 2,000 turns of 28 s.w.g. enamelled or cotton covered wire and you have the main coil ready.

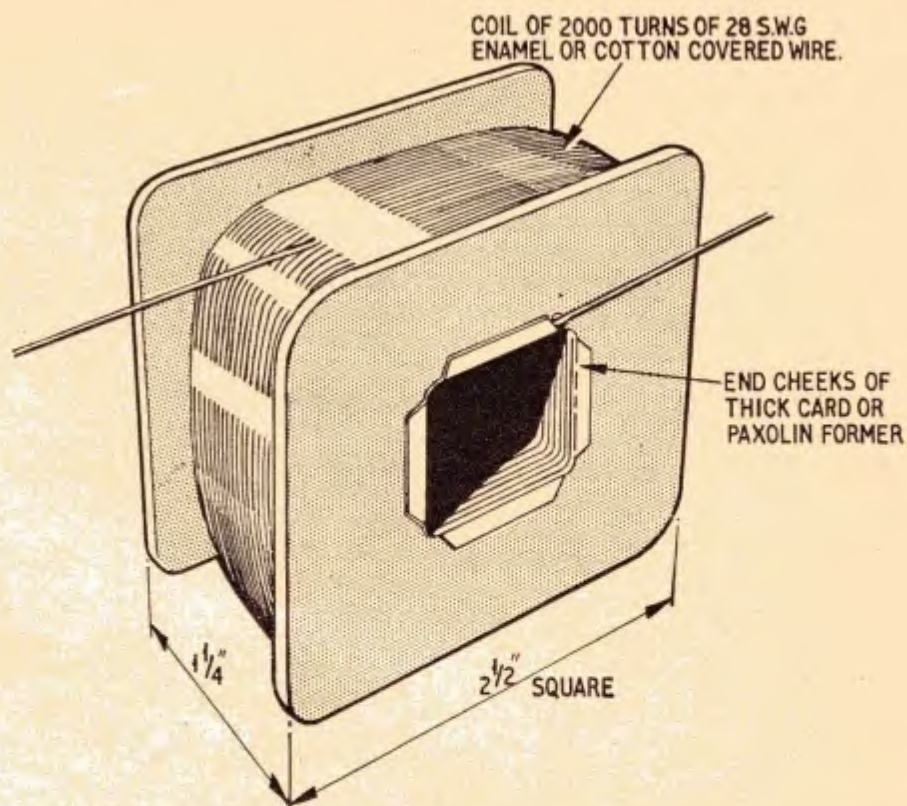


Fig. 8.5. The coil for induction experiments. It can be wound conveniently by using a hand drill brace held in a vice, with the former held in the chuck by means of a wooden block and screw

### EXPERIMENT NO. 1

Push a fairly strong magnet into your coil after you have connected it by long leads to the galvanometer described earlier in this series. If the magnet is strong enough and the coil has enough turns the galvanometer needle should show a deflection and therefore convince you that an electric current has been produced.

If no deflection is observed, connect up a sensitive meter such as a 1mA moving coil type and try again. (Perhaps at the school science room?).

Further experiments with this coil will be described next month. In the meanwhile time is available for you to construct this simple apparatus.

As we have mentioned, inductive effects are present all the time in any electrical circuit (as of course, are capacitive effects) and it is very useful to develop an awareness of these "built in" stray components. The strays cannot be seen as such, and do not start to be noticed electrically until high frequency, or fast waveform operation is being used.

In future articles we shall have a look at the construction of common types of inductors and then go on to study the effects of alternating currents.

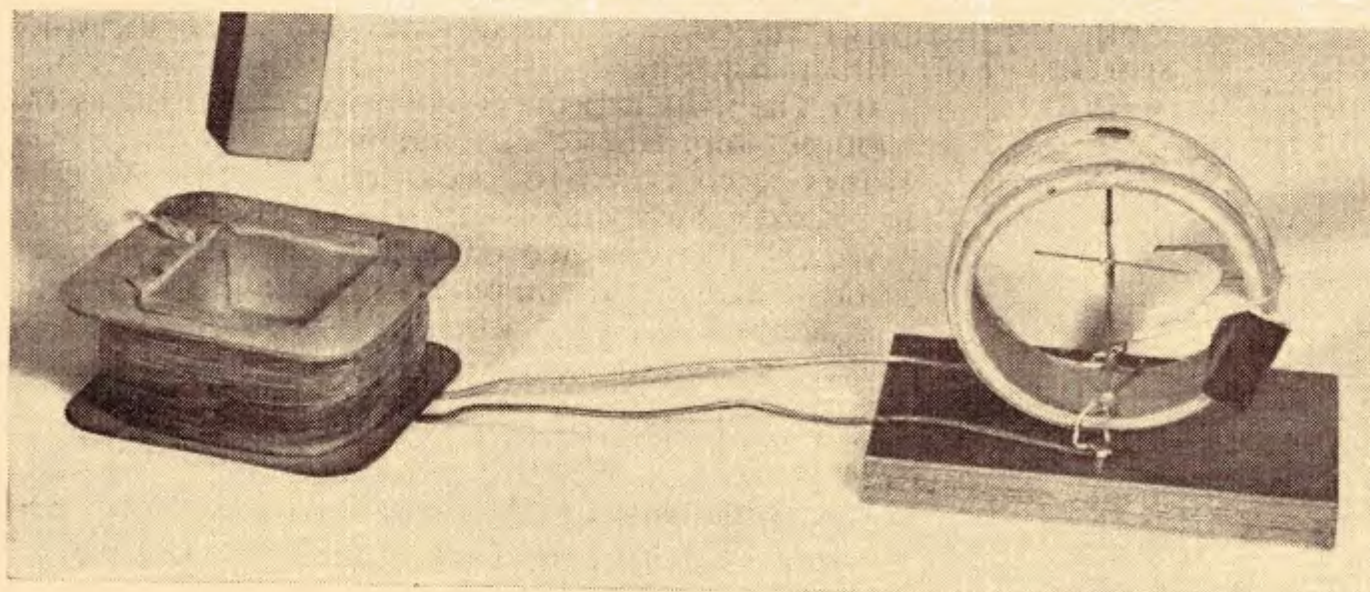


Fig. 8.6. Faraday's experiment. Try both ends of the magnet, moving it slowly and then faster. Quite a number of effects can be noticed. The simple home-made galvanometer was described in the third article of this series (January issue)



# VOICE DISPLAY UNIT

BY J HERMISTON



INTEREST has recently developed in an application of electronics to the problem of teaching deaf children to speak intelligibly, by means of an instrument known as a voice display unit or "calligraphone".

It will be appreciated that a profoundly deaf child cannot hear the sound he or she produces, and therefore has no aural means of monitoring these and modulating them as required to produce intelligible speech. The unit here described presents voice sounds as recognisable patterns on a cathode ray tube, enabling the child to experiment with voice modulation and pitch until the correct pattern is obtained for a given sound. In addition, the size of the pattern is related to the volume of the voice input, so that useful training in breath control can also be given.

## PRINCIPLE OF OPERATION

The basis of operation is comparable with the generation of Lissajou's figures in that an amplified audio signal is fed into a resistance-capacitive network which divides it into two attenuated components having a 90 degree phase relationship (Fig. 1). A purely

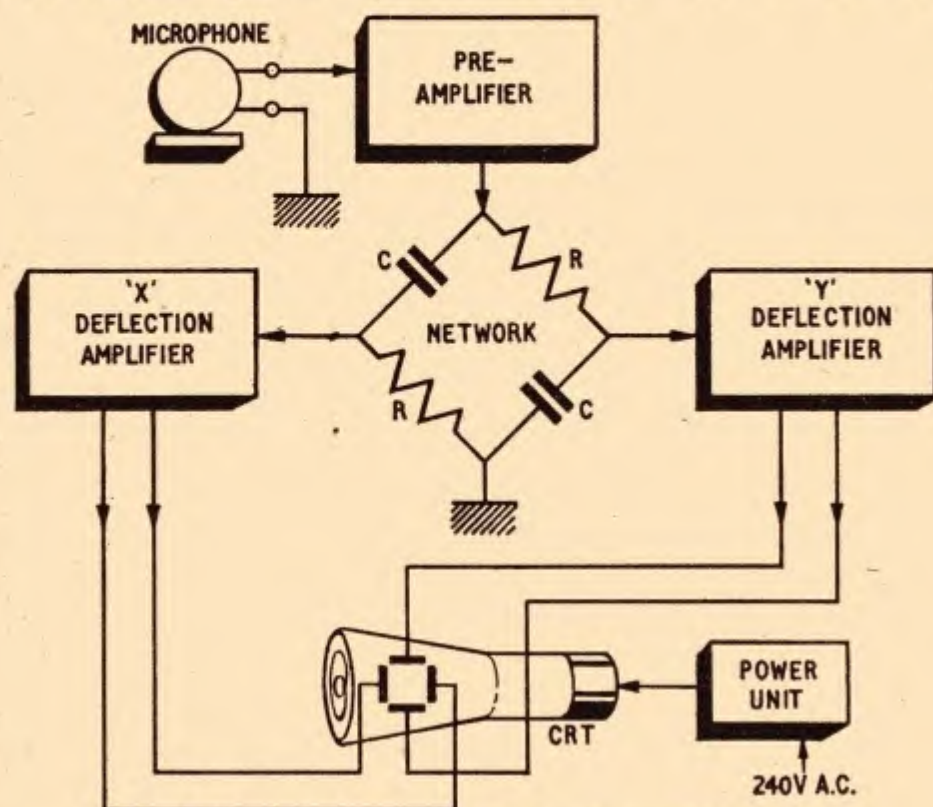


Fig. 1. Block diagram of the voice display unit

sinusoidal input, i.e. without harmonics, produces a circular trace provided the c.r.t. deflecting amplifier gains are adjusted to compensate for the difference in X and Y plate sensitivities and attenuation of the divided signals. The presence of harmonics, as in normal speech sounds, distort this basic circle into figures characteristic of each sound.

