Practical Electronics

FREE INSIDE

2 BLUEPRINTS

ULTRASONIC REMOTE CONTROL
FIG. 1 — THE CIRCUIT DIAGRAM
**FIG. 6 — KEY TO TRANSISTOR AND DIODE CONNECTIONS**

**FIG. 7 — CHASSIS LAYOUT AND INTERBOARD WIRING**

**COMPONENTS LIST**

**Resistors**
- R1 4.7MΩ R9 470kΩ 1W 5% R17 4.7kΩ
- R2 27kΩ R10 2.7kΩ R18 4.7kΩ
- R3 100kΩ R11 680kΩ 1W 5% R19 680kΩ 1W 5%
- R4 470kΩ R12 470kΩ R20 2.2kΩ
- R5 4.7kΩ R13 100kΩ R21 27kΩ
- R6 27kΩ R14 470kΩ R22 2.2kΩ
- R7 4.7kΩ R15 4.7kΩ R23 1MΩ
- R8 4.7kΩ R16 27kΩ

All carbon ±1% unless otherwise stated.

**Potentiometers**
- VR1 500kΩ ±20%
- VR2 10kΩ ±5%
- VR3 500kΩ ±20%
- VR4 10kΩ ±5%

All miniature carbon, preset, linear.

**Capacitors**
- C1 0.5µF paper C5 500µF electrolytic 6V
- C2 500µF electrolytic 6V C6 10µF electrolytic 12V
- C3 500µF electrolytic 12V C7 100µF electrolytic 12V
- C4 2.0µF electrolytic 12V

**Diodes and Transistors**
- D1 Z8-6-8 7V Zener diode
- D2 Z8-6-8 7V Zener diode
- D3 Z8-6-2 6V Zener diode Brush Crystal Co:
- TR1 OC443 silicon
- TR2 OC443 silicon
- TR3 OC303 germanium
- TR4 OC443 silicon
- TR5 OC443 silicon
- TR6 OC303 germanium
- TR7 OC303 germanium

**Miscellaneous**
- BY1 9V battery Ever Ready PP9 or equivalent, and connector
- PL1 Coaxial socket, chassis mounting
- PL2 Coaxial socket, chassis mounting
- S1 Rotary switch 3 pole, 3 way and pointer knob
- SK1 Chassis mounting socket for VB1 (VB3066)
- SK2 Chassis mounting socket for VB2 (VB3064)
- VB1 Veroboard Plug-in type, 16 conductor strips, 21 holes per strip, 0.15in hole spacing, 2.5in wide, 3-in long. Gold-plated plug-in conductor-stripe ends (VB3503)
- VB2 As VB1 Hand swl for separating conductor strips into sections (VB3011)
- Suitable aluminium case, measuring approximately 5in x 8in x 2½in deep, with lid.
EAGLE PRODUCTS

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MICROPHONE STANDS

Horn Tweeter CTE10

10-Watts, 18-18,000 C.P.S., 16 ohms, High Sensitivity, Amazing Value 27/-.

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INTEGRATED TONE CONTROLS

40-WATT TRANSISTOR STEREO

Integrated Tone Controls, Five Inputs. £18.15. 0.

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Be first to own the only amplifier of its kind in the world

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THE SINCLAIR X-10 is a high fidelity integrated power amplifier and pre-amp using 11 transistors and having a transformerless output of 10 watts for feeding into a 15 ohm loudspeaker system. It requires only the addition of tone and volume controls plus a twelve volt D.C. power supply to make it a complete mono high fidelity assembly of exceptional quality. Stereo is achieved by using two X-10 amplifiers and ganged or separate controls. Input sensitivity is sufficient for all crystal or magnetic pick-ups and the manual supplied with the X-10 gives detailed instructions for connecting the controls and for using the amplifier in a wide variety of applications.

This radically new transistor amplifier (patents applied for) is the first to be marketed anywhere in the world using the Pulse Width Modulation principle (P.W.M.).

This technique permits an enormous reduction in the power dissipation in the output transistors of an amplifier; and in the case of the Sinclair X-10, the output efficiency is about 95% as compared with about 60% for conventional class B output stages. Thus the dissipation is only 1/4th or less of that occurring in all other amplifiers. That is why no heat sink is used and why the X-10 will operate from two 4f/ batteries with normal use for about 3 months.

NEW DESIGN PRINCIPLES PERFORMANCE!

- Number of transistors 11
- Overall size 6" x 3" x 1.5"
- Input Sensitivity 1mV
- Total harmonic distortion < 0.1%
- Output power 10 watts
- Frequency response 5-20,000 c/s ± 0.5dB
- Speaker impedance 15Ω
- Damping factor Greater than 100
- Quiescent consumption 75mA
- Supply voltage 12 to 15 volts

SINCLAIR X-10 COMBINED 10 WATT AMPLIFIER & PRE-AMP

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**THE SINCLAIR X-10** is the only amplifier in the world to give you the unique benefits of Pulse Width Modulation. Briefly, with this system, the audio signal from pick-up, radio, microphone or tape head modulates a high-frequency square wave "carrier" by varying the mark-space ratio. These variations are converted to energy in the output stage. Being independent of the transfer characteristics of the output transistors, the output is an exact replica of the input signal. The improvement in the quality of reproduction from the loudspeaker is instantly apparent. Transient response is much clearer, there is no falling off in the higher audio-frequencies, no intermodulation distortion and the response curve so flat you could draw it with a ruler! A new type of output stage and P.W.M. plus many other circuit refinements result in an amplifier which is compact, rugged, stable and does not require a heat sink—and it costs so little. The X-10 may be used with low-input pick-ups such as Decca Deram, Ortofon, etc., as well as with tape playback heads. Used in pairs the X-10 brings new depths to stereo listening and there are no channel matching problems.

**SINCLAIR X-10 MANUAL**

supplied with every every X-10, built or in parts, this 12 page manual explains how the amplifier functions and how you can add the correct tone and volume control system to suit your requirements. A variety of systems is shown for mono and stereo use, none of which will add more than a few shillings to the original cost of your Sinclair X-10 amplifiers.

FREE WITH AMPLIFIER. AVAILABLE SEPARATELY, PRICE 1/-
It’s easy to build the SMALLEST RADIO IN THE WORLD

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SINCLAIR MICRO-6
SIX-STAGE POCKET RECEIVER
Build it in an evening!

Building is simple and straightforward when the meticulously detailed instructions are followed. All parts including MAT transistors, diodes, printed circuit board, lightweight earpiece, case and dial, and 8-page instruction manual come to 'TRANSBISTA' black nylon wrist strap for wearing the Micro-6 like a wrist watch (see illustration opposite) and packed with instructions: 7/6

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Telephone: COMBERTON 682
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TRAVELLING

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We are all, nowadays, electronics conscious. Yes, even the layman, while not conversant with the technicalities involved, has a general appreciation of the vital part played by this young but exuberant branch of electrical engineering in the complex world of today... and this is but the beginning.

As we step over the threshold into a new exciting technological age, our dependence upon electronics is all too apparent: terrestrial developments centre around automation, with electronics providing the brain and guiding hand for power-operated machinery; extraterrestrial exploration relies utterly upon electronics for remote control, communications and telemetering services.

These grand scale developments have an impact on the entire field of electronics, for in their wake come new components, new circuits, new methods and, of course, new applications.

Without a doubt the amateur enthusiast will be eager to reap his share of these benefits of technological progress, as he has been indeed in the past. For it is true that amateurs have been conducting experiments and building electronic equipment since the earliest days of radio communication; even before the thermionic valve drove the crystal diode into (temporary) oblivion, and long before the very term “electronics” entered into general use.

But, in more recent times, the technical revolution triggered off by the invention of the crystal triode or transistor some 16 years ago has quite dramatically transformed the situation to the advantage of the home constructor.

Thanks to the transistor, gone largely is the need for a metal chassis and the tedious metal work this often entailed. Much transistorised equipment can be assembled satisfactorily on a piece of plastics board or even on an offcut of hardboard. A small battery replaces a bulky and heavy power pack and so demolishes what was undoubtedly a psychological barrier for some would-be constructors and experimenters—apprehension of high voltage supplies. With miniature components and simplified assembly methods, construction can indeed be a kitchen table operation nowadays.

Yes, truly can we say that in the realm of electronics a new emphasis has been given to the word practical.
ULTRASONICS IN NATURE

In the year 1793 Lazzaro Spallanzani established after a long series of experiments that the common bat could navigate and detect its prey without being able to see. After establishing that any loss of acuteness in the bat's hearing resulted in a loss of ability to navigate, he put forward the hypothesis that they were able to navigate and detect their prey by emitting and receiving a vibration of the same nature as that of sound but with such high frequency that it was inaudible to the human ear.

The scientific minds of the day rejected this suggestion, and Spallanzani joined the ranks of those scientists whose reward for systematic investigation and logical thought was ridiculed.

It is now quite firmly established that these ideas were correct and that other creatures, including the porpoise are able to use ultrasonic emission and reception for various means.

The definition of an ultrasonic wave is very simple, being a pressure wave whose frequency is higher than that to which the human ear will respond. It is generally accepted that 20kHz is the lowest usable ultrasonic frequency, although in fact human audibility does not reach this high level.

The properties of an ultrasonic vibration are, since they are fundamentally the same as sound vibrations, identical with the properties of sound. They may be propagated in gas, fluid or solid, may be absorbed by soft surfaces, reflected by hard surfaces and refracted by changes in temperature and pressure of the medium in which they are propagated.

PRODUCTION AND DETECTION OF ULTRASONIC VIBRATIONS

There are three main techniques by which ultrasonic vibrations may be produced.

1. Magnetostrictive methods.
2. Piezo-electric methods.
3. Oscillation of air or fluid jets.

The first of these methods uses the fact that certain materials when subjected to a varying magnetic field undergo very slight changes in dimensions. A nickel rod is usually used as the core of a coil through which a high frequency current is flowing. The result of this is that the nickel rod is subject to a slight length change with the same frequency as the current through the coil.

The second method relies on the fact that certain naturally occurring materials such as Rochelle Salt or Quartz and certain man-made materials such as ceramics, including Barium Titanate and Lead Zirconate Titanate, are subject to a change in dimensions with a directly applied voltage.

If an oscillatory voltage is applied to the opposite faces of such a slab of material the material will execute vibrations at twice the frequency of the applied voltage.

The reason for the frequency doubling effect is that the domains, i.e. groups of molecules, which are normally random in their orientation change direction according to the polarity of the applied electric field. Hence both the positive and negative peaks of the applied voltage will cause the corresponding expansion or contraction which results in the frequency doubling effects.

If the material is originally polarised, i.e. all the domains are arranged to lie in approximately one direction by means of application of a large electric field in the early stages of manufacture, then the fact...
that these domains are not completely free results in the piezoelectric vibration being of the same frequency as the applied oscillatory voltage.

The third method of production is only of interest where very high power is required, usually for emulsification of suspensions, and relies on the principle of a high powered jet of gas or fluid impinging on a blade. Under these conditions the blade will execute ultrasonic vibrations, assuming due care has been given to the dimensions of the blade, which will be transmitted through the gas or fluid.