The basic requirement is clearly that each figure should be simple, preferably a single trace, consistent and sufficiently stable to be easily recognisable by a child, when comparing it with the teacher's correct figure or some form of chart. For several speech sounds these requirements are met in practice and typical figures obtained are illustrated in Fig. 2a.

## USING CONVENTIONAL EQUIPMENT

Quite useful results can be obtained using either a reasonable audio amplifier with microphone input facility, or microphone pre-amplifier with low output impedance, and an oscilloscope with fairly high input impedances.

One such set-up used by the author comprised a conventional 10 watt push-pull amplifier with crystal microphone input and a 5in oscilloscope with input impedances 30 megohm/31pF and 2.9 megohm/21pF, and sensitivities 50mV/cm and 10mV/cm r.m.s., for X and Y respectively. The phase shift network arrived at was 350 $\mu$ F/30 ohms, and it will be noted that this fulfils the following criteria:

- The joint impedance is well below the input impedance of the c.r.o.
- The crossover frequency is well below the voice frequency range.
- The joint impedance approximately matches the output impedance of the amplifier.

However, condition (c) does not appear in practice to be particularly vital.

Others have reported on results obtained, here and in the U.S.A., with equipment of a similar nature, or with adapted television sets, and references to some of the relevant papers are given at the end of this article.

## PURPOSE-MADE UNIT

In building a completely self-contained unit simplicity, suitability for day-to-day use in schools and low cost are prime requirements as is the necessity for adequate protection where children are concerned.

An experimental unit was built with results comparable to those obtained with the conventional equipment previously referred to (see heading photograph).

The front controls were limited to brilliance, focus, gain (pre-amplifier only) and on/off switch. Other controls were fitted internally and pre-set or replaced with fixed resistors determined by trial and error.

From the block diagram (Fig. 1) it will be noted that neither time-base nor triggering circuits are required and it has been established that very high quality amplifiers are not necessary and may even be detrimental to the production of good single trace figures. In fact under certain circumstances it was found that much improved figures were produced with an old 6in elliptical loudspeaker directly coupled to the pre-amplifier input, i.e. compared with multiple traces displayed when using the microphone.

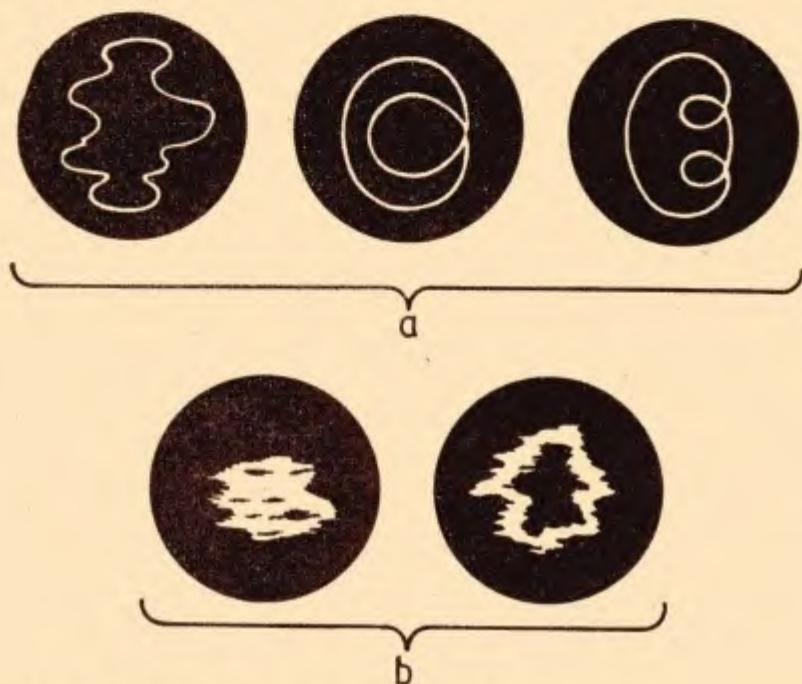


Fig. 2. Lissajou's figures of voice sounds  
(a) Simple single trace line figures  
(b) Complex sound traces simulating 'SS' and 'ZZ'

### PRE-AMPLIFIER

To allow scope for experimenting with various R and C values in the network a low output impedance for the pre-amplifier was sought. A circuit with cathode follower output stage ( $\frac{1}{2}$  ECC83) was adopted and gave a  $Z_{out}$  value of 600 ohms which proved satisfactory.

### THE NETWORK

Combinations of R and C were chosen to give cross-over frequencies ranging from 15 to 400c/s and all produced reasonable results. However, it was found that very similar figures were in some cases produced with different sounds, but this occurred with alteration of the crossover frequency and considerable modification to voice pitch.

The conclusion thus reached was that only one network should be used for any one instrument and there is no universal chart of correct sound patterns which could apply whatever the network and whatever the pitch. This, however, may not be a disadvantage, since it can be used as a means of improving the pitch of the voice to match the teacher's pitch.

R at 100 kilohms and C at  $0.1\mu F$ , as originally suggested<sup>1</sup>, were found to be as good as any.

### DEFLECTING AMPLIFIERS

Input grid resistors of 2.2 megohms were found to have negligible shunting effect on the lower arms of the network.

Balanced output for the deflecting amplifiers, coupled with low current demand, was obtained with push-pull class A triodes (ECC83). Using a 320V h.t. supply adequate linear voltage swing was obtained for a 6in type VCR97 (ECR60) c.r.t. with reduced e.h.t. from a 1,000 volt transformer secondary.

### CONCLUSION

For those readers with a supply of odds and ends and who are willing to spend time searching through the surplus equipment available, an instrument of this type can be constructed for less than £10.

It will be appreciated that in its simple form, the equipment is only suitable for the indication of sustained sounds—although even this is of considerable value. The figures illustrated (Fig. 2b) for certain sounds such as SS and ZZ are characteristic and identifiable, but clearly they are less satisfactory than the single traces. By other means, including the use of c.r.t.'s with long-persistence screens it may well be possible to display fleeting sounds such as the explosive consonants P and T.

It does appear that the Voice Display Unit has a future as a useful supplemental aid, in the context of a comprehensive speech training programme making use of all the established methods. It should offer plenty of scope for the exercise of electronic ingenuity and know-how, in a very worthwhile cause.

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# DETACHED PARTICLES

By John Valence

## JUST A WORD

ONE day, it is certain, the word transistorised will become superfluous. Already the greater preponderance of electronic equipment uses transistors and we are rapidly approaching the stage when it will be more sensible to apply a distinctive label to equipment using valves—such equipment being the exception rather than the rule.

So perhaps before long we will be referring to *valved* equipment, and dropping the *transistorised*. The latter has never seemed to me a particularly attractive word, anyhow. Also I feel it would be a good idea if this change came about before the even more unwieldy term *semi-conducted type* become widely adopted. The well known manufacturer who applies this adjective to a certain microwave relay system that uses no thermionic valves is being a bit too pedantic. If one wants to cover the fact that diodes as well as transistors are included, why not use the adjective *solid-state*. This is surely more euphonious and less laboured than the expression *semi-conducted*.

## TIED DOWN

THE very ease with which a plug can be fitted into the ubiquitous mains supply outlet is not without dangers. A particular hazard I am thinking of at present concerns the long flexible cable necessitated by certain mobile apparatus. One example that is especially topical at this time of the year is the electrically powered lawn mower.

This seems to be one of the rare cases where mains operated equipment has but dubious advantages. If your lawn is large enough to warrant a powered machine, the chances are that the resultant cable will be much too long for comfort and safety!

I am therefore glad that one manufacturer at least has brought out a mower powered from a car type battery. A rectifier unit is built in and the battery can be recharged overnight from the mains supply. Incidentally this must be one of the

few occasions when the weight of the lead acid battery is actually of some purpose.

## DOMESTIC SCIENCE

ALL this is really a digression. What I really had in mind was the domestic machine now being developed in London University and about which you may have read in the national press a little while ago. This automated maid will do most of the household chores like cleaning floors and carpets and clearing up the table; it or "she" will even walk upstairs to make the beds and (once a week) change the linen.

It all sounds quite familiar and yet still fantastic. But I was rather disillusioned to learn that the machine would require a trailing mains cable. Somewhat a let down, me thinks. One would expect such encumbrances as cables to be dispensed with in the case of highly advanced equipment of this nature.

Why should not the machine contain its own power source? At the end of a tour of duty, it could then toddle back to a cubby hole, plug itself into the mains and so recuperate for the morrow.

## THOSE TORTOISES

IN this connection one's mind goes back to the electronic tortoises designed by Grey Walter some 15 or so years ago. I expect some readers will recall seeing these synthetic animals demonstrated on television.

Light is the food these "animals" exist on. As the voltage of the internal battery falls below some critical level the mechanism is set into motion and the tortoise moves around seeking light, adroitly avoiding obstacles on the way. The photocell sensing device eventually guides the tortoise to a "hutch" where it plugs itself into the mains and recharges its accumulator.

Designed and built before the transistor had been invented, these "animals" were more than a scientist's toy. They were the first really successful attempt to produce a machine that could think and act on

its own accord. They heralded the beginning of cybernetics, the science that has brought us the modern computer among other things.

## ROVING EYE

WELL, it was no great surprise that the international television conference in Vienna failed to come to a decision on a standard colour system for Europe.

It was significant that the BBC Director of Engineering when interviewed on TV after his return from the conference did not mention SECAM. Restating the British view that NTSC was the best system, the BBC representative conceded that the German PAL system was a close runner-up, and would be second choice; the French system, which happens also to be the Russian choice, was apparently not even in the race!

So the gulf widens. With two systems in operation there are headaches ahead for British set manufacturers if they hope to secure a large part of the Eastern European market for colour receivers.

Still, do not despair, for the CCIR meets again next summer—in Oslo. And they say travel broadens the mind.



Have you been at the a.c. supplies again?

FOR amateur and science teacher alike the study of radioactivity has been made a practical proposition with cheaply and easily made instruments employing the Geiger-Müller (G.M.) tube.

Results obtainable with suitable circuitry can be fairly accurate and well within the limits required for health physics monitoring or educational experiments.

The silicon surface barrier (S.S.B.) detector is offered as a possible alternative to the G.M. tube in this respect, but certainly not as a complete replacement. Indeed it has considerable advantages over the G.M. tube and only one real disadvantage in the type of application envisaged here.

Until recently such devices were of little practical interest to the amateur or teacher due to their prohibitively high price which was not compensated for by their advantages over the G.M. tube. However, small units are now available at a price comparable with the G.M. tube and of a form ideally suited to the needs of modern physics teaching.

For the benefit of the prospective constructor unfamiliar with this device the following simple comparison of its operation with the G.M. tube should throw some light on the reasons for and against its choice as the basis of a radiation measuring instrument.

effects until the whole length of the anode is surrounded by a "sheath" of ionised gas.

So great is the speed of the electrons in comparison with the relatively massive ions that all have been collected on the anode almost before the ions have begun to move. The wire is therefore left surrounded by a positive field distributed over a much larger radius than the wire and therefore the intense field conditions in the tube are reduced and the action ceases.

The ions then drift rather slowly across virtually the whole radius of the tube towards the cathode, inhibiting by their presence for a considerable part of this collection time any further avalanche. This "dead time" as it is called is of the order of  $200\mu\text{S}$ . The negative going signal pulse seen at the anode is composed mainly of two parts. One is a small initial rise due to the electrons being collected from very near the wire and then the major component of the signal induced by the receding ions.

In a self-quenching counter a quenching gas is present in small quantities to neutralise the ions which might otherwise react with the cathode on impact and produce further discharges. It should be remembered that this entire process can be initiated by the formation of a single ion-pair in the tube.

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## A SOLID-STATE RADIATION DETECTOR

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By D. V.  
SMITH

### THE GEIGER-MÜLLER TUBE

A description of the action of the G.M. tube provides a good starting point for a comparison of this nature, mainly because most people being more familiar with the G.M. tube will think of the S.S.B. detector in terms of it and might in some circumstances encounter pitfalls as a result.

It is assumed, of course, that the G.M. tube is operated under the correct conditions of voltage, i.e. in the "plateau region" which is that portion of the count rate versus e.h.t. curve which exhibits the least change of count rate with change of e.h.t. in a fixed radiation field. (Fig. 1.)

When particulate radiations, that is beta particles, enter the active volume of the G.M. tube, some of the atoms of the filling gas are ionised, the electron-ion pairs so formed being separated by the applied voltage field. The positive ions will drift in the direction of the negative cathode and conversely the electrons to the positive anode.

For most gases used the amount of radiation energy required to create an ion pair is about 30 electron-volts (eV). The number of ion pairs initially formed therefore will depend ideally on the total radiation energy dissipated in the gas by collisions.

The freed electrons drifting towards the anode in the applied field gain kinetic energy due to the field, only to lose most of it in colliding with, but not ionising, the gas atoms barring their passage. However, when the electrons get very close (1mm, or so) to the anode wire the very high field conditions brought about by the small size of the wire radius compared with the cathode radius cause them to accelerate rapidly and attain sufficient energy to ionise the gas atoms with which they collide. The electrons released in this way cause further ionisation in their turn until an "avalanche" of electrons reach the wire. This avalanche, it is believed, causes other avalanches by means of photo-electric

### THE S.S.B. DETECTOR

The S.S.B. detector is to all intents and purposes a silicon diode which must, for reasons to be discussed, have a very low reverse leakage current characteristic within its working voltage range. The forward characteristics are of little interest as the device is normally operated under reverse-bias conditions.

The arrangement (Fig. 2) is essentially the same for most S.S.B. detectors. It consists in this particular case of a nickel outer shell containing a small slice of *n*-type silicon which is exposed to the radiation via an end window. Over this area of silicon a thin film of gold is deposited which fulfils two purposes. Firstly, it forms a light shield as the silicon diode is sensitive to incident light in the same way that a transistor is if its outer case is damaged. Secondly, the gold being a good conductor of electricity effectively shields the silicon from interference and also completes the conductive path from the outer shell to the *p-n* or rectifying junction created on the surface of the silicon by a naturally formed oxide layer.

On the opposite face of the silicon is an aluminium back contact which is purely resistive, that is, non rectifying. To this contact is applied the positive bias via the signal lead which is taken out through an anchoring cement in the lead-out hole. The body is threaded 4 B.A. for ease of connection and mounting.

It is worth noting at this point that the most vulnerable part of this otherwise extremely robust device is the gold window which can be irreparably damaged by careless fingering. For this reason it is worth while leaving in position the small piece of plastic sleeving supplied with the unit which will tend to prevent damage while not affecting for most purposes the use of the unit.

When a bias is applied to the detector the electric field within the silicon causes the very thin charge free layer which exists immediately behind the gold to

be expanded. It can be visualised as the volume between the gold and a positively charged surface which moves away from the gold layer like a piston in a cylinder according to the amount of bias applied.

This, of course, is virtually a variable capacitor and indeed it is this very effect which is employed in voltage-dependent capacitors. We shall see later that the change of capacity with bias is an important consideration in the use of the device.

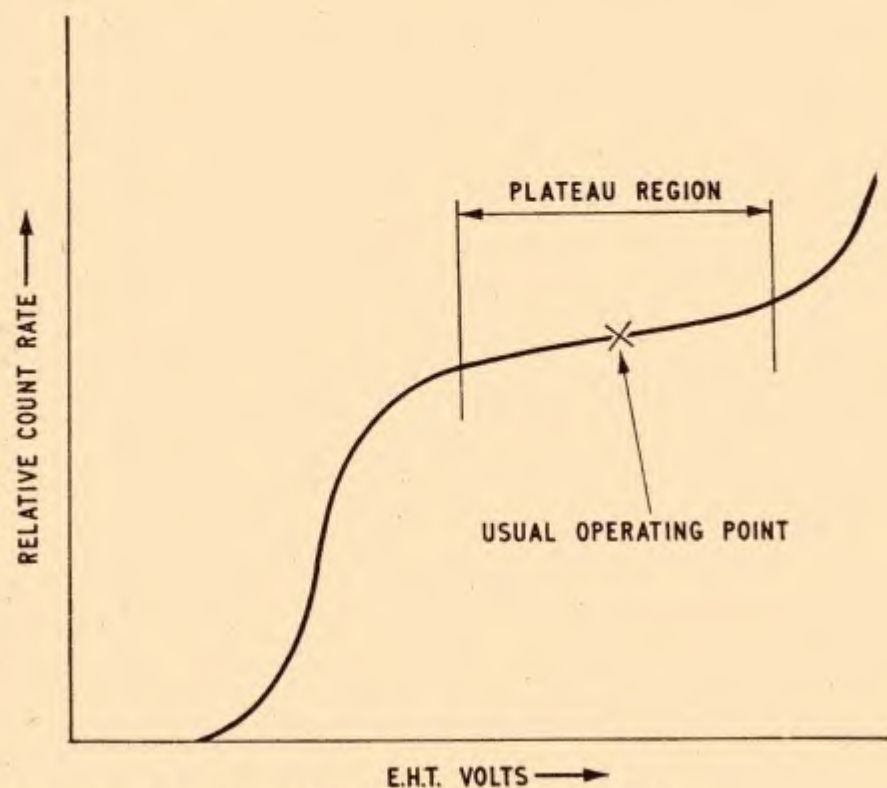


Fig. 1. A Geiger-Müller tube characteristic

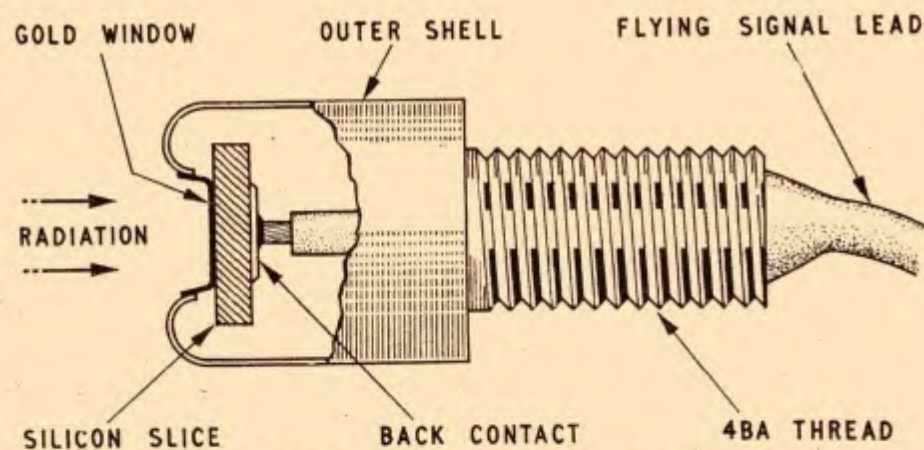


Fig. 2. A cross section view of the S.S.B. detector

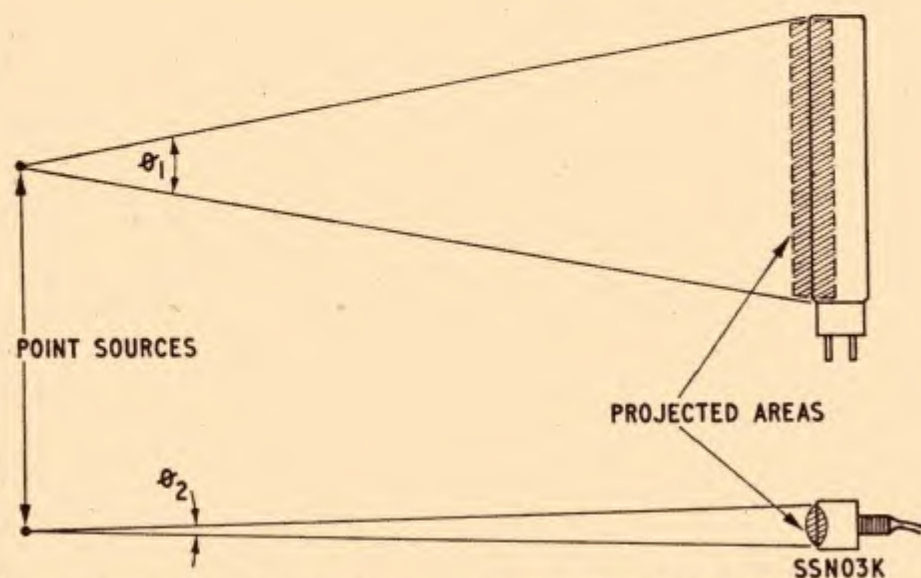


Fig. 3. Comparison of source geometry for S.S.B. detector and typical G.M. tube

The term used for this charge free layer is *depletion layer* and its distance from the gold surface the "depletion depth" which may be calculated from the formula

$$d = \frac{(\rho v)^{\frac{1}{2}}}{1.8}$$

where  $d$  is the depth in microns (1 micron =  $10^{-3}$ mm)

$\rho$  is the resistivity of silicon (ohm-cms)

$v$  is the applied voltage bias.