APPLICATIONS OF ULTRASONIC VIBRATIONS

Among the first fully developed applications of ultrasonics were the fields of cleaning, drilling, welding and soldering. In each of these cases the ultrasonic techniques have certain advantages over conventional techniques.

The advantage of cleaning, by immersing the object concerned into a tank of fluid in which ultrasonic vibrations are produced, is twofold: firstly, the tremendous reduction in time when compared with manual cleaning; secondly, the advantage that very delicate and complex assemblies, such as internal parts for valves or components, may be cleaned without the risk of physical damage which is present when using conventional cleaning methods.

By using an ultrasonic vibration in a solid rod one can drill through materials for which standard drilling methods are not very satisfactory, examples being crystals or glass, or other such brittle material. A second advantage when using this method for drilling is that one has dispensed with the necessity for a rotating bit, hence one can drill holes of any desired shape.

In the case of welding and soldering, the obvious advantage is that the tremendous production of heat which can destroy or impair the efficiency of delicate assemblies is avoided, and in the case of soldering the use of any form of flux becomes unnecessary. A further advantage to the soldering technique is that it can be used to solder materials not solderable by previous methods, for instance aluminium.

The third method of producing ultrasonic energy, the jet method, is used in the textile and food industries among others; a characteristic example of products which require a process of emulsification being peanut butter.

MEASUREMENT BY ULTRASONICS

Apart from applications involved in the field of production or manufacturing, such as those previously described, ultrasonic vibrations may be used for performing scientific measurements.

Examples of these are ultrasonic thickness gauges and flow meters.

If an ultrasonic vibration is propagated through a solid material, any change in the nature of the material will result in some reflection. By measuring the attenuation or the time taken for an ultrasonic wave to cover the total journey it is possible to estimate very accurately the thickness of the material. One example of the use of ultrasonics in this respect is the measurement of the thickness of fat on certain animals, such as pigs, and in this context has an obvious superiority over any other methods which might be devised.

By launching an ultrasonic vibration into a moving fluid and using the Doppler effect, i.e. apparent change in frequency with velocity, it is possible to measure the flow rate of the fluid concerned. Although there are simpler methods for flow rate measurement, this technique has the advantage that it may be used with either corrosive or very dangerous fluids.

An example of the use of this technique lies in the measurement of the flow rate of molten sodium which is used for heat transfer in certain atomic reactors.

Although it is not a scientific measurement, the similar technique to that for thickness may be used to detect flaws in factory-made products without the necessity of destroying the product in the process of inspection. An ultrasonic vibration introduced at one face of perhaps a complicated plastics moulding will be reflected by any small voids or cracks in the material. These reflections may be compared with the pattern which is the result of a flawless product, hence inspection may be carried out very rapidly and without any destruction of the items concerned.

Probably the most dramatic use of ultrasonic energy is in the field of echo sounding. This is an extension of the thickness measurement technique by which a ship may launch an ultrasonic wave and establish the time taken for reflection from the ocean bed. This is a direct and continuous indication of depth.

Apart from indicating depth this technique may, of course, also be used to detect the presence and position of either ships or shoals of fish.

ULTRASONICS IN AIR

There are a number of ways in which the properties of an ultrasonic wave in air may be used to perform useful tasks. Probably the four main applications are in object detection, distance measurement, remote control and communications.

The property of reflection may be used in air, as it is in water, to measure the distance to a given object.
A similar system may be used for remote control or communication, but in this case the ultrasonic wave is directly controlled at the transmitter.

Since a pressure wave of this sort may be modulated in much the same way as a radio wave, with sufficiently sophisticated electronic equipment the transmitted ultrasonic wave may be either amplitude modulated, frequency modulated or pulse code modulated in order to transmit information or instructions over short distances.

Concerning the remote control of model boats, it must however be noted that control may be effected over much longer distances if the wave is transmitted through the water, since the attenuation of ultrasonic waves is considerably less in a liquid medium than in air.

The transmission of ultrasonic waves in air is a field which is very suitable for the experimenter as suitable transducers for transmitting and receiving are available commercially at comparatively low prices. Although the range of control is a little limited, something of the order of 100 to 300ft being the maximum practical at the moment, an ultrasonic system for remote control has certain advantages over radio control. The most obvious of these being the fact that the ancillary amplifiers are usually cheaper to make and considerably more simple. There is, of course, the added advantage that a transmitting licence is not required, as in the case of radio wave propagation.

ULTRASONIC TRANSDUCERS

When transmitting ultrasonic energy through air the direct use of a vibrating crystal is not the most satisfactory method since, although great power is available from such a crystal, the dimensions of the change in size are so small that the range would be very limited.

In order to improve this range a technique is used whereby the movement of the crystal is mechanically amplified to get a greater degree of movement from the transmitting element.

Fig. 1 shows the technique which is used to achieve this mechanical amplification. A thin crystal is cemented to a small thin round plate mounted on a central stem. As the crystal is energised it attempts to change its dimensions in the plane of its two parallel faces. Since it is securely cemented to the metal plate the latter is forced to bend with the movement of the crystal, and this results in an oscillatory bending movement of the metal plate at the frequency of the applied voltage—hence the transmission of a pressure wave into the air.

Correspondingly, a pressure wave impinging on the plate will cause very small movement of the plate which is sufficient to generate across the crystal a signal corresponding to the frequency of the incoming pressure wave.

Fig. 1. Mechanical amplification of the transducer crystal is achieved by use of a small metal plate

THE EXPERIMENTAL APPLICATIONS OF ULTRASONIC ENERGY

Most amateurs, or indeed small industrial users, are limited to the application of ultrasonics directly in air, as this is the only application for which the general purpose transducers are available on the market.

There are a number of aspects of ultrasonics which are certain to capture the imagination of the enthusiastic amateur, especially in the field of remote control and voice communication.

The fact that in this medium the experimenter is free from the necessity to acquire transmitting licences is a major attraction of these techniques.

In the case of amateurs or small industrial users who feel sufficiently confident to manufacture their own transducers from fundamental ceramic materials which are freely obtainable, the field of underwater transmission could be particularly exciting. This has the previously mentioned advantage of considerably greater range and would offer at least one immediate application, this being the facility of direct voice communication between aqualung divers.
Designed to suit the experimenter and amateur constructor, this stabilised power supply is ideal for supplying transistor circuits with 0—14 volts d.c. at up to 4 amperes. It eliminates the need for expensive battery replacements when working on the test bench.

The circuit (see Fig. 1 on blueprint) consists of a step down battery charger transformer $T1$ feeding into a bridge rectifier consisting of $D1$—$D4$, the output of which is smoothed by the $2,500\mu F$ capacitor $C1$ at about 22 volts off load.

The two Zener diodes $D5$ and $D6$ in series stabilise the base of $TR1$ to about 14 volts, thus maintaining the voltage at the top end of $VR1$ in the emitter circuit of $TR1$ at the same—since the gain of a grounded collector (or emitter follower) transistor is virtually unity.

Variation of the output voltage is carried out by "potting down" the variable resistance $VR1$, the slider of which feeds into the base of another grounded collector transistor $TR2$.

The output from across the $TR2$ emitter load is then fed into the bases of $TR3$ and $TR4$ connected in parallel, again in grounded collector configuration, the emitter load for these two transistors being the device to be supplied with power.

**SEMICONDUCTOR DETAILS**

When constructing the power supply, various precautions should be taken. Before mounting the transistors $TR1$—$TR4$ and bridge rectifier diodes $D1$—$D4$ ensure there are no burrs around the drilled holes in the chassis otherwise the insulating washers will be punctured and expensive smoke could be generated!

Also, prevent damage occurring to the face of the chassis where the transistors, diodes and heatsinks are to be mounted, since good thermal conductivity is essential for the long life of the semiconductors.

A smear of silicon grease on the chassis and semiconductor mating faces will assist heat conduction and maintain the insulation.

The insulating sleeves for diodes $D1$—$D4$ inclusive were cut from the outer casing of some old television coaxial cable; however, any form of insulating sleeving will do provided it functions properly.

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Continued on page 101
Construction of the intercom unit is simple • its finished appearance will enhance any desk or table in home and office • installation is easy, requiring only a two-cored cable between a pair of units.

The circuit of the amplifier which is the heart of the equipment is shown in Fig. 1 of the blueprint. It is a simple two-stage common-emitter transistor amplifier using germanium alloy junction transistors. It will be seen that there is no d.c. path shown for the collector current of the output transistor. This is because the collector current of this transistor goes down one of the line conductors to the loudspeaker in the other unit returning via the other conductor. The 0.1 μF capacitor C4 which is connected from the collector to the negative supply reduces the impedance of the collector load at the higher audio frequencies thus lowering the effective gain of this stage at these frequencies. This overcomes a tendency to high frequency oscillation. The 32 μF capacitor C6 connected across the supply lines was found to be necessary to prevent low frequency oscillation ("motor-boating") occurring when the battery runs down.

In Fig. 2 is shown the circuit of the rest of the unit. A four-pole three-position switch S1 selects the various functions. This switch is biased to its centre position ("LISTEN") and in this position only the loudspeaker/microphone is connected to line. When the switch is thrown to the "SPEAK" position, the loudspeaker/microphone is connected to the input of the amplifier and the line to the output (as described above). The other switch position is "CALL", and when the switch is held in this position the line is connected to the output of the amplifier and a 0.1 μF capacitor C7 is connected from the output of the amplifier to its input terminal. This causes the amplifier to oscillate violently at about 500c/s and results in a loud tone being emitted by the loudspeaker in the other unit.

CONSTRUCTION AND COMPONENTS
An attractive cabinet constructed of wood with an aluminium facia panel is shown in detail in Fig. 4.
VARIABLE LOW VOLTAGE D.C. SUPPLY UNIT continued from page 99

The faces of heatsinks for TR3 and TR4 can be painted with a black paint which has a matt finish and must be heat resistant capable of withstanding temperatures of at least 100°C. The heatsinks (and transistors) should be painted after assembly since the mating faces must be clean of paint for good heat conduction.

The usual precautions of using heat shunts such as pliers and not applying heat for longer than is necessary should be taken when soldering.

CHASSIS DETAILS

The blueprint shows the chassis construction full size and from these drawings any dimensions can be taken off.

The chassis itself is a proprietary item that can be purchased from any dealer, and the cover was made from expanded metal and is fixed to the main chassis with self-tapping screws and washers.

When fixing the fuse holder for FS1 an insulating sheet is required between the chassis and holder otherwise a short circuit will occur.

Before fixing transformer T1 the fixing brackets were removed to facilitate “drop through” mounting to the chassis.

TESTING

Check for continuity and correctness of wiring and ensure polarity of connection of C1 is correct.

Check insulation of diodes D1–D4 and transistors TR1–TR4 between cases and chassis. Don’t use a high voltage megohmmeter, the ohms x 100 range is sufficient on an AVO model 8.

Once satisfied with the wiring, rotate potentiometer VR1 knob fully anticlockwise, connect the mains power to the unit and switch on.

When VR1 is rotated clockwise the indication on M1 should rise from zero to 14V d.c. in the fully clockwise position. Should the response be different to above switch off immediately and ascertain fault.