The area of the window and the depletion depth determine the active volume of the device.

When particulate radiation enters this volume under these conditions some of the silicon atoms are ionised in a similar fashion to the gas atoms in the G.M. tube. Instead of electron-ion pairs, however, electron-hole pairs are formed and although the two are analogous the difference made in terms of operating speed is enormous, the holes in silicon having a mobility several orders of magnitude greater than the ions in the gas.

The amount of radiation energy required to form an electron-hole pair is about 3.5eV for silicon.

For the case where a particle loses all its energy in the depletion layer the charge  $Q$  produced at the "collector" is:

$$Q = \frac{E \times 1.6 \times 10^{-19}}{3.5} \text{ coulombs.}$$

Where  $E$  is the incident radiation energy (eV).

The charge collected is therefore directly proportional to the radiation energy lost into the depletion layer. The S.S.B. detector is then a proportional counter since there is no avalanche action. Similarly as in the G.M. tube the negative-going signal obtained is composed of two parts. First, the small initial rise due to electron collection, and then the major portion being the signal induced by the fairly rapidly retreating holes.

Since the distances travelled by the holes are very small—of the order of microns—the signal is of very short duration. There is no dead-time as in the G.M. tube because the depletion layer is only partly ionised and there is no reason why at any time another particle should not react with another region. The device is therefore capable of very fast operation.

A summary at this point shows that the G.M. tube is limited in its operating speed but gives the same large output for even a single ionising event. The S.S.B. detector is potentially very much faster with an output which is proportioned to the radiation energy lost in ionisation but small in comparison because there is no multiplication as in the G.M. tube.

The G.M. "enthusiast" is unlikely to be converted by these considerations it is true, for the large output signal he obtains is easily handled and certainly for most applications the G.M. tube is quite fast enough.

The first real clue to the reasons for choosing the S.S.B. detector appears when the types of radiation to be detected are considered.

### GAMMA RADIATION

Any references to gamma radiation have been avoided so far because a very complicated situation exists in its detection by either type of device.

Gamma and X-rays will be referred to as *gamma rays* since they are identical in every respect except for their origin. Their detection depends on several physical effects, mainly photon formation, Compton scattering and direct ion-pair production. These effects are dependent on incident radiation energy to

varying extents and those sufficiently interested are recommended to consult some of the many excellent works which deal with this subject (1) (2).

For the purpose of this text it is sufficient to say that the relative efficiencies of the two devices are roughly equal in this respect and usually of the order of less than one per cent.

The main disadvantage of the S.S.B. detector shows itself here when one considers its size relative to the average G.M. tube. As a general rule the effectiveness of a detector of gamma radiation is governed by its projected area. Fig. 3 demonstrates the geometric advantage of the G.M. tube in a given radiation field.

Since gamma radiation is not highly ionising and therefore highly penetrating by nature the chances of many interactions in either device are small. This means, of course, that very little energy is likely to be liberated in the depleted volume of the S.S.B. detector and therefore correspondingly small signals may be expected as a result.

For the G.M. tube the problem is resolved into the chances of a single ion-pair being produced as previously discussed.

The situation is not as black as it might appear for the S.S.B. detector. As long as the signal can be separated from noise, detection and counting is fairly straightforward, as the simple electronics required indicate.

### BETA PARTICLES

Both devices are more efficient in beta particle detection, but a much more favourable situation exists for the S.S.B. detector. The geometric consideration still applies although in this case it is the relative volume of the G.M. tube against that of the S.S.B. detector which is the important factor, rather than the projected area as with gamma rays.

Volume for volume the S.S.B. detector has in general a higher detection efficiency than the G.M. tube.

The S.S.B. detector claims an important advantage by virtue of the extremely thin window.

Beta particles being more highly ionising than gamma rays are as a consequence less penetrating and while the thin window of the S.S.B. detector absorbs negligible radiation energy the glass wall of the G.M. tube presents a formidable barrier. G.M. tubes designed for beta detection therefore usually have much thinner glass walls than gamma only types and a beta transparent cathode which might be an open spiral wire or a thin conductive coating on the inside of the glass.

For the sake of completeness it is worth mentioning that windowless G.M. tubes exist which effectively contain the low beta energy sample within the active volume and so overcome the problem of an intervening barrier. These tubes, however, require carefully controlled conditions and a continuous gas flow and are therefore out of the question for cheap portable equipment.

When the beta particle enters the depletion layer of the S.S.B. detector it has a chance of being deflected by ionising collisions unlike the gamma ray and a simple comparison may be drawn with the action of the balls in an electric pin-table. Many will miss the scoring targets altogether. Most will register some score while a very small proportion will be bounced from one target to another and achieve the maximum possible. So it is with the beta particle—oversimplified certainly, but sufficient in this case.

The pulses obtained from a mono-energetic source will range therefore from a few of maximum height

down in ever increasing numbers until they are lost in noise. (Fig. 4.)

Signals similar to those due to gamma rays will be experienced.

### ALPHA PARTICLES

For alpha particle detection any glass walled tube is totally unusable due to the absolute certainty that a very highly ionising particle like alpha will lose all its energy into the glass with negligible penetration.

It is with alpha particles, however, that the best results are obtained with the S.S.B. detector. Again, the thin gold window hardly obstructs at all the passage of the particle and so certain is the possibility of complete energy loss into the depletion layer that practically 100 per cent counting efficiency is obtained for those particles which arrive on the window.

So dense is the ionisation of the silicon in the track of the particle that there is a chance that some of the electron-hole pairs will recombine and thereby slightly

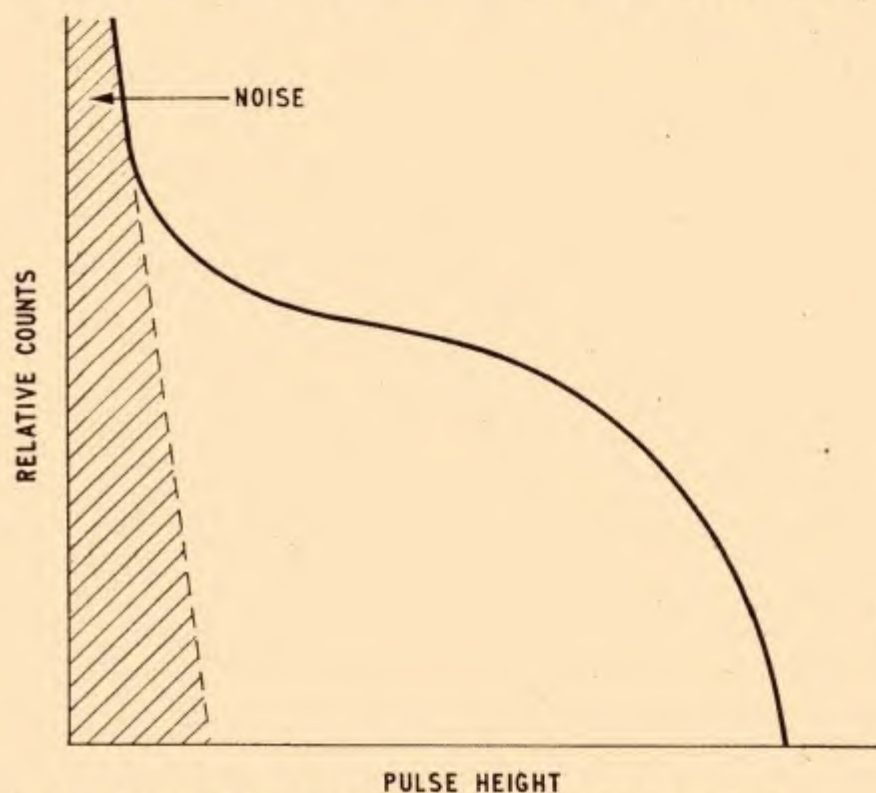


Fig. 4. Typical beta spectrum from S.S.B. detector

reduce the charge to be collected. No problem is created by this as far as detection is concerned because only a very small fraction of the charge is lost in this way, depending to some extent on the magnitude of the applied field.

Most alpha particles encountered have high energies, i.e. in the 1-10MeV region and correspondingly large signals are obtainable. This also gives rise to an excellent signal to noise ratio and simplifies the circuit techniques for detection.

The advantage of the S.S.B. detector is becoming more apparent now with its very desirable ability to detect alpha particles and low energy beta particles, a feature with which no ordinary G.M. tube can compete.

In beta particle detection the very robust construction of the S.S.B. detector compares most favourably with the very fragile nature of the G.M. tubes designed for beta work. Their fragility and higher cost than "gamma only" types make them a rather risky investment for the amateur.

Possibly the user interested in detecting only gamma radiation would be better advised to choose the G.M. tube for its geometric advantage although it is not impossible that the small size of the S.S.B. detector may be to its advantage in some situations.



## SIGNAL AND NOISE

The operating conditions for satisfactory use of the S.S.B. detector in this context are determined primarily by the type of radiation to be detected and its energy.

From the above it is clear that the greatest difficulty lies with gamma radiation with its low detection efficiency and similarly but to a lesser extent with beta particles. The problem can be resolved further into the question of whether the available signal to noise ratio is usable.

It is true to say that the S.S.B. detector can detect any energy of the three types of radiation mentioned, however small, but obviously noise limits the minimum practical level.

## CAUSES OF NOISE

What are the causes of noise in the S.S.B. detector?

First and foremost is the thermal agitation of the silicon atoms which gives rise to a signal at the output

depletion layer and so increase the chances of its reaction with the silicon. The gain is two-fold with the simultaneous reduction of detector capacity as can be seen from the expression

$$V = \frac{Q}{Cd + Cs}$$

Where  $V$  is the signal voltage obtained.  $Q$  is the charge released in the active volume.  $Cd$  is the depletion layer capacity.  $Cs$  is the stray capacity associated with the amplifier input.

The obvious limit to the size of the depletion depth is the physical thickness of the silicon slice and when operated under limited conditions the S.S.B. detector is referred to as being totally depleted. Such a condition will not be reached if the bias voltage required is above the rated maximum for the particular unit, as is likely.

Since the leakage current will rise with bias so also will the noise level to degrade the signal to noise ratio

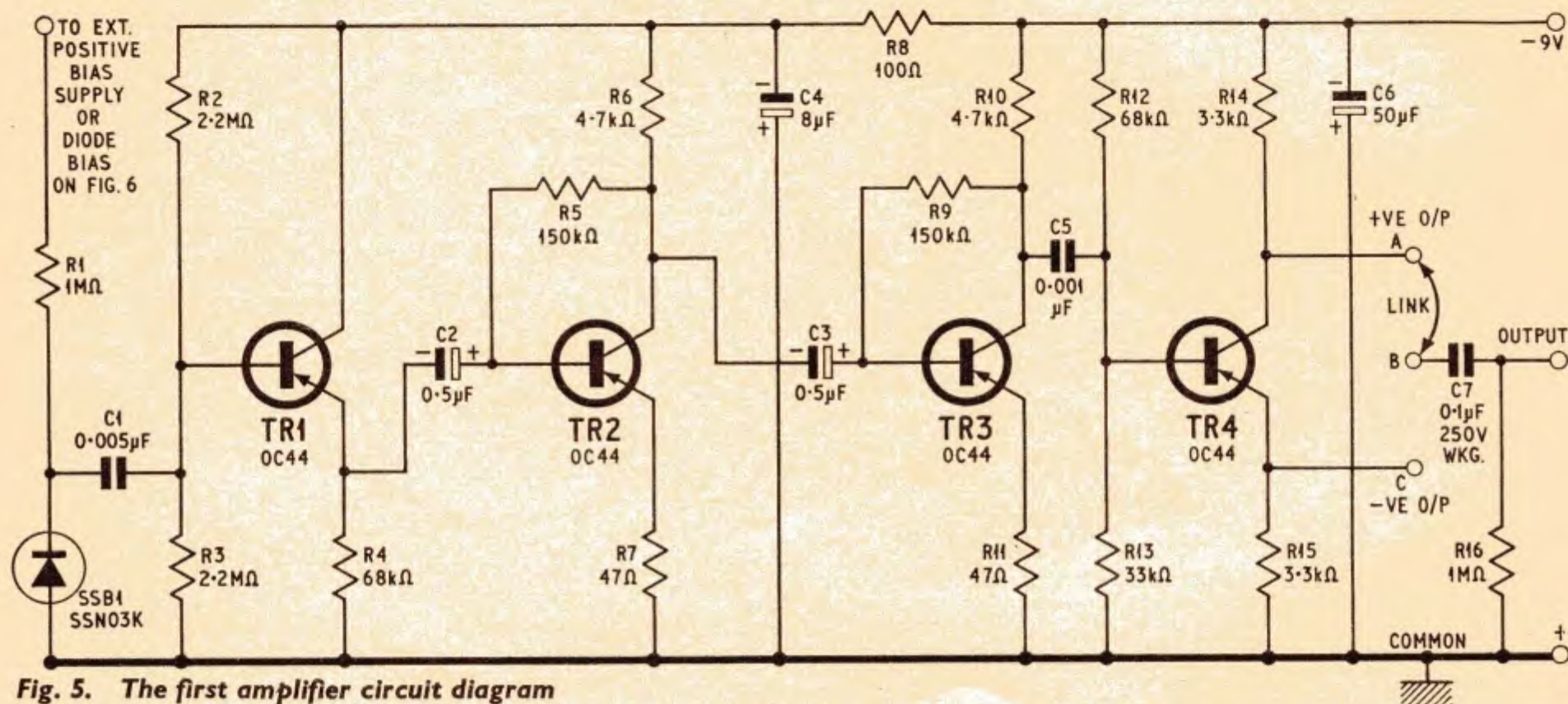


Fig. 5. The first amplifier circuit diagram

equivalent to about 20keV radiation energy at room temperature. This figure, incidentally, will double for approximately every 10 degree C. rise in temperature.

The second important contribution is due to the reverse leakage current which like any current is random in nature and therefore constitutes noise. Its value will depend on the characteristics of a particular diode and to a certain extent on ambient temperature.

Thirdly is the possibility of noise between the aluminium contact and the conducting cement which attaches the signal lead. Its magnitude depends on no controllable factors and is obviously a question of inspection tolerance on the part of the manufacturer. Generally speaking though, its contribution to the overall noise level is very small.

The question remains, therefore, how to obtain the best signal to noise ratio. Logically the next step then is to see how the largest possible signal may be produced.

It will be remembered that the advantage of the G.M. tube over the S.S.B. detector is that of greater size and hence better possible geometry. Therefore any increase that can be made in the active volume of the S.S.B. detector will be to its advantage and this is achieved, of course, by raising the bias. The effect of this is to increase the possible path lengths of the radiation in the

and a compromise must be sought in extreme circumstances. On one hand there is a small signal due to the high capacity and small depletion layer and on the other high noise due to excessive leakage current.

For the purposes of experiment it might be possible to reduce the noise to some extent by cooling the detector, provided that the amplifier contributes a lower noise level.

## AMPLIFIERS

The noise contribution of a given amplifier is an important factor which cannot be overcome. Most of the noise appearing at the output is due to the first stage whose noise receives the most amplification.

A small low capacity detector such as the 20th Century Electronics SSN03K will out-perform the amplifier to be described which has a noise level equivalent to about 50keV radiation energy at the input depending on the individual first transistor selected.

The amplifier is arranged in two sections, the first is for alpha particle detection. In this application large signals are experienced not requiring high gain and consequently a high signal to noise ratio is achieved. The second section of the amplifier which will be

described later is intended as an add-on unit to extend the capability of the combination for the detection of beta and gamma radiation.

### FIRST AMPLIFIER

The first section of the amplifier is shown in Fig. 5.

When alpha particles only are to be detected this amplifier suffers no embarrassment due to noise. For instance, if the input noise is equivalent to even 100keV the detection of 5MeV particles means a signal to noise ratio of 50:1 and so in this case the noise level may be ignored.

The sensitivity of the associated ratemeter will obviously set the lowest alpha particle energy detectable since the signal will be proportional to the radiation energy in this case.

A typical output for a 5MeV alpha particle would be  $1\frac{1}{2}$  volts and if the ratemeter has an input sensitivity of say 50 millivolts then pro-rata the lowest energy detectable will be 165keV.

Most existing G.M. ratemeters require a negative input pulse and so, provided that the sensitivity of the instrument is sufficient, this amplifier may be used to convert the set-up for alpha particle detection using the S.S.B. detector.

The purpose of the 250 volts working output capacitor C7, is to add a degree of protection to TR4 in cases where the G.M. tube e.h.t. voltage is not entirely removable.

If it is not intended to add the second amplifier section for beta and gamma detection, an economy may be made where an instrument sensitive to negative pulses is used. The output in this case may be taken via the output capacitor C7, direct from the collector of TR3 and so obviating the need for TR4. The loss of the differentiating network making no difference in this type of operation.

### SECOND AMPLIFIER

For optimum results with the combined first and second section amplifiers, the sensitivity of the rate-