Next connect a 4 to 5 ohm resistor of at least 20 watts rating to the output terminals and adjust VR1 until 14 volts is reached on M1.

The ammeter M2 reading should remain steady at about 3 to 4 amperes depending on the value of load.

Transistors TR3 and TR4 will get very hot and TR1 and TR2 quite warm. This is normal.

OPERATION

The fuse rating in FS2 position will depend upon the application. For example, an average transistor radio may take up to 100mA and a medium power inverter may take up to the maximum rating of 4A.

Currents of 5 amperes and more can be handled intermittently but for good transistor life 4 amperes should not be exceeded.

Ambient conditions are important, too. Allow plenty of air-space around the unit and avoid operating it in places or near to objects of relatively high temperatures.

Regulation is very good, the change in voltage from no load to 4 amperes at 6 volts is less than 0.25 volt and at 12 volts less than 0.5 volt.

SINCLAIR X-10 AMPLIFIER

With reference to our New Products feature last month, it has been brought to our notice that Technical Suppliers Ltd. are wholesale distributors only. All individual retail enquiries concerning this amplifier should be addressed to the manufacturers: Sinclair Radionics Ltd., Comberton, Cambridge.
Curtain Up

To half a million enthusiasts in 200 countries practical electronics means the art of radio communication—and half a million is the approximate number of actual or would-be transmitting amateurs scattered all over the world. Collectively, licensed amateur stations far outnumber all the broadcast, point-to-point and other professional service stations put together—and note that word "service". The amateur movement is a "service" and is designated as such in the International Telecommunications Union regulations agreed at Geneva in 1959. These half-million members of the Amateur Service are truly at the service of the communities in which they live. They contribute know-how in practical electronics—that all-pervasive phrase again! They contribute even their stations when emergency communications are needed. They intercommunicate in the universal language of "radio English" (more about this another month) on six world-spanning frequency bands and three more local v.h.f. ones, by morse, speech, teletype and video. They are at once diverse yet homogeneous.

It is about these people that the present feature will talk. The Editor's brief to the writer is that this feature should address itself primarily to readers who are at an early stage in amateur radio rather than those that have been in it for many years. This does not mean that we shall be writing "a beginner's guide" to the art of amateur radio: there are plenty of those to be had from various sources at various prices. Rather, we shall aim to help as much as we can by discussing the type of questions that baffle enthusiasts with feet on a lowish rung of the amateur radio ladder hesitant to hoist them on to the next one up—questions such as "What type of receiver should I buy—or should I try to make one?"

Or again: "Which are the best bands to listen on and at what times—and what am I likely to hear on them?"

Recognising, too, that nearly every short wave listener aspires to acquire in time that coveted transmitting licence we will help as far as we can with advice on this most important point.

What of aerials? Or v.h.f.? Or "sideband"? Amateur radio's very diversity means that there is going to be much to discuss in The 73 Page, and we cannot promise to get round to covering all possible topics at short order. It will take time to deal with even a few of the subjects which currently occupy the attention of the amateur service.

However, we will try—and your comments will be welcome for discussion here. Did you feel inclined to write in on any aspect of this specialised part of practical electronics that interests you.

Meaningful Number

Before one proceeds further a word or two about the running title to this feature may be to the point, for this title will headline it each time it appears (nice recognisability!).

Why The 73 Page? Because 73 is the most meaningful set of digits in amateur radio. It is the last thing a transmitting amateur says before he signs off a contact with a colleague.

It means Best Wishes. It is sought after as a motor car number, even as a house number. The Radio Society of Great Britain has it as its telephone number.

Its origin, lost in the mists of the early days of the electric telegraph, is believed to stem from abbreviations invented by the pioneers of the American railroad for quick communication between lonely signal cabins strung out across the prairies.

Today it is the most venerated phrase in amateur radio. We feel that none more appropriate could head this column.

Heart of "The Shack"—the Receiver

So much by way of introduction. Leaving generalities—now, and coming down to brass-tack practicalities, there is one question above all others that must be answered by every aspirant to amateur radio listening which will be examined on The 73 Page later on, and the destinations to which they lead explored. A number of them suggest methods of approach that offer the delights of h.f. reception at remarkably little cost, coupled with the fulfilment that comes from building equipment yourself.
Part Two

Having chosen the machine that suits both pocket and purpose, it is necessary to make the best use of it; not merely to tape the budgie and baby's first words, then relegate the recorder to the niche beneath the stairs. Like the car fanatic or the photography fiend, the tape recording enthusiast will soon be casting around for ways to improve upon his investment, and to obtain the best possible use from his machine.

First let us consider the microphone. If a microphone is supplied with the machine, it may be assumed that this suitably matches the input circuit of the recorder. But it may be required for an additional microphone to be used; there may indeed be a requirement for several microphones, plus a gramophone or radio input, to record a "programme", such as the commentary to a ciné film. Some care is necessary in selecting both microphones and that vital piece of equipment which is used to combine their outputs, i.e. a mixer.

Mixers

There are two types of mixer, the passive and the active. The former type consists simply of a selection of sockets, with matching resistors and perhaps variable attenuators acting as level controls for the various inputs. The output from this device is plugged into the tape recorder so that the combined signal modulates the tape in the same way that a single microphone would. But such a device has severe limitations; there is bound to be an insertion loss, and it may not be possible to adjust the level controls to give sufficient combined output to modulate the tape correctly.

The answer to this problem is to use an active mixer, or mixer/pre-amplifier. There are many different types on the market, the simplest being a transistorised, single-stage amplifier to boost the low level signals to an acceptable voltage for the "radio/pick-up" input of the tape recorder, while mixing the microphone signals as before, and providing attenuation of the latter to match the inputs.

More comprehensive models use several separate pre-amplifiers for the different inputs, with individual gain controls, and perhaps a magic eye type of modulation level indicator. This type of device is intended to apply a signal to the high level input of the tape recorder, and will give better quality recordings because of the better signal-to-noise ratio.

The electronic mixer will have inputs for different types of microphone and other sources and should, properly, have a cathode follower output so that it may be used at a distance from the main machine, the signal transfer then being at low impedance.

For serious recording, a good mixer unit is indispensable. Fortunately, this is not a difficult item to construct; and circuits for suitable types will no doubt appear in future issues of Practical Electronics.

Modulation Level

Mention has already been made of the need for applying a signal of adequate strength to modulate the tape. The correct modulation level makes all the difference between a recording that is acceptable, and one that is either weak and hissy or overloading into distortion on peaks of sound.

It is worth while spending some time experimenting with one's tape recorder to find the correct modulation level for a known input.

If a magic eye is fitted, the leaves or bar of the eye should nearly meet on peaks, but not overlap, and the input gain should be adjusted for this optimum. If a weak input is used, the replay will have to be turned up more to compensate for this and the upshot will be a higher level of amplifier noise as well as the required signal.

The dynamic range of the individual machine will have to be determined by trial and error. At the lower level the hiss of tape noise will outweigh the recorded signal when this is played back. At the upper level the amplified signal will overload the machine and cause distortion.

Where a meter is used for signal level indication, or modulation level readings, it is possible to assess the optimum recording level more accurately. But the type of meter, and the associated circuit, needs some
There are various methods of obtaining indications, changes and give a mean level indication. Some circuits deliberately designed to average out the sound of a moving coil meter, compared with the quicker consideration. Apart from the inherent sluggishness and again, information concerning the conversion of a "domestic" tape recorder to more professional standards with meter indication in place of, or in addition to, the magic eye, will probably follow in due course. It is a subject worthy of some attention.

Whether a meter or magic eye is used, the aim is to record at a level which approaches the maximum modulation level. If the machine is correctly adjusted, this should give the best signal-to-noise ratio. But exceeding this value will bring about distortion, due to a clipping of peak voltages in the amplifier circuit. When using a meter, the correct level, if not indicated, must be assessed by trial and error. With a magic eye indicator, the illuminated "leaves" or "column" should approach one another, but not overlap.

The correctly modulated tape is then played back, and the controls adjusted for comfortable listening level. Control of tone is also carried out during playback. The circuits are intended to produce a "tailored response" during recording so that the replayed output follows the equalised response curve exactly. Tone modification can then be made to taste.

**TEST SIGNAL**

To test the correct setting of the modulation level indicator, a steady signal, as pure as possible, is required. We have a ready-made test source in the television test signal that precedes a programme and is also broadcast several times during the test card periods of the morning on both BBC and ITV. This is a steady tone, a sine wave, and, provided the television receiver is in good order, the output should be level and unvarying.

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There are many tape splicers on the market, varying from the simple slot in a block to the elaborate devices with clamps and clips and measuring scales. Whatever method is used, the technique is to make a cut which matches the angle of the joining piece of tape (which is why a splicer is a better idea than a kitchen knife on the corner of the table). The ends are laid together and a piece of jointing adhesive fixed across the back of the joint; that is, on the shiny side, not the duller, oxidised side, of the tape.
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This article sets out to discuss some of the important practical questions involved in the design of a universal pre-amplifier with transistors, capable of both audio and metric applications. A complete design is given as well, detailed drawings appearing on the blueprint included in this issue of Practical Electronics. This pre-amplifier was developed and built by the author primarily for use between the probe and Y-amplifier input of an oscilloscope and for use with a transistorised tape recorder for various laboratory experimental purposes. Obviously many further applications exist.

GENERAL CIRCUIT DETAILS

Fig. 1 on the blueprint shows the complete circuit diagram of the prototype. This comprises two separate circuit cards, each having a gain of exactly 10. A central switch S1 connects either one or both of these cards between the input and output terminals, giving gains of exactly 10 or 100 respectively, or, in its third position, it switches the unit off.

The left hand circuit card VB1 contains three cascade transistors TR1-TR3 and a d.c. peak bypass input circuit to the base of TR1. The latter is an essential feature in a universal unit of this nature, to prevent destruction of the transistors due to d.c. charging surges of anything up to several hundred volts when connecting the input to the anode circuits of valve equipment.

It may seem strange to use three transistors for a gain of only 10, but this is necessary to achieve the required high constancy. When properly built and adjusted, this circuit shows no perceptible change of gain (as displayed on an oscilloscope or meter) over temperatures from the freezing point up to over 50°C. (over 122°F), or for battery voltage variations between 6V and 11V.

The pre-amplifier design here described should be suitable for tropical temperatures when shielded from the direct rays of the sun, or for European summers, outdoors in full sunshine. Even considerable heating indoors, due to standing the unit on top of valve operated items of equipment of high power dissipation, should give no gain fluctuations or other troubles.

With the assurance that the gain really is rock steady throughout all working conditions likely to be met, it was convenient to make it exactly 10 per circuit card, wherewith the complete unit is a decimal-step pre-amplifier. The great advantage thereof is that, when used in conjunction with calibrated oscilloscopes, or with a.c. voltmeters, the existing scales can still be read-off and mentally multiplied or divided by powers of 10, i.e. a mere shift of the decimal point is required.