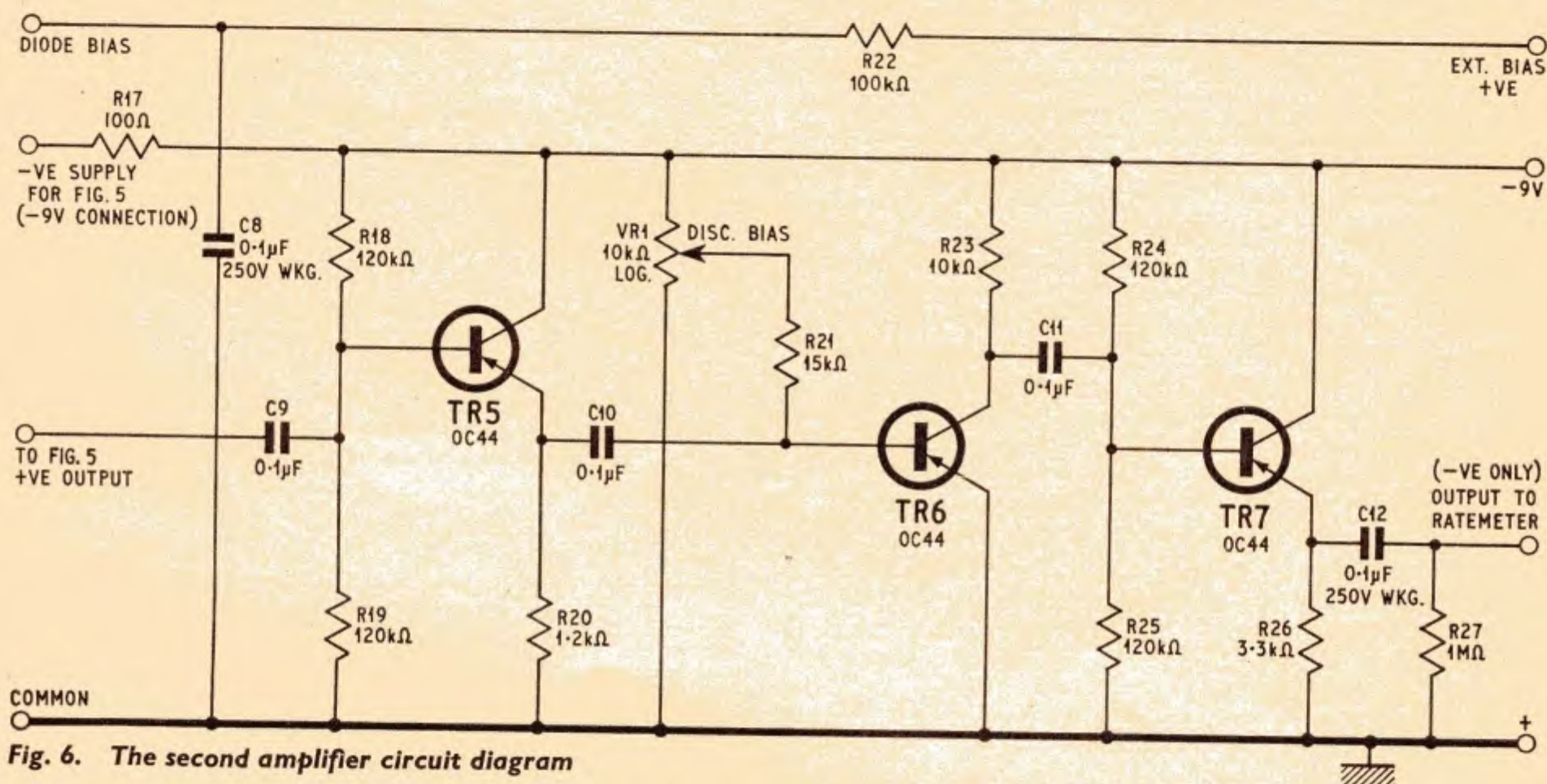


Fig. 6. The second amplifier circuit diagram

Maximum output of the amplifier is about  $2\frac{1}{2}$  volts positive or negative going so the ratemeter must be more sensitive than this, although it is unlikely that the alpha particles encountered will be sufficiently energetic to produce this size of output.

The outer shell of the detector is taken to the common earth line and the collector connected via the 1 megohm load resistor R1 to a positive bias supply which for most practical purposes can be 9 volts. The voltage pulse appearing across the load is applied to the base of TR1 which is operating as a low noise emitter follower. TR2 and TR3 are conventional voltage amplifiers with a total gain of about 500. The output from TR3 collector is fed via a differentiating network, C5, R12, R13, to TR4 which operates as a phase splitter output stage.

The purpose of the differentiation is to enhance the signal to noise ratio by limiting the bandwidth of the amplifier.

Positive output with link A-B and negative with link B-C is available so that ratemeters having sensitivity to either polarity pulses may be used.

meter to negative going pulses should be as high as possible and certainly not less than 200mV. The circuit of the second section of the amplifier is shown in Fig. 6.

It consists of an input emitter follower, a variable current discriminator/amplifier and an emitter follower output stage with a similar protecting network as in the first section.

The second section requires the positive going output from Fig. 5.

If the input of Fig. 6 is connected to point A (collector of TR4) this will leave the normal negative going output of TR4 (link B to C), free as a separate source of pulses from alpha particles only, in a situation where electronic discrimination against beta and gamma radiation is required. For needless to say, the amplifier combination will still respond to alpha pulses if they are present.

At this point it might be interesting to examine the operation of a discriminator of this type and the effect it will have on the counting efficiency of the whole unit.

## DISCRIMINATOR ACTION

Fig. 7 depicts the action of a discriminator showing the component parts of the signal presented to it.

(a) Represents the ideal signal pulses of amplitude "A" peak and a discriminator level " $E_1$ " which would satisfactorily detect them.

(b) Shows the noise component of maximum amplitude " $2A$ " peak to peak. The same discriminator level " $E_1$ " sees signals of amplitude "A" peak and so responds in exactly the same way as for the true signal.

When the two are combined as in (c) it can be seen that the discriminator level " $E_1$ " will produce a higher count than in (b) due to the presence of the signal pulses. At the level " $E_2$ " only signal pulses which have added to the instantaneous value of noise and so increased their apparent amplitude will be detected.

For a level " $E_2$ " which is just sufficient to suppress noise a superimposed signal however small stands a chance of being detected. The likelihood depends on the relative sizes of the signal and the noise.

It can be readily seen for instance that under these conditions only 50 per cent of a signal just equal to the peak noise value is likely to be detected.

Losses will cease to occur when the signal is equal to or greater than the peak to peak noise value.

From this it can be seen that the lowest energies of beta or gamma radiation that can usefully be detected with a given instrument will depend upon the total noise appearing at the input of the amplifying system.

The considerations of detector noise as stated above will not generally apply in this particular case as it out-performs the amplifier at most bias voltages.

To return to the Fig. 6 circuit we see that the input emitter follower TR5 is necessary to drive the low impedance current discriminator TR6 without upsetting the output of TR4 in the first section.

The operation of TR6 as a current discriminator is very simple. The standing base current set by VR1 and the 15 kilohm base resistor R21 is used as the negative discriminator bias which the positive going signal current from TR5 must overcome for the pulse to be detected. Once this has happened TR6 operates as an amplifier, the resulting negative pulse is fed to the output via emitter follower TR7.

Due to the action of the discriminator the output pulses are no longer proportional to the radiation energy lost into the detector.

The setting up of the discriminator is very simple, VR1 merely having to be adjusted until the noise pulses are just suppressed.

It will be noticed that if VR1 is adjusted, so that the bias current is zero, the noise will again disappear. This condition should be avoided as the circuit will be inoperative.

As previously mentioned the ratemeter input sensitivity should be not less than 200mV. This is to ensure that it is possible to record the noise when setting up and so allow critical adjustment to be made.

## BIAS VOLTAGE REQUIRED

The variation of detector capacity with bias volts obeys a half power law, that is, it varies rapidly for the low values, the variation soon flattening out until quite a substantial change of bias alters the capacity very little.

In practice it is still sufficient to operate the detector at 9 volts as with alpha particles although as discussed; higher bias values will obviously enhance the operation.

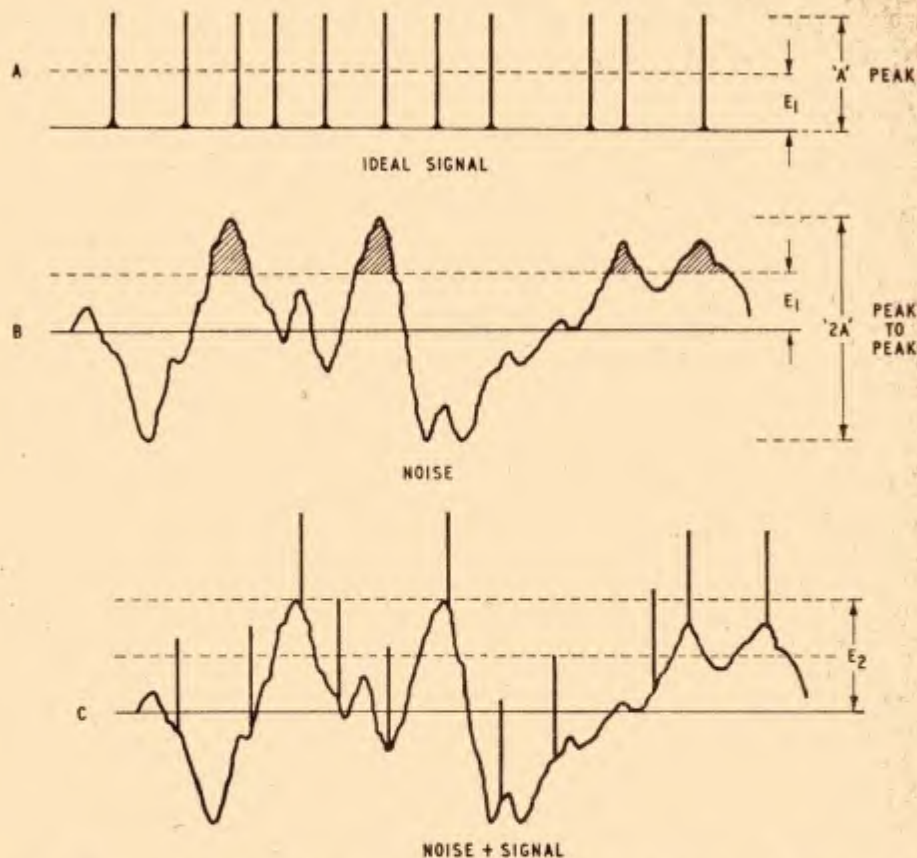


Fig. 7. Use of discriminator to separate signal from noise

## FINAL SUMMARY

Although it is obvious that more circuitry may be required to use the S.S.B. detector compared with the G.M. tube it cannot be denied that the device has some very attractive advantages, particularly with regard to power supplies. One can satisfactorily detect alpha, beta and gamma radiation with only 9 volts "e.h.t." compared to the 500 volts or so required by the G.M. tube and the task of producing this for a battery operated portable instrument can prove awkward for the amateur.

It is emphasised that this article is intended only as an introduction to the S.S.B. detector and necessarily much has been left unsaid. To employ it, as its name implies, merely as a detector of radiation is probably an insult to this very versatile device.

The use, for instance, of the S.S.B. detector in the field of radiation energy spectrometry is one of its very important applications.

Its small size and outstanding performance also make it a useful tool in space research where the emphasis is on smaller and lighter instrumentation.

The mention of this type of application might, in another context, deter the amateur from considering the device as the basis of a do-it-yourself instrument.

It is hoped, therefore, that this article has opened up a new field of experiment which can be implemented without great difficulty.

In a later article a portable S.S.B./G.M. ratemeter suitable for employing the above amplifiers will be described.

## ACKNOWLEDGEMENT

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# NEWS BRIEFS

## Early Bird

**E**ARLY BIRD, the first commercial communications satellite, launched from Cape Kennedy on 6 April, has settled in position 22,300 miles above the equator in mid-Atlantic. Before settling in this relatively "stationary orbit" it completed two orbits during which it was "kicked" into position by signals from Carnarvon in Western Australia and Andover in the North East of U.S.A.

Electric power for Early Bird's radio equipment is derived from the Sun via 6,000 solar cells. Messages will be sent between Andover, Maine (U.S.A.), Goonhilly Downs, Cornwall, and Bodou in Brittany. Alterations to equipment at Goonhilly Downs for communication by Early Bird have cost between £500,000 and £750,000. The life of the satellite is expected to be three years.

## Quelle Couleur?

**I**T SEEMED to a certain extent inevitable that the international colour television controversy described in our February issue should fail to end in complete agreement on the adoption of one common system. All three systems had their favourable points. It was with some surprise, therefore, that on 27 March we learned that the Soviet Government had signed a general agreement for the adoption of SECAM, the French version.

Perhaps this was some kind of omen, for the final vote at the International Consultative Committee for Radio Communication gave SECAM 21 votes, including the entire Communist bloc, four Western European countries and a number of newly independent African nations, some of which were purely theoretical since they did not anticipate adoption in the near future.

Eighteen votes favoured the American NTSC or German PAL systems, mostly with an amendment stating they would welcome a proposed combination of these technically similar systems.

While the balance is theoretically in favour of SECAM, the result can be seen to be evenly divided. Perhaps we may at some time see a combination of all three systems, which could be politically favourable, although the technicalities involved may be somewhat difficult.

## "Ham" Colour

**B**EFORE leaving the subject of colour television entirely, it is interesting to see that this subject is being exploited by amateurs as well as professionals.

At the North Midlands Mobile Rally, held at Stoke-on-Trent in April, the Midland Amateur Radio Society and the Stoke-on-Trent Amateur Radio Society organised a number of attractions including a television display put on by the British Amateur Television Club. Both live and closed circuit picture transmissions were shown and a colour television demonstration was given.

## Computers and Organs

**T**HE Slade Radio Society in Birmingham have a particularly interesting programme of events within the next few weeks. Among these are:

May 14 "Logic and Digital Circuits"—lecture by D. Collins.

May 28 "Designing an Electronic Organ"—talk and demonstration by R. H. Edmunds.

June 11 "Tapesponding with America"—tapes sent by the Catalpa Amateur Radio Society of Birmingham, Michigan.

Details of these and other activities may be obtained from R. L. Jenkins, 42 Warwick Road, Warley, Birmingham, 32.

## Penfriends by Computer

**E**LECTRONICS have entered the field of pen-friend correspondence. More than a million people in 135 different countries who are interested in any of 282 special subjects have found pen friends with similar interests through a computer.

This international communication is a direct outcome of the New York World's Fair where an I.B.M. 1440 computer selects applicants with appropriate interests for correspondence with others. The subjects are vast in range from aeronautics to anthropology and are available to any country in up to 45 languages.

More detailed information and registration forms (open to anyone free of charge) can be obtained from Parker fountain pen dealers or by writing to: Penfriend, The Parker Pen Co. Ltd., 15, Grosvenor Gardens, London, S.W.1.

## Radio by Oscar III

**T**HE Atlantic has been bridged for the first time on v.h.f. via a communications satellite on an amateur basis. From a home-made transmitter and receiver at Chalfont St. Peter, Buckinghamshire, Mr. C. J. McClelland (G6AG) has made contact with Germany, Switzerland and Sweden, and had reports from U.S.A., Czechoslovakia, France, Belgium and many English Stations of his transmissions via the Oscar III satellite.

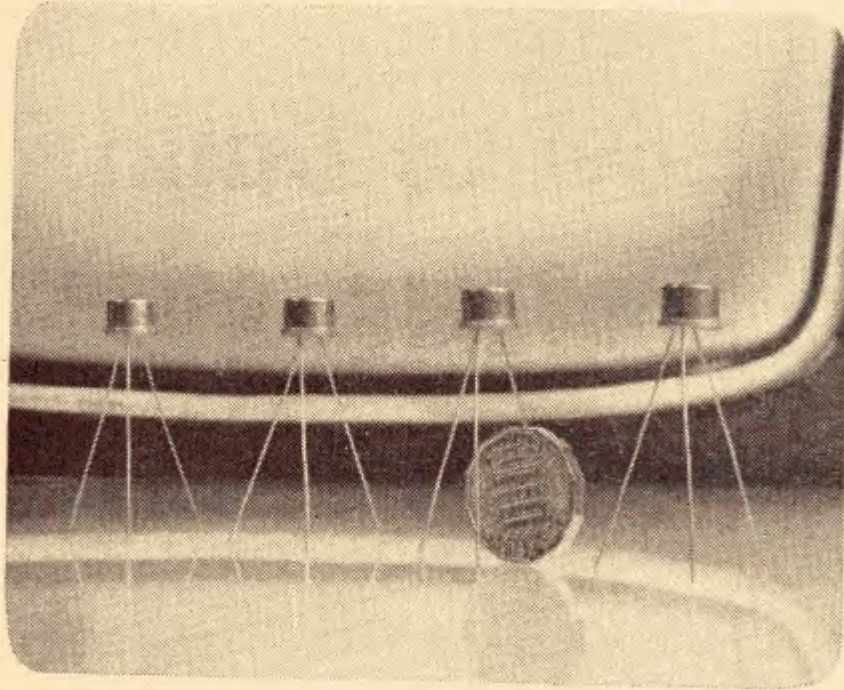
When orbiting between 38° to 48° longitude west, line of sight communication is possible with the U.S.A. for a period of approximately five minutes. The satellite is receiving at a frequency of 144.1 Mc/s with a pass band of  $\pm 25$ kc/s. This is converted to a re-transmission frequency of 145.9 Mc/s  $\pm 25$ kc/s. In the absence of any received signals by the satellite, nothing is radiated, as the circuit is a pure r.f. translation process.

Mr. McClelland is transmitting with 1 kilowatt at 144.1 Mc/s and an aerial gain of approximately 14dB horizontally polarised. It is hoped to try circular polarisation in the near future.

A few of the purposes of these experiments are to observe communications with different modes of transmission, signal polarisation effects and the associated aerial problem, and Doppler shift.



# NEW PRODUCTS



## Transistors For Television Receivers

Mullard Ltd., Mullard House, Torrington Place, London, W.C.1.

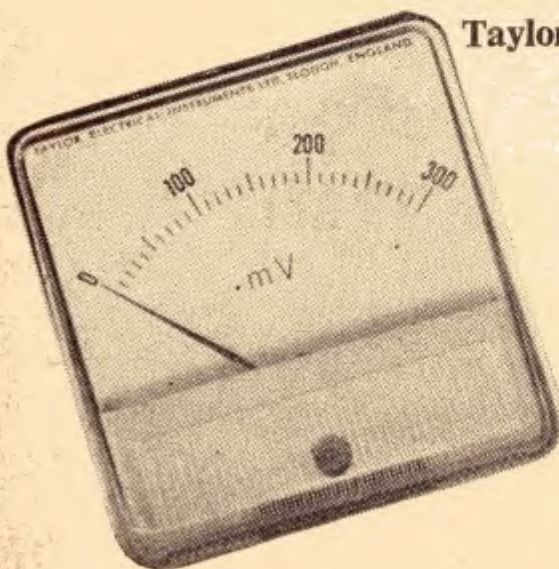
Mullard announces the development of a new range of transistors specially designed for use in television receivers. These new transistors, marketed under the trade mark "TVistors", have been specially designed to meet the high frequency response, high current-levels and high power gains associated with television receivers. Another advantage is that the heat dissipation within the cabinet is kept to a minimum and consequently greater flexibility in cabinet design is possible.

One of these, the AF180, combines a low noise performance with automatic gain control for the first time.

Our photograph shows the complete range which is as follows:

- AF186—u.h.f. tuner (amplifier and self-oscillating mixer)
  - AF180—v.h.f. tuner (amplifier)
  - AF178—v.h.f. tuner (mixer/oscillator)
  - AF181—
  - AF179—
- } vision i.f. amplifier

Taylor Electrical Instruments Ltd.,  
Montrose Avenue,  
Slough, Bucks.



New from Taylor Electrical Instruments Ltd. is a range of meters incorporating a new insert in nine different colours.

This new range has the trademark "Clarity C" and as the name implies the meters have been designed with the emphasis on ease of reading. The scales are clear and concise, the division markings are easily recognisable and the lettering is not so small, as the case in some meters, that one has to squint or move from the apparatus under test to the meter to take any readings.

## New Hi-Fi Tape Recorder

Brenell Engineering Co. Ltd., 231/235, Liverpool Road, London, N.1.

The Brenell range of tape recorders is probably well known to hi fi enthusiasts already, whether they have the complete precision built machine or have built their own amplifier around one of the tape decks.

New models from the above firm are very rare and far between, but when a new model is announced it is normally only after very stringent tests have been carried out. This is the case with the Brenell Mark 5 type M model shown in our photograph.

It is based on the Mark 5 series 3 deck with three motors (synchronous type for capstan drive); a large flywheel statically and dynamically balanced; a self-compensating braking system and four tape speeds, 15, 7½, 3¾, 1⅞ inches per second. The wow and flutter is less than 0.05 per cent at 15in/sec, 0.1 per cent at 7½in/sec, 0.15 per cent at 3¾in/sec, 0.25 per cent at 1⅞in/sec.

The "M" series is a special mono half-track recorder fitted with separate record and playback heads and amplifiers. It has mixable inputs, bass and treble controls and output sockets for headphones, external amplifier and speaker, and is capable of taking spools up to 8¼in diameter.





### Portable Home Juke-Box

Kolster-Brandes Ltd., Footscray, Sidcup, Kent.

Our photograph shows the new "Discomatic" portable juke-box now being produced by K-B Ltd, and available to the public, price 69 guineas.

Only slightly larger than a record player it automatically plays 40 seven inch 45 r.p.m. records and has a 100 per cent automatic mechanism. It selects, gently picks up, plays one or both sides of the 40 records, and finally stores them in the original position.

The player has a diamond stylus which is automatically cleaned by smooth brushes after each play. The clear, plexiglass lid keeps records clean and free from dust and when the lid is opened the power is cut off automatically. The transistorised amplifier, with "instant" sound, gives a maximum of 2½ watts output. An illuminated finger always indicates the number of the record being played and the keyboard shows the order of playing. Facilities are available for an extension speaker and external amplifier.