The right hand circuit card VB2 contains another identical cascade of three transistors TR4-TR6, giving a gain of 10 once again. The only difference compared to the first card is that the d.c. peak bypass circuit is here omitted, because the input signal is always applied to VB1. The right hand circuit card VB2 also contains the emitter follower output stage TR7.

The circuit of VB1 is always operative, in both the gain 10 and gain 100 settings of the complete pre-amplifier. In the gain 10 setting, TR7 is switched directly onto the output of TR3 in VB1 and TR4-TR6 idle with C4 shorting the base of TR4 for a.c. to prevent parasitic instability. C4 is connected up to the negative supply line (and not to chassis) for this purpose, to prevent application of d.c. voltages of incorrect polarity; either connection would be just as good for pure a.c. signal considerations.
In the gain 100 setting, the output of VB1 is connected through to the input of VB2, via C4, and the output at TR6 is connected through to TR7.

**IMPEDANCE**

If the pre-amplifier is to be used for metric purposes between the probe and the input socket of an oscilloscope or valve voltmeter, the input impedance must be equal to that of the instrument in question.

In the published design the input impedance at PL1 has been adjusted to exactly 135 kilohms to match the Y-amplifier input impedance of the author's oscilloscope. Adjustment of the input impedance to other values will be fully discussed later. But, in brief, it should be explained that this will involve a change of values for R3, R4, R6, R8, R9, VR1, and VR2, also possibly the replacement of TR3 by an OC304.

The output impedance at PL2 is very low, as given by the setting of VR2 or VR4 (the respective base feeds for TR7 in the gain 10 and gain 100 settings) divided by the current gain of TR7 (about 20); it is, in fact, about 500 ohms. The purpose of this low output impedance is to permit arbitrary lengths of uncompensated coaxial cable between the output and the oscilloscope Y-amplifier input without loss of bandwidth due to cable stray capacity.

As far as audio uses are concerned, the low output impedance gives satisfactory performance on 4,000 ohm headphones, or even on ones of somewhat lower impedance, and long runs of screened cable are permissible from the output to a remote main amplifier without loss of treble when using the unit as a microphone head pre-amplifier.

**PERFORMANCE**

The bandwidth of the pre-amplifier as described in this article extends from 2c/s at the low frequency end on either gain setting to about 100kc/s at gain 100 or about 150kc/s at gain 10 at the high frequency end. These figures refer to the so-called 3dB-down points, i.e. the gain has dropped to one-half of that at midband frequencies at these limits. The response is substantially flat over the entire "hi fi" audio frequency range from 20c/s to 20kc/s and some way beyond either end.

Harmonic distortion is extremely low up to drives giving an output of 1 volt r.m.s.; it is not visible as deformation of a sinewave on an oscilloscope up to this signal level, a fairly sensitive visual test. Phase-shift is negligible, so that pulse and transient responses are excellent.

The unit is thus equally satisfactory for both high fidelity audio work and for waveform display on an oscilloscope.

**APPLICATIONS**

Fig. 8 shows the manner in which the pre-amplifier may be connected to increase the Y-deflection sensitivity of an oscilloscope. The input impedance of the pre-amplifier must of course be adjusted to match the oscilloscope.

Fig. 9 sketches the arrangement to be adopted when using the pre-amplifier to increase the sensitivity of any a.c. valve voltmeter. The impedance matching requirements are here the same as for oscilloscopes if one desires to use the existing probe of the valve voltmeter at the input of the pre-amplifier while maintaining exact decimal step sensitivity increases.

If a simple diode peak rectifier circuit is interposed between the pre-amplifier output and the meter input, d.c. valve voltmeters or high resistance multimeters...
on low d.c. ranges may therewith be converted to sensitive a.c. “valve” (transistor) voltmeters. There are no impedance matching conditions to be observed in this case, provided that the meter and rectifier circuit impedance is much greater than the output impedance (500 ohms) of the pre-amplifier. Multimeters having a resistance of 4,000 ohms per volt and upwards on the d.c. ranges can thus be operated from the pre-amplifier output.

Fig. 10 shows a suitable rectifier circuit to make the meter indicate peak volts of one polarity. Reversing the diode and the connections to the meter makes it indicate peak volts of the other polarity. In the case of arbitrary non-sinewave signals applied to the input of the pre-amplifier, where the peak voltages on negative and positive half cycles may differ, corresponding different readings will be obtained.

Taking the Caby Model B20 multimeter as a typical example, we have a lowest d.c. voltage range of 0-5V f.s.d., 2,000 ohms impedance, available on the meter. This is satisfactory in every way for connecting to the output of the pre-amplifier via the rectifier circuit of Fig. 10 which may be built into the coaxial connecting cable fitting PL2 on the pre-amplifier at one end and the multimeter terminals at the other end. The multimeter is therewith an a.c. voltmeter giving full scale deflection for 50mV peak or 5mV peak (gain 10 or gain 100 settings respectively) applied to the pre-amplifier input, an excellent sensitivity. Moreover, the arrangement is usable not only at power mains frequency, but at any frequency over the entire hi fi audio range. If measuring positive and negative half cycles separately where these differ, it is important to remember that the pre-amplifier inverts the signal in the gain 10 setting, but not in the gain 100 setting.

Table 1 lists some typical audio applications of the pre-amplifier. These certainly do not require the accurate decimal step and stabilised gain, but it is, in the interests of universality, necessary to point out that the pre-amplifier is in every way suitable for such applications as well.

THE VEROBORD SYSTEM

Although orthodox printed circuit panels would be used in commercial systems of this nature wherever the production numbers are at all high, the Veroboard System is more suitable for small production numbers and especially for amateur and experimental equipment.

The VB2503 panel is made of plastics card drilled over its entire surface with a square grid of holes having 0.15in spacing, 16 holes across the width and 21 holes along the length. The rear side only is fitted with 16 parallel strips of copper, each respectively running along one row of 21 holes along the length of the panel. These strips are thickened and gold-plated at one end, where the whole card plugs into a linear 16-contact socket.

Components are arranged on the front side (Fig. 2 and Fig. 4), where there are no copper strips; the wire ends are pushed through holes at respectively convenient positions, soldered with a spot of solder at the rear where they pass through the copper strip, and then cut off close.

If alterations are subsequently required, melt the solder by applying an iron at the rear while pulling the component wire with pliers from the front. Then jab a piece of bare tinned copper wire through the hole
THE ELECTRONICS
OF LIGHT-OPERATED SWITCHES

Described by G. J. KING

Our heading illustration shows the Mullard ORP cadmium sulphide photoconductive cell. The sensitive element is contained in a glass dish 14mm in diameter and 8mm deep.

There are hosts of applications for a device capable of switching electrical contacts on or off automatically when its light-sensitive control element is subjected to changes in level of illumination. A typical application is for switching on a car parking light at dusk and switching it off again at dawn without human control.

A similar application is for switching on house, shop, office, factory or street lights when the ambient illumination drops below a predetermined level, and for switching them on again when it rises. This does away with the old-type time-switch. This application is also useful to discourage unwanted visitors when the house is left unoccupied for any lengthy period, such as during holidays and so forth.

Other applications include the automatic opening of the doors of a garage when the light-sensitive element picks up the rays of the headlamps of the oncoming car, the counting of articles as they drop through and thus interrupt a ray of light which is directed onto the light-sensitive element, a smoke alarm, for use in smokeless zones, where a ray of light is interrupted by the presence of excess smoke in a chimney flue or stack, this reducing the intensity of light falling upon the light-sensitive element . . . and so on.

The basic functions of light-operated switches are the production of a potential, the change in a potential or the change in characteristics—such as resistance—of the light-sensitive control element. Such effects can be utilised to energise or de-energise a relay, thereby opening or closing a pair or more of electrical contacts, which in turn operate a light, bell or other alarm device, or an electric motor often in a form of servo arrangement.

BASIC CONTROL

In cases where the control current is very high, a secondary relay with a heavier set of contacts than those of the primary relay is controlled by the contacts of the primary relay. The basic controlling features are shown in Fig. 1.

![Fig 1. Basic control circuits for light-operated switches. At (a) a relay switches a lamp on and off, at (b) an alarm bell is controlled via a mains power unit, and at (c) a secondary relay switches power to a motor.](image-url)
At (a) we have the straightforward case, such as may be used to switch a parking light on and off. Here the battery could be the car accumulator (6 or 12V). This battery, being a d.c. supply, could both operate the relay by way of the light-sensitive element and work the bulb in the parking light.

The idea is that during the day the light-sensitive element in conjunction with its control circuit would pass insufficient current to energise the relay. The contacts thus remain open and the bulb extinguished. At lighting up time, however, the light-sensitive element and associated control produces an increase in current from the battery through the winding of the relay. This energises the relay, closes the relay contacts and thus passes battery current through the bulb which then lights.

At this juncture it should be noted that the arrangement could be reversed. That is, the relay could be energised during the daylight hours, under which condition the contacts would be open, and then de-energised during the night time, when the contacts would be closed to pass battery current through the bulb. It is just a matter of choosing the required light-sensitive element controlling circuit and relay.

At (b) we have a little more complicated arrangement, where a mains power unit is employed both to operate the alarm bell and the relay, the latter via the light-sensitive element and its associated circuit.

At (c) is shown an arrangement which features two relays. Here the primary relay is operated by a battery in the light-sensitive control circuit. When the contacts of this relay close, power from the mains supply is caused to pass through the winding of the secondary relay, which is a mains-operated type. The heavy contacts of this relay then close and pass mains power to the drive motor, which may work a garage door or some other mechanical device.

It is possible, of course, to make the whole control unit mains-operated to avoid the battery for the primary relay. This could be accomplished by an extension of (b), where a mains power unit supplies a d.c. voltage for the relay and light-sensitive control circuit, or by using a mains-operated primary relay.

So much, then, for the basic control and relay circuits, but what about the light sensitive element itself?

LIGHT-SENSITIVE DEVICES

An early light-sensitive element was the photoelectric cell. This was used extensively not only for controlling switching circuits by light but also for the replay of sound tracks on cine films. The photoelectric cell is, in fact, still used for the latter application, but other light-sensitive elements are better suited for control work. The photo-electric cell is a device which delivers a small amount of electricity (potential) when light is directed upon it. The greater the light intensity, the greater the potential, within limits, of course.

Recent innovations include the phototransistor and the photoconductive cell, the latter being illustrated in our heading, and it is mainly about these that this article will be concerned.

Let us first look at the phototransistor. This works in a similar way to a normal transistor into which light is allowed to enter. A transistor is, in fact, a light-sensitive device, but its usual opaque coating prevents it from responding to changes in level of illumination.

PHOTOTRANSISTOR

However, the phototransistor is a transistor designed to fully exploit the inherent photo-electric properties. It can be considered as a light-sensitive semiconductor junction diode (photodiode) in which the light current is amplified by the normal transistor action.

The forward current in any semiconductor diode is caused by a uniform interchange of current carriers across the junction. These can be electrons moving in one direction and positive holes moving in the opposite direction.

This unhindered flow across the junction, giving rise to the normal flow of electricity, results because the potential applied across the junction is in opposition to and outweighs the so-called "potential barrier" which is formed across the junction when it is manufactured, due to the initial diffusion of current carriers.
The potential barrier is thus broken down by the applied forward potential.

Now, when the diode is biased in the reverse sense, the inherent potential barrier is effectively reinforced. This means that normal current flow is prevented because the barrier prevents the interchange of current carriers. Thus, we have the normal rectifier action where current can flow freely in one direction and is virtually prevented from flowing in the opposite direction. The same effect is exhibited by a diode valve, of course.

However, with a junction diode there is some difference. With a thermionic valve diode, if the anode is negative with respect to the cathode, no current whatsoever will be passed. But with a semiconductor diode, a "leakage current" results under this reverse-biased condition. This is because of a flow of "minority carriers" (these being positive holes in n-type material and electrons in p-type material).

In effect, the minority carriers tend to multiply when light is allowed to fall on the junction. The leakage current then rises, and as the light intensity increases, so does the leakage current increase. The normally low leakage current when no light is falling on the junction is called the "dark current", and the higher value of leakage current when the junction is illuminated is called the "light current".

The light-to-dark current ratio is enhanced considerably by amplification due to the normal transistor action of the device, and with a well designed circuit this ratio can be made as high as 480 at a temperature of 25°C. Temperature comes into it because the minority carriers also tend to multiply as the junction temperature increases. Thus, at 45°C the ratio may drop to around 20.

Under normal operating temperatures the sensitivity of the device is remarkable. For example, if a 2½V pea lamp is barely lit from a 1½V source, and the resulting small illumination is focused by a simple lens on to the sensitive area of the phototransistor over a distance of a few centimetres the amplified current rises from the order of microamperes (the dark current) to in excess of 5 milliamperes! Thus, the usefulness of the phototransistor as a light-sensitive element can be appreciated.

**SWITCHING CIRCUITS**

Fig. 2 shows a simple switching circuit using the Mullard OCP71 phototransistor. Extra sensitivity and temperature compensation is given by the use of a transistor d.c. amplifier following the phototransistor, as shown in Fig. 3. Both of these circuits lend themselves to considerable experimentation to suit specific applications. The base resistor can give a degree of temperature compensation if of the negative temperature coefficient type. The actual value is best determined experimentally to suit both the conditions of maximum temperature and the light level. However, a component in the order of 5 kilohms is suitable for most applications.

The relay should have a coil of about 5 kilohms and it should pull-in at a power of about 5mW for reliable operation.

**PHOTOCONDUCTIVE CELL**

The photoconductive cell is essentially a resistive element made of cadmium sulphide which has the property of decreasing greatly in resistance when subjected to illumination. In complete darkness the resistance is in the order of 10 megohms and this can drop to as low as 75 ohms when the cell is fully illuminated. This very large dark-to-light resistance ratio means that the cell is extremely sensitive. More so, in fact, than the phototransistor.

The cell, which is often called a light-sensitive resistor (l.d.r., for short), is made by Mullard in three versions. There is the ORP12, which has maximum response in the red region and is intended for general purpose industrial applications and automatic contrast and brightness control in television receivers. This has a maximum limit of power dissipation of 200mW up to 40°C. At higher temperatures the allowable dissipation reduces progressively to zero at 60°C.

The RPY15 (formerly called the ORP15) has a maximum power dissipation of 400mW at 25°C and is thus more suitable for applications where power is an important factor.

A low power unit is the RPY14. This has a maximum dissipation of 20mW at 25°C and is designed essentially for exposure meters and automatic camera applications.

![Fig. 4. A photoconductive cell (light-dependent resistor) can be arranged in this simple circuit to provide an effective light-operated switching action](image-url)

The l.d.r. has several advantages over the phototransistor for certain applications. For one thing, the sensitivity that it can convey to a control circuit is greater than that of the phototransistor. The larger versions can dissipate a greater power than the phototransistor, the collector dissipation of the OCP71, for instance, being limited to 100mW at 25°C (50mW at 45°C). Moreover, the l.d.r. can operate over a wider range of potentials than the phototransistor including operation at a.c., and polarity is not important. It can be arranged in a simple series circuit, as shown in Fig. 4.

**SIMPLE L.D.R. CONTROL CIRCUIT**

Here the l.d.r. is shown connected in series with a 5 kilohm relay coil and a 12V d.c. supply. If the relay is adjusted to pull-in at about 12mW (e.g. at a current of a little over 1·5mA), a very sensitive light-operated switching device can be evolved from the simple circuit. For reliable results, however, a sensitive relay is desirable.

A more robust Post Office type relay can be utilised by following the simple l.d.r. circuit with a transistor d.c. amplifier, as shown in Fig. 5. Here the l.d.r. is caused to change the base bias of the OC72 transistor and thus give an increase in collector current (and hence, relay current) when the resistance of the l.d.r. drops under the influence of illumination.
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- 6 transistors and diode.
- 350mW output.
- Superhet circuit, ferrite rod aerial.
- Weymouth Radio printed circuit board.
- Component positions and references printed on back of board.
- Nicely styled wooden cabinet, 11 x 7 x 5".
- Vinyl covered in various colours.
- 6 x 4" speaker giving good bass and treble response.
- Full instruction booklet 2/- Free with kit.
- L.F. frequency 470 kc/s.

Lining up service if required.

All parts supplied separately. Write for list. S.A.E. please.

Set can be supplied fully built for £6.17.6 tax and carriage paid.

9V battery required. VS9 or P.P.9 (3/9 with kit).

"MINOR" Record Player with "MAJOR" Performance

Packed of 3 coded RF transistors (equivalent of OC44/5) 7/6 post paid. A set of 6 transistors and diode with circuit diagram. Nicely packed in foam-lined box; useful for presentation. 1/5 post paid.

TRANSISTORS

ELECTRONICS (Gamberley) Ltd.
15 Victoria Avenue, Gamberley, Surrey.
(Closed Saturday)
Fig. 5. A d.c. transistor amplifier following the l.d.r. allows the use of a more robust relay and provides a facility for sensitivity adjustment

The 5 kilohm potentiometer is used to adjust the base bias to give the required light/dark sensitivity conditions. Note that the diode across the relay winding in Figs. 2, 3 and 5 is to suppress the voltage surges which are otherwise likely to develop across the coil and damage the transistor during the switching cycle.

Several light-operated switches of the nature of those described in this article have been built by the author, and one application which has not yet been mentioned is for the measurement of speed.

This application is useful at race meetings of all types. At the finishing post a beam of light is arranged to cross the track and hold-on a relay of a light-operated switch. Now, when this beam is broken by the winner passing the finishing post, the relay switch changes over and operates a mechanical arrangement which stops a timing watch or other type of timer. Thus, provided the timing device is started when the race commences (this can be arranged automatically as well if needed) the winner himself stops the timing, and the actual time taken can be read off the dial in the ordinary way.

The experimenter in electronics will almost certainly find many other applications for the circuits described in this article.

PRACTICAL ELECTRONICS BINDERS

EASI-BINDERS specially designed to hold twelve issues of PRACTICAL ELECTRONICS are now available.

These binders are finished in maroon waterproof and greaseproof cloth and are embossed with gold lettering on the spine.

Order your binder from:
Binding Department,
George Newnes Ltd.,
Tower House,
Southampton Street,

The price, per binder, is 13s. 6d., inclusive of postage.

PRE-AMPLIFIER continued from page 109

PRECISION DECIMAL STEP

rapily while again applying the iron, to clear the hole of solder before inserting the new component.

It is advisable to use a miniature pencil-bit iron, e.g. of the 6 volt 10 watt variety. The copper strips on the cards take solder extremely rapidly and readily, so that it is possible to work quickly enough to prevent damage to transistors.

In the diagrams, Figs. 2, 3, 4, and 5, the rear copper strips have been numbered 1 to 16 from left to right as viewed from the front (components side) of the cards, and the 21 holes along any strip have been lettered A to U commencing from the socket end. Any hole can thus be specified by the corresponding number and letter combination.

The copper strips are to be interrupted at all the specified holes on the rear side of each card. Messrs. Vero Electronics sell a special hand awl, Cat. No. VB3011, for this purpose. This consists of a wooden tool handle carrying a small drill shaft of somewhat greater diameter than the width of the copper strips.

The copper strip away at the desired point.

Drill is therewith held central while it scrapes the copper strip away at the desired point.

The two circuit cards, together with their associated sockets, can be accommodated quite conveniently in a box measuring approximately 5in by 5in and 23in deep. Fig. 7 shows the arrangement of the items inside the box and also details the interboard wiring.

Next month: the concluding part of this article will discuss some of the principles involved in the design of the pre-amplifier; factors which determine the input impedance will be explained and practical information given for adjusting this to some other value.

Contributed Articles

The Editor will be pleased to consider for publication articles of a theoretical or practical nature. Constructational articles are particularly welcome, and the projects described should be of proven design, feasible for amateur constructors and use currently available components.

Intending contributors are requested to observe the style in our published articles with regard to component references on circuit diagrams and the arrangement of the components list.

The text should be written on one side of the paper only with double spacing between lines. If the manuscript is handwritten, ruled paper should be used, and care taken to ensure clarity, especially where figures and signs are concerned.

Diagrams should be drawn on separate sheets and not incorporated in the text. Photographic prints should be of a high quality suitable for reproduction; but wherever possible, negatives should be forwarded.

The Editor cannot hold himself responsible for manuscripts, but every effort will be made to return them if a stamped and addressed envelope is enclosed.
REMOTE control of apparatus is possible over distances upwards to 20 feet with this simple transmitting and receiving equipment.

The transmitter is housed in a popular type of torch case and is indeed as simple to operate as a normal electric torch. Just point the transmitter at the receiver, switch on and the ultrasonic beam radiated will be picked up by the receiving transducer, converted into electrical energy, and applied to operate a relay.

Unlike radio wave transmission, this "wired" control system does not require a G.P.O. licence or other official sanction before it can be used.

APPLICATIONS

Apart from the obvious novelty value this ultrasonic equipment has certain very practical applications. We can only mention a few, but other applications will occur to many readers.

Remote channel selection on television receivers is possible if an electrically operated channel selector switch is fitted in the receiver. This switch would move one position for each pulse sent out by the transmitter. Radio receivers with preset tuning could be similarly controlled.

The control system does not require a G.P.O. licence or other official sanction before it can be used.

Any mains powered equipment could be brought into operation from a distance. For example, garage doors could be operated from inside a car, if the necessary electro-mechanical equipment is installed in the garage.

Although the effective range of the equipment as described in this article is 20ft maximum, some hints are given for increasing this upwards to 100ft for those who may wish to experiment further with ultrasonic remote control.

TRANSUDCERS

Two identical Gulton type 1404 ultrasonic transducers are used in this equipment. One functions as a transmitter—radiating pressure waves at a frequency of 40kc/s. The other transducer operates in the reverse manner converting the pressure waves back to electrical energy. The two units may be freely interchanged between the transmitter and the receiver.

Transducers should be bought as a pair, since it is important that their nominal frequencies be the same within ± 500c/s.

TRANSMITTER CIRCUIT

A pair of OC71 transistors are used in a feedback oscillatory circuit, this is shown in Fig. 4. The transducer X1 is connected in the feedback loop and provides a high Q circuit with a resonant frequency of 40kc/s.

Power for the transmitter is obtained from a miniature 9V battery (P3 or DT3). The current consumption is 4mA.

RECEIVER CIRCUIT

A transducer of identical type to that used in the transmitter is incorporated in the receiver, see Fig. 1. A voltage is developed across this transducer X2 when it is subjected to pressure waves. This voltage is applied to the base of the first amplifying stage TR3.

The collector of this transistor is directly coupled to the base of TR4 and the gain of these two stages is stabilised by means of overall negative feedback.

The signal is passed on via C2 to another two-stage directly coupled amplifier consisting of TR5 and TR6. Negative feedback is used here also to maintain constant gain. A tuned transformer T1 couples TR6 collector to the output stage TR7. This transformer is tuned to 40kc/s and ensures optimum sensitivity as well as providing rejection of other ultrasonic signals.

A relay RLA is connected in the collector circuit of TR7, and this becomes energised when TR7 is switched on by a signal passed on from the preceding stages of the receiver. The single-pole, make-break contacts of RLA can be used to switch power supplies or to operate other circuits in the apparatus it is intended to remotely control.

A 9V battery supplies the receiver. The consumption is 6mA.

RECEIVER CONSTRUCTION

All components for the receiver are accommodated quite easily on a laminated plastics board measuring 4in x 4½in. The prototype model described and illustrated here was built on, a piece of Veroboard. It is not essential of course to use this particular material and if preferred a similarly sized piece of laminated plastics or even hardboard could be employed.

In such a case the components could be secured to terminal posts consisting of short pieces of 18 s.w.g. tinned copper wire inserted through holes drilled in appropriate positions (see Fig. 3). Use a drill slightly smaller than the wire to ensure a tight fit. Push the wire through the board until about ½in emerges then cut off leaving a similar length protruding at the other side. Wire up the posts on one side of the board to agree with the diagram in Fig. 2 before mounting the components on the other side.

If the Veroboard is being used, remember to break the copper strips where indicated (see Fig. 2).

The relay coil is held in position by two loops of wire which pass through holes in the board.

INSTALLING THE RECEIVER

Mounting or housing arrangements for the receiver assembly will depend upon the application requirements or personal choice.

Generally speaking, it will be convenient to mount the receiver unit adjacent to the apparatus being controlled, or even within the same cabinet as for example in the case of a radio or television receiver. In this way the wiring from the relay to the controlled circuit is kept short.

The transducer must be mounted in such a manner that it will "look" directly towards the transmitter when the latter is brought into operation. If a 0-937in diameter hole is drilled in the front of the cabinet or container, the transducer can then be pushed through so it is flush with the front surface. If the cabinet material is not sufficiently thick to permit this method being adopted, a hole approximately ½in diameter should be drilled and the transducer secured to the inside surface by means of a clip or bracket.
When wiring up the relay contacts to the controlled apparatus, ensure that these connections are well insulated and isolated from the components and wiring of the ultrasonic receiver.

The relay contacts have the following maximum ratings:

<table>
<thead>
<tr>
<th>Power</th>
<th>15W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>1A</td>
</tr>
<tr>
<td>Voltage</td>
<td>250V</td>
</tr>
</tbody>
</table>

Contact resistance is 0.05 ohm and the actuate time is 2msec.

TRANSMITTER CONSTRUCTION

The transmitter uses few components and the circuit is quite simple. However, due to the compact form of its assembly a certain amount of dexterity is called for during construction.

No insurmountable problems should arise if a torch case of the type and size specified is obtained. A larger torch case could be used if so desired; it would be necessary then to increase the width of the component panels to ensure a good fit in the case.

The first task is to prepare two small pieces of Veroboard as shown in Fig. 5.

Next mount the resistors and transistors in position on each board. The most tricky operation comes next. Solder one end of C1 to the (inner) side of panel A, at the point indicated in Fig. 5. Carefully manipulate the other lead on this capacitor to allow this to be soldered to panel B as indicated. Finally, secure this sandwich assembly by inserting short lengths of 20 s.w.g. tinned copper wire through facing holes in the two panels at the four positions 1A, 4A, 1J and 4J.

Initially solder these four wires to one panel only. Carefully adjust the position of the panels until there is a separation of 3/16 in between their inner surfaces, and then solder the other ends of the four wires to secure.
Fig. 4. Circuit diagram of the transmitter

Connect two insulated flexible leads to the miniature coaxial plug, twist these leads and cut off leaving a 1in length. Solder the free ends, one to panel A and the other to panel B as indicated "to x 1" in Fig. 5.

Connect a lead of about 3in length to the linking wire A1 as indicated in Fig. 5. Use blue covered plastics covered flexible multi-strand wire. Single conductor leads are not at all suitable for this purpose—since their rigidity will inhibit the manoeuvres that are involved in the assembly process, and will probably result in breakages occurring at soldered connections.

Fig. 5 (above, left). The transmitter panels showing the arrangement of components. Panel B is above; Panel A below. Each panel measures 1\(\frac{3}{4}\)in by 1in.

Fig. 7 (above). Modification to the torch switch.

Fig. 8 (below). A sectional view of the torch case with the transducer, transmitter assembly, and battery installed.

TORCH CASE

A "Vesta" plastics torch case available at many multiple stores is used in this design. This particular case is made in a variety of colours, it is 5\(\frac{1}{2}\)in long and has an internal diameter of 1in.

Remove the top cap from the torch case. Take out the glass, bulb, and reflector; these items are discarded.

Examine the switch mechanism. The brass tongue which protrudes towards the top of the case must be cut off as far down as possible. This can be performed with a pair of tin snips. Solder a (red coloured) plastics covered flexible lead to the stub and bring this lead down and out through the bottom of the case. Refer to Fig. 7. A small instrument type iron is essential, and care must be taken not to allow the bit to make contact with the plastics case. Place the transmitter assembly inside the lower portion of the case, but with its end protruding slightly.

Connect the red lead from the switch to point A4. Now gently push the assembly up inside the case until the coaxial plug emerges at the top. Fit the transducer to this connector. Refit the plastics top cap.

Move the assembly back down the case (applying slight pressure on the transducer face at the same time pulling gently on the blue battery wire) until the face of the transducer is level with the top edge of the torch cap.

continued on page 146
Fig. 16. Some typical transistor encapsulations from the Newmarket range

TRANSISTOR DOs AND DON'Ts

DO:
1. Check polarity (npn or pnp).
2. Check battery supply polarity.
3. Identify leads correctly.
4. Ensure correct type.
5. Ensure whether transistors should be insulated from chassis.
6. Ensure contact of the faces of power transistors are smooth and that thermal contact with the heat sink is efficient.

DON'T:
1. Bend leads too close to the seal.
2. Solder leads without heat shunt.
3. Apply heat too long.
4. Mount in or near strong magnetic or electrostatic fields.
5. Operate transistors above maximum ratings.
6. Use “quick heat” gun type soldering irons.

Useful Tips
1. Silicone grease smeared on the surfaces in contact with the heat sink will increase heat conduction.
2. Black matt heat-resistant paint used on heat sinks and transistors helps dissipation of unwanted heat.
3. Long nose pliers, or a crocodile clip with two copper slugs soldered into the jaws, serve as heat shunts, when soldering into position. The heat shunt should be attached to the wire being soldered.
The circuit in Fig. 15 shows the three basic configurations in which transistors are used: emitter-grounded, collector-grounded, and base-grounded.

**Fig. 1.**-Circuit 1

**Fig. 2.**-Construction

**Fig. 3.**-Characteristic curves

**Fig. 4.**-Circuit 2

**Fig. 5.**-Circuit 3

The circuit shown in Fig. 5 is practically identical to the circuit shown in Fig. 4 except that the input signal is applied to the base instead of the collector.
**Transistor**

For the purpose of this booklet, pnp transistors only will be considered but the information given will also apply to npn types except that biasing and h.t. supplies have reverse polarity d.c. voltages applied.

The addition of an extra element to the junction diode, p-type material in the pnp transistor and n-type in the npn transistor produced a device capable of amplification. In practice the n-type material in a pnp transistor is extremely thin. Typical constructions of some transistors are shown in Fig. 14.

---

**Triode**

De Forest found that the addition of a third element or electrode (called a grid) to the diode placed close to the cathode relative to the anode enabled a small variation of voltage on the grid to produce a large variation of anode current. This discovery and its development precipitated a technological revolution, the implications of which the world still hasn't fully realised.

**Construction**

The varieties of triode types are too numerous to be treated fully by this booklet but a typical receiving triode, the construction of which is common to all types, is shown diagrammatically in Fig. 8. The grid can be seen to be a form of spiral wire. The electrons pass from cathode to anode through the spaces between each turn of the coil.

**Theory**

The characteristic curves given in Fig. 9 of anode current against anode voltage for various values of negative grid voltage are similar to those for the diode except that the grid voltage is the third parameter.

From the characteristics it can be seen that as the grid voltage is made more negative the anode current is eventually reduced to zero. It is this variation of anode current with grid voltage that produces amplification and is known as mutual conductance. The change in voltage across a load resistor, placed in series with the valve anode and h.t. positive rail, is greater than the change in grid voltage that produced it. More detailed information on this principle is given in the centre portion of this Data Booklet to be given with the January issue of Practical Electronics.

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**Fig. 7. Triode circuit symbol (left)**

**Fig. 8. Triode construction (below left)**

**Fig. 9. Triode characteristics (below)**
In Fig. 13, and as controlled receiver. Some of their characteristics are shown on page 13. Further development of the function of Fig. 12, with typical circuit shown in Fig. 13, which is described in the region described in the Rocard section is emphasized.

Fig. 11. Period

Fig. 10. Tension

Other Types of Valves

Continued from page 2
Six transistors are employed in the power amplifier, the circuit of which is shown in Fig. 6. The first transistor, TR5, is connected as an emitter follower, the collector being grounded to a.c. by the 32μF capacitor C15. This mode of operation gives high current gain and zero phase shift between input and output, a good match therefore exists for practically any type of input. Stabilisation is achieved by C14 across the bias network.

The output from the emitter of the first stage is directly coupled to the high gain stage TR6. C17 assists in reducing the high frequency rising characteristic of this stage. The collector of this stage is directly coupled to the base of the phase reversing npn transistor TR8 and via D1 to the base of TR7.

TR7 and TR8 operate in the class B Darlington mode to increase current gain. This again has the advantage of push pull emitter follower operation. It will be noted that each stage is directly coupled throughout the amplifier; there is therefore no phase shift or frequency losses due to capacitive coupling.

FORWARD BIAS

The output transistors TR9 and TR10 have a small forward bias to minimise crossover distortion. This bias is set by the voltage drop across the 1 kilohm resistors R26, R27 which are in parallel with their input. Capacitors C18, C19 are connected across these resistors and stabilise the circuit reducing the drive some 70 per cent at 30kc/s.

Transistors TR7 and TR8 are biased for the same reason by the voltage drop across the OA10 diode D1.

FUNCTION OF THE DIODE

A 70 ohm resistor could be used in place of the diode D1 to serve the same function; a resistor would not, however, give any temperature compensation and the bias would be disturbed accordingly. True thermistors could be used to compensate for the...
temperature variation of the emitter base resistance, but their performance is not comparable with the OA10 diode which has characteristics similar to the germanium transistor.

Having explained the reason why the diode is used and its function in the amplifier circuit, it would be well to describe a precaution that must be observed in placing it in the circuit when constructing the amplifier.

The OA10 is a high current, low voltage germanium junction diode. It is important that no alternative diode is used in the amplifier and great care should be taken during construction that it is connected the correct way round in the circuit. The function of D1 is to assist in temperature stabilisation of the circuit and to couple the complementary pair TR9, TR10 in a correct push pull mode.

It is important that the base inputs to the driver transistors are never open circuit with respect to one another at any time. An equivalent condition arises should the OA10 diode be inadvertently reversed. If this happens the base of the driver transistor TR7 becomes more negative while the base of TR8 becomes more positive, moving towards the earth rail. The resulting large bias increase will cause the collector/junction resistance to become extremely low and the output transistors will then draw excessive current through the base in a matter of seconds resulting in collector to emitter short and the ruining of expensive transistors. (This is of course no different from connecting the grid of a thermionic valve to a 400V line.)

To enable the amplifier to be used with low-level sine wave testing, 1 ohm resistors are inserted in the emitter circuits of the output transistors, giving reverse bias and further aid to linearity.

The quiescent current is some 50mA rising to 500mA for full sine wave output.

**Fig. 7. Layout of components and wiring**

The h.t. is normally 28 volts with 32 volts maximum. The amplifier will perform quite satisfactorily at a reduced output of 300mW when supplied by a 9V battery.

Overall feedback of some 17dB is applied via the 15 kilohm resistor R30 from the amplifier output to the base of TR5.

**CONSTRUCTION**

Construction is straightforward and follows similar lines to that of the pre-amplifier, as described in last month's article. If larger components than those shown in the layout diagram (Fig. 7) are used, the
circuit board (Fig. 9) may have to be enlarged accordingly, but providing the general layout arrangement is adhered to no difficulties should arise on this account. There is no hum level to worry about and the whole unit is extremely stable.

The construction of the heat sinks is quite simple if the following procedure is adopted. Obtain a piece of hard wood 1in square and 4in in length. From a sheet of 16 s.w.g. aluminium cut two pieces each measuring 44in x 4in. Hold each piece in a vice and bend it round the mandrel to form a C channel heat sink. See Fig. 8.

In the centre section of each heat sink drill the holes for the power transistor fixing screws and the feed-through holes for the base and emitter connections. In the corners of each heat sink drill four holes for fixing the assembly boards into their final positions.

Special care must be observed when connecting the ASY28 npn transistor TR8. The collector looks towards the positive rail and the emitter towards the negative side of the output electrolytic C20. This is, of course, opposite to the connection of the OC72 pnp transistor TR7.

SETTING UP

When the power amplifier panel has been completed, check the connections carefully. A loudspeaker must be connected to the output terminals before power is applied to the amplifier. The output impedance of the amplifier is less than 1 ohm and ensures good loudspeaker damping. Any speaker having an impedance of from 3 to 15 ohms can be used.

If you have any doubts regarding the speaker impedance you propose using, remember a very easy way of finding the impedance is to measure the d.c. resistance and multiply this by √2. The power supply can be derived from either a battery or from a mains power unit giving a d.c. output of 32V.

The improved loudspeaker damping and absence of an output transformer (which is both costly and inefficient) are quite definite steps in the direction of true quality reproduction. Class B amplification has the advantage of low quiescent current and high efficiency at full output, the average current consumption on music being about one-third of that on maximum sine wave output.

BIAS ADJUSTMENT

In principle, the two output transistors should be biased to cut off; however, strict adherence to this condition results in crossover distortion which is most unpleasant to the listener. This serious disadvantage which takes the form of a thin reedy kind of noise, which at low input gives the impression of a displaced loudspeaker cone, can be overcome by applying a small forward bias to each transistor, as stated in the earlier description of the transistor functions stage by stage.

Any slight distortion discernable can be eliminated by careful adjustment of the variable voltage level control VR4 between the base of TR5 and emitter collector junction rail to TR9, TR10. The ease of this adjustment is only apparent when final setting up is taking place at a low volume of a piano recording of, say, Beethoven's "Moonlight Sonata". Once the correct position is set, no further adjustment is necessary.

CAUTIONARY NOTE

Do not attempt to use the amplifier at any time without a speaker or equivalent d.c. resistive load connected between the output capacitor C20 and earth. Always remove the d.c. supply before disconnecting the speaker: very large transient currents are built up in the large electrolytic capacitor and, if undamped by the low resistance of the speaker, will surge through the output transistors and damage them.

COMPONENTS...

<table>
<thead>
<tr>
<th>Resistors</th>
<th>Capacitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>R20 4.7kΩ</td>
<td>C14 220μF ceramic</td>
</tr>
<tr>
<td>R21 47kΩ</td>
<td>C15 32μF 10V</td>
</tr>
<tr>
<td>R22 39kΩ</td>
<td>C16 64μF 10V</td>
</tr>
<tr>
<td>R23 1.5kΩ</td>
<td>C17 1,000μF polyester</td>
</tr>
<tr>
<td>R24 470Ω</td>
<td>C18 4,700μF polyester</td>
</tr>
<tr>
<td>R25 8.2kΩ</td>
<td>C19 4,700μF polyester</td>
</tr>
<tr>
<td>R26 1kΩ</td>
<td>C20 1,250μF 25V</td>
</tr>
<tr>
<td>R27 1kΩ</td>
<td></td>
</tr>
<tr>
<td>R28 1Ω 3W</td>
<td></td>
</tr>
<tr>
<td>R29 1Ω 3W</td>
<td></td>
</tr>
<tr>
<td>R30 15kΩ</td>
<td></td>
</tr>
</tbody>
</table>

All 1W, cracked carbon, high stability 5%, unless otherwise indicated.

Potentiometers
VR4 200kΩ carbon preset (skeleton type)

Transistors
TR5 OC71 TR6 OC72 TR7 OC72 TR8 ASY28 TR9 OC35 TR10 OC35

The next and concluding article will describe a simple mains power supply unit giving 28V from a standard battery-charger transformer. This article will also include some advice on the stereophonic arrangements for those who are interested in stereo reproduction and do not mind the cost of duplicating the amplifier and pre-amplifier.
LECTRONORAMA

HIGHLIGHTS FROM THE CONTEMPORARY SCENE

Valves Still Used Here!

This gigantic device is a new 200kW power transmitting triode, shown by the English Electric Valve Company at the recent British Exhibition in Sydney. The picture shows the structure of the grid and filament.

“Early Bird” with Travelling Waves

The Post Office is installing water-cooled C-band travelling-wave tube amplifiers in the world's first commercial communications satellite system—“Early Bird”. The tubes will give an operating power output of 10kW at 6,301 Mc/s with a tuning range of the r.f. structure of 225 Mc/s and small-signal bandwidth better than 30 Mc/s.

The satellite will be launched into a “stationary” position 22,000 miles above the Atlantic to provide a 24-hour link between North America and Europe. It will be able to transmit live television programmes of provide up to 240 two-way telephone circuits.

Olympic Relay

Syncom III satellite, which was used as a vital link for the transmission of television pictures of the 1964 Olympic Games, held in Tokyo in October, to Point Mugu in California, was not specifically designed for television transmission. The r.f. bandwidth of the satellite circuit, 13 Mc/s, is insufficient to provide adequate bandwidth for a television signal with the high deviation f.m. system used. The video bandwidth of about 2.7 Mc/s cannot be increased by reducing the deviation without degrading the signal/noise ratio. To overcome this problem a helical scan tape recorder was used in Tokyo.

Sound programmes were sent from Tokyo to Hawaii via the recently laid trans-Pacific telephone cable and thence to Vancouver by means of the Commonwealth Pacific telephone cable (COMPAC). Microwave radio links carried the signal across Canada to the Canadian transatlantic telephone cable (CANTAT) for linking to the British trunk telephone system in Scotland.

International Conference on Lasers

New possibilities in the fields of measurement and communication are being found by using lasers. The Conference on Lasers and their Applications, held at the I.E.E. in London in conjunction with the I.E.R.E. and the American I.E.E. in September, revealed some interesting advances in laser techniques.

The laser produces a very intense light beam with many properties, similar to radio waves, which ordinary light does not possess. Laser transmissions can be focused into very narrow beams enabling very long range and a high degree of accuracy to be obtained in rangefinding and communication applications. Laser beams can also be used for precision welding (see last month's issue) and cutting applications. It is envisaged that, due to the very high frequency which lasers provide, there is a possibility for virtually unlimited capacity for telephone and television transmissions.

The picture shows one application of the ruby laser exhibited by the University of Southampton as a bleaching agent for blue dye. When the laser is “pumped”, oscillation first occurs with the dye absorbing. The ruby rod then sees the full reflectivity of the mirrors and Q-switched operation ensues.
Denmark on the Dial!

The first high capacity telephone cable between Britain and Denmark was brought into service on 1 October to increase the number of telephone circuits between Britain and Germany, Denmark, and Holland. The cable, which is laid between Winterton in Norfolk and Esbjerg, will provide 120 high quality speech circuits.

This is the second of five cables planned to be laid across the North Sea by 1966. One of two to Germany was opened earlier this year. Two cables will be laid to improve the facilities to Holland. Twenty-four submerged repeaters are spaced evenly along the 300 nautical miles of cable to boost the speech signals. One of these is shown above giving a layout of the various units.

International subscriber trunk dialling will be introduced from Britain to Denmark in the spring.

Electronics "See" Ten-millionth of an Inch

A research chemist in New York has been using an electron microscope, which is capable of seeing particles one ten-millionth of an inch in size, to study the crystal structure of silver halides during chemical reaction. The enlarged electron micrograph in the picture below shows what is happening to silver bromide crystals in a solution of potassium iodide as seen by the microscope at 30,000 diameters. The crystals are being dissolved by the potassium iodide as silver iodide (small crystals) is formed.

The Shape of Circuits to Come?

A new grade of copper-clad Bakelite laminated sheet has been developed for the preparation of printed circuits. The new grade is made by bonding copper foil to polyester film and may be coiled and folded. It could enable the size of an assembly to be considerably reduced. Processing is achieved in the normal way by etching or printing techniques.

It is expected to find useful applications in automobile wiring, computers, telephone and switchboard wiring, radio and domestic appliances.
Three stages of i.f. amplification (at 10.7 Mc/s) are employed, and these are followed by a ratio detector.

It is worth mentioning at this point that although some hi-fi people would regard this with some surprise, the decision to use a ratio detector is backed by sound principles. Eyebrows may be lowered. The ratio detector is capable of just as linear a response as the Foster-Seeley or the earlier Rond-Travis discriminators; and although the Foster-Seeley has been the "standard" for valve users for a good many years, nowadays more and more designers are using the ratio detector.

For transistor circuits the Foster-Seeley has notable disadvantages unless a relatively low i.f. is used, and the bandwidth needed has to be obtained by a much more critical i.f. amplifier set-up.

The theoretical man will appreciate that the mathematics of either type of discriminator show just the same opportunities for distortion, and that this can be minimised by using an i.f. amplifier whose response curve is "gaussian"—that is, bell-shaped—giving the most linear phase change through resonance points. Any reasonably advanced text book on electric circuit analysis may be consulted on this point, for example M.I.T. Radiation Laboratory Series Vol. 18—Vacuum Tube Amplifier (Valley & Wallman; McGraw-Hill Book Co.).

What is very important is to see that the i.f. amplifier and detector overall response is a smooth curve, rising steadily (though rapidly) to a peak at resonance and dropping off thereafter in an equally steady and rapid way. Any bumps or spikes on this curve are reflected in irregularities of phase-change, and consequent kinks in the phase characteristic. Fig. 13 illustrates a good and a bad type of response curve, with the appropriate phase characteristic.

To ensure that the i.f. amplifier has the proper response fixed neutralisation has been abandoned, and variable neutralising capacitors are used instead, TC3, 4, and 5. These have to be adjusted, when the i.f. amplifier has been built, to get the proper response curve.

CRITICAL WINDDINGS

The construction of the i.f. amplifier transformers is also somewhat critical, especially as regards the gauge of wire used and the spacing between primary and secondary. (Refer to data and Fig. 8 in last month's article.) Coupling has been arranged to be a little less than "critical", except in the detector stage where joint critical coupling is employed.

If any difficulty exists in deciding the spacing, one should err on the generous side, rather than bring the windings even fractionally too close. Also the wire must be wound close, that is, with the adjacent turns touching. Any systematic gap will increase the winding length unacceptably. This is not usually a bother when coils are wound by hand, but if a winder is used the coils should be carefully inspected after construction.

Correct spacing is best obtained by cutting a strip of drawing paper the exact width required, and with it winding a spacer centrally on the former. The windings can then be started from the centre, hard up against the spacer; the latter may be removed later, when the fixing cement is hard and dry, but there is no real need to do this.

With regard to the detector transformer T7, particular care is necessary here, since a number of associated components have to be fitted inside the screening can in addition to the actual transformer assembly. Provided the smallest size of components is used, the "long" can specified will accommodate all items shown inside the dotted line which represents the can in Fig. 11. Details of the assembly of these components on the coil former are given in Fig. 12.

THE ETCHED CIRCUIT BOARD

The etched circuit is set out on a piece of copper clad laminate measuring 2½in by 8in, as shown in Fig. 10. The conductors are relatively few, and may be drawn direct on to the laminate surface with an acid resist. Thinner cellulose paint may be used for this quite successfully, but the vapour is dangerous to inhale and the process should be done in the open—or at the least, in an extremely well-ventilated room.
The best resist the writer has discovered is a proprietary French polish type of fluid known and marketed as "Glitseal", which is obtainable from "do-it-yourself" shops. This has to be diluted with about one-third of its volume of methylated spirit, as it is too thick for accurate small work, and for visibility it is dyed with a few crystals of crystal violet, obtainable from any dispensing chemist.

The conductors may be drawn with this mixture, using a ruling pen preferably as a small brush cannot readily be set against a straight edge. It should be noted that the conductors N, P, Q, and R are the earthing strips for the i.f. transformer cans, and conductor S is the earth point for the coaxial socket output to the i.f. strip. The conductor A is the common "earth" connection, and is best made quite wide as several component leads have to be soldered to it.

When the "conductors" are dry and hard, a careful check should be made to see that all is well. Then the etching process may be carried out, using 30 per cent ferric chloride solution in the usual way—see last month's article.

The theoretical circuit of the i.f. amplifier, detector, and pre-amplifier is given in Fig. 11, and during the wiring-up procedure this diagram should be consulted frequently to ensure that no errors occur. When wiring is complete the circuit board should be given a coating of varnish—the "Glitseal" is excellent for this purpose—to protect the copper laminate against corrosion.

ALIGNMENT OF THE I.F. STAGES

To set up the i.f. amplifier the following method should be followed. This will enable a stable and well-tuned amplifier to be achieved, which is then trimmed for the correct response curve.

A multimeter is needed, and a signal generator capable of supplying a signal of 10-7Mc/s, amplitude modulated or unmodulated at will. The leads from the multimeter should be decoupled at the ends by means of 5 kilohm resistors, and these soldered lightly to tags 3 and 11 (across the stabilising capacitor of the ratio detector). The leads must be arranged to lie well away from the i.f. stages.

Set the multimeter to the 50µA or 100µA range, and the signal generator to high output.

Set the neutralising capacitors TC3, 4, and 5 to minimum. Disconnect the two 1000Ω decoupling resistors R17, R21 from the B—line; this leaves only the ratio detector driver transistor and the pre-amplifier transistor in operation. The battery supply is now connected.

Most likely at this stage the microammeter will show a reading, indicating the stage is oscillating. Rotate the adjustment of TC5. Two positions will be found at which the stage breaks into oscillation, with a space between when no oscillations occur. Obtain the centre setting. Switch on the signal generator and bring the "live" lead near the base of TR6. Rotate both cores of T7 until maximum deflection of the meter is obtained, reducing the signal generator output if necessary. It may well happen that as the transformer is brought into line TC5 will require re-adjustment, but there is no difficulty at all in tuning up this stage and neutralising it.

Next tune the secondary of T5 until maximum meter deflection is reached, once again adjusting TC5 as necessary to recover stability. No contact should be necessary between the signal generator lead and the base of TR6, but if the signal generator output is small the lead may be connected via a small capacitor to the primary of T6 at the collector terminal of TR5.

Next transfer the signal generator lead to the base of TR5, again without physical contact, and re-tune the transformer T6. As the transistor for this stage is not working yet, a small reading only will be obtained unless the signal generator output is increased. Connect up the decoupling resistor of this stage (R21), to bring the stage into operation. Again, oscillation will probably result, and in the absence of an input signal a meter reading will be obtained. Adjust TC4 to stabilise the circuit, and tune the secondary of T5.

Couple in R17, and repeat the above adjustments with T4, T5, and TC3. At this stage it may well be found that very small adjustments of TC4 and TC5 are required to retain overall stability. These will amount only to a fraction of a turn—10 degrees or so of adjustment is usually enough.

Now that the i.f. amplifier is stable and roughly tuned the signal generator output lead should be plugged into the coaxial socket SK2, and the output reduced to a few microamperes r.f. Re-tune the entire receiver for maximum output at the meter. It should
be found that the stages tune quite independently. If not, neutralisation is not exact. Very slight adjustments of all three neutralising capacitors are now needed, with re-tuning of the transformers as necessary, until the transformers tune independently, and a change in the setting of one core does not affect the timing of the next stage.

**VISUAL ALIGNMENT**

If a wobbulator (i.e. frequency modulated oscillator) and an oscilloscope are available it is possible to align for the best response curve.

For this, deviation is set to the maximum; and the stabilising capacitor C38 temporarily disconnected from points 3 and 11, and the oscilloscope connected to these points. If necessary, one of these points may be earthed temporarily. Extremely slight adjustment of transformer tuning and of the neutralising capacitors will permit a smoothly-rounded curve to be obtained.

**THE DETECTOR**

The next step is to adjust the ratio detector. Re-attach the stabilising capacitor C38 between points 3 and 11, and connect a pair of headphones (or audio amplifier) to detect the modulated output. Connect the signal generator output to the coaxial input socket SK2. Switch on the modulation in the signal generator. Maximum sound output will not be obtained, but there should be some. Rotate the core of the secondary of the discriminator transformer T7 until zero output is obtained. This will be quite sharp.

Next, if a wobbulator is available set to 25kc/s deviation and connect its r.f. output to the input socket and the oscilloscope between points 5 and earth. While listening to the output, tune the wobbulator gently so that its output frequency slowly reaches the intermediate frequency to which the i.f. amplifier is tuned.

As the wobbulator comes into tune, the harsh-sounding third harmonic should disappear completely, leaving a pure tone. Meanwhile the trace should show a straight line inclined to the X axis. Increasing now the deviation to a large extent will reveal all or part of the phase response curve. If all has gone well, the trace should closely resemble Fig. 9a. If not, very slight further adjustments may be made until the perfect characteristic is approached.

If exceptionally high fidelity is not the aim, the wobbulator test may be omitted, the final check being to tune the signal generator gently through the i.f. with the meter connected across the stabilising capacitor C38 as before, and the amplitude modulation switched on. The output should be monitored aurally.

As resonance is approached the meter reading should rise steadily, in the same way as the amplitude characteristic of Fig. 9a, as the sound output increases. As resonance is approached the sound should die away to zero as the meter approaches maximum. A check should be made that the peaks of the most intense sound are equally spaced about the zero point. Also, by connecting a meter between point 10 or 13 and chassis, check that a zero reading is obtained at the zero sound output point and that equal positive and negative readings are obtained at equal frequencies off resonance.

The conditions necessary for this are that the ratio detector transformer should be absolutely symmetrical, and that it should be matched each side. The 470 ohm and 6.8 kilohm load resistors R29, R30, R31, and R32

---

Fig. 10. Printed board. The small numerals refer to similarly numbered points on the circuit. The small numbers in brackets are the pin numbers of the coils. See Fig. 11. The common earthing strip on the left-hand side is referred to as “A” in the text.
should therefore be matched as exactly as possible from stock; for "hi fi" results, match should be to 1 per cent or better. In such a case a matched pair of OA79 diodes is useful, and if they differ (as supplied) by more than 10 per cent it may be advisable to increase the 470 ohm resistors to 680 ohms—also carefully matched.

The two 500pF capacitors C36 and C37 should also be close in value, but this is less important. It is better to get a close match between the load resistors than to be very precise about the actual numerical value.

**OUTPUT ARRANGEMENTS**

The pre-amplifier stage TR7 is arranged for pre-set output. If this receiver is to be used in association with a sensitive power amplifier (such as the 5W Integrated Amplifier currently appearing in our pages) it may be feasible to dispense with the gain of this stage and instead employ the transistor TR7 as an emitter-follower. This is recommended for the highest quality reproduction.

To effect this change, remove VR1 and connect the collector of TR7 direct to the B—rail. Change the value of R35 to 1-8 kilohm, and remove C41. Output at a few ohms impedance is then taken from the emitter of TR7.

If a coupling capacitor is to be used between this and the next audio stage, a 500µF capacitor should be used. It will be preferable however to use direct coupling into the base of the next stage if d.c. conditions can be achieved correctly.

**I.F. INTERFERENCE**

The author has found that in certain locations interference can be obtained from transmissions on the intermediate frequency of 10-7Mc/s if any r.f. signal finds its way into the i.f. amplifier. Provided the interfering signal is not so strong as to cause cross-modulation with the desired signal, direct r.f. pick-up can be avoided by good screening and by adequate selectivity in the r.f. stages.

However, in this receiver unit construction is employed, and connecting cables may cause a certain amount of pick-up at i.f.; added to which is the possibility of direct pick-up on the circuit wiring of the i.f. amplifier, unless an earthed screening