The "Discomatic" gives over four hours' (7½ hours on E.Ps.) continuous playing time and is more flexible in operation than normal juke-boxes because selected programmes can be changed at any time. Also, because the records are stored in a removable rack, it can be interchanged with another loaded rack to extend the playing programme.

# NEXT MONTH IN Practical Electronics

## How to Build

### 1 PORTABLE STEREO RECORD PLAYER



### 2 INFRA-RED RAY DETECTORS

### 3 ELECTRONIC PHOTO FLASHGUN

July Issue on  
Sale June 17th

**ORDER YOUR COPY NOW!**

# Readout —

## A SELECTION FROM OUR POSTBAG

### Tunnel effect

Sir—Thank you for keeping up the quality of the articles in PRACTICAL ELECTRONICS since it first started. The only fault that I can see is that it is a monthly periodical and it seems an awfully long time between issues.

I would like to take this opportunity to ask you and if possible my fellow readers for an idea to combat those enemies of a lawn, moles. Preferably an electronic device which an enthusiastic amateur might knock-up. Although my problem must be limited to a few of your readers there must be a bright idea from someone who is a lover of the old English lawn.

M. Hawes,  
Hastings,  
Sussex.

*This is certainly an unusual request, any ideas?*

### Zener dynamo regulator

Sir—With reference to the article in the March '65 issue on a Zener diode power supply regulator, would you please supply me with details of how this can be used with a 6V source to produce a constant e.m.f. of 3V (component values, etc.).

The unit would be useful in conjunction with a bicycle dynamo so that when its e.m.f. drops below 6V, the lights will still glow brightly, and so that they will not "flicker".

J. W. Arthur,  
Edinburgh, 11,  
Scotland.

*We regret that we are unable to supply circuit diagrams to individual requirements. However, our Ingenuity Unlimited page is open to readers' suggestions and circuit details.*

### Light meter conversion

Sir—In you March issue, on page 348, you give details of an Automatic Parking Light the principal being that when light falls on the OCP71 an electric current is transmitted which to a certain extent balances a current in the relay coil. As soon as there is a decrease in light, the OCP71 does not conduct enough current and the relay releases so switching on the parking light.

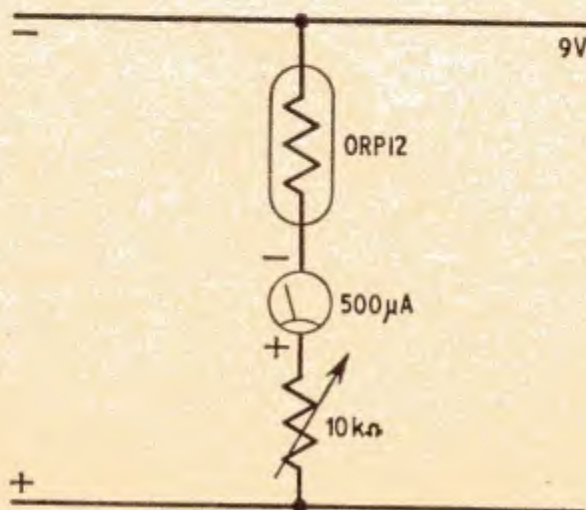
If a meter be used instead of the coil can one measure the amount of light which falls on the OCP71? This then could be used in photography to meter enlargements, test safe lights, etc.

Please could you tell me what value meter one should use, what resistance be connected in series with a 500 $\mu$ A meter if used, and will a lower voltage be required?

W. Maciejewski,  
Norbury,  
London, S.W.16.

*The circuit, as shown, is not really suitable for use as suggested since great inaccuracy will result because of temperature variations and changes in position of the OCP71, etc.*

*The ORP12 is far less sensitive to changes of temperature and is only sensitive on one side. It can be used by itself with a 500 $\mu$ A meter and, if the supply is stable enough, will give accurate results. To adjust to the right sensitivity, a 10 kilohm potentiometer can be included in the circuit (see diagram).—A. K. Stevenson.*



### Transistors cap valves

Sir—May I add a comment to the "Printed Circuits" discussion in your correspondence columns? One of the disadvantages already mentioned—and accepted even by Mr. Sutherland, who spoke up in favour of printed circuits—is that the need exists to "mess about with chemicals". It is perhaps relevant to mention that anybody who calls himself an engineer—even an amateur engineer—cannot afford to pass by any technology or technique of use. There is no difference in principle between messing about with chemicals and messing about with sheet metalwork, and to reject the former and give up printed circuitry is as sensible as giving up the latter and reverting to breadboard construction. In fact chassis construction is far more difficult and is indeed messy in its own right. The opinion of the lady of the house might be sought about whether she would prefer a little ferric chloride in the kitchen sink or the usual odds and ends of metal swarf in the carpet!

Whether one likes it or not, printed circuits are here to stay. Except for special purposes valves are "old hat" and so are the chassis wired circuits that went with them. Transistors are with us, and the amateur electronic engineer might as well get with it too.

D. R. Bowman,  
R.A.F. Henlow,  
Bedfordshire.

### Beat this

Sir—Regarding S. W. Burrows' guitar for six pounds my father made the guitar as in PRACTICAL ELECTRONICS. The pick-up was wound as described and the body was made from four pieces of  $\frac{3}{8}$ in plywood, which would be lighter than oak. The total cost is as follows:

	£	s.	d.
Pick-up (magnets)		4	6
Strings .. ..		7	6
String Winders ..	12		6
Varnish .. ..		6	0
Fret Wire .. ..		3	0
Araldite .. ..		6	0
<b>Total .. ..</b>	<b>1</b>	<b>19</b>	<b>6</b>

P. Moat,  
Newcastle-on-Tyne 4.

continued

## Pirates beware!

Sir—The following notes may be of interest to Mr. Evans of Crawley whose letter was published in the February issue, and anyone else interested in Japanese walkie talkie sets.

Most of these transceivers operate at frequencies around 27Mc/s, but this band has been designated by the Postmaster General for industrial and scientific use, including radio control of models. Since the P.M.G. will not licence the transmission of speech on these frequencies, any use, including switching on for demonstration, would constitute an offence.

Some transceivers also operate at higher frequencies around 28.5Mc/s, which frequency falls within one of the bands reserved for licensed amateur use, and before a licence is granted, the applicant must pass the necessary tests.

Several prosecutions have recently been conducted against the unlicensed use of transmitting equipment, with great success. Also, much havoc has been caused amongst radio controlled models by the interference from these sets.

M. Connell,  
Wembley,  
Middlesex.

## Relays, please

Sir—One thing I have never seen in any of the magazines on electronics is an article on Relays, for beginners. Retailers do not seem to follow any consistent method in describing these components, and a definitive description of the points to look for would be of great assistance.

J. Cardno,  
Aberdeen,  
Scotland.

An article on this subject is already under way.

## Sound off . . .

Sir—I would like to comment on K. R. Baker's letter (*Readout*, March issue) on costing each project.

If I had bought the components for the "Electronic Didjeridoo" (see page 39, November 1964 issue) from a certain supplier, it would have cost just over £11 excluding cabinet and microphone. From yet another source it would have cost £6.

I could have built it for a fraction of this cost by using "surplus" and "cut price" components, and drawing upon my array of junk boxes. If this were done, it would probably have resulted in an instrument of poor quality, causing every aborigine worth his salt to emit indignant cries of "Chacun à son Didjeridoo!" and to commence upon mass production of the original timber version. If you buy very cheap components, you may come up against such problems as low amplification, excessive transistor hiss or noise, mismatching of the diodes, etc. It is best to avoid "dodgy" components.

It is pleasing to know that Mr. Baker's Didjeridoo "works all right". Of course it should! The author first used one a few years ago as vocal accompanist with a Blackpool R & B group, and would report that, used judiciously, the effects go down quite well.

Other sound effects were tried and I hope to describe some of these in future issues of PRACTICAL ELECTRONICS, if acceptable to the Editor.

I would like to hear readers' views and ideas on novel sound effects which might be produced by a "live" performer without resort to miming. Of particular interest are those devices which, from one vocalist and a microphone input, produce the sound of more than one voice without use of an echo chamber.

A. J. Bassett,  
Chorley,  
Lancs.

## . . . and again

Sir—Thanks for the very good articles described in the April '65 issue. The pick-up amplifier was just what I had been looking for, but on reading through the book I failed to see the components required advertised.

Why couldn't a note be added "turn to page ???" where a firm could advertise these parts and their cost. Then all one need do is send for or collect the kit of parts required.

The p.u. amplifier is required for playing a Bush record player through a Sony CT 500 tape recorder—will it suit?

W. F. Bush,  
London, E.1.

We are looking into the matter of component sources for our projects, but it is not easy to tie up with suppliers at the time that the articles are published. It is likely, however, that advertisers will reveal the availability of certain parts in issues following that in which the article appears.

The p.u. amplifier would be suitable for the application that you have in mind.

## What's stereo?

Sir—Three months ago I completed a hi fi cabinet which I made myself. Now, I have decided that I would like to convert it to stereo. As I am a complete beginner in this field could you please give me information on the basic essentials necessary for stereo and what is meant by a balance and how does it work. If you could supply me with this information I shall be extremely grateful.

M. R. Allen,  
Kingston-upon-Thames,  
Surrey,

In general, it is quite difficult to convert ordinary mono outfits to stereo and often it is found that few of the existing components are useable for stereo. Conversion may be possible when the power amplifier is separate from the control facilities, for then a second power amplifier can be added (for second stereo channel) and the mono control unit can be replaced by a stereo version. As for the balance control, this merely alters the relative volume in the two channels so that the stereo image can be centred between the speakers.

The basic essentials for stereo (using discs) are a stereo pick-up designed specifically to reproduce the two channels of information in the groove, plus a turntable free from excessive vibration which would cause rumble, an amplifier and control section having two separate channels for amplification, and, finally, two speakers correctly positioned in the room. Stereo cannot be obtained in a simpler way than this. — C. Brown

Next month we shall be publishing full constructional details for building a portable stereo record player designed specially for use with stereo headphones, but having facilities for speaker outputs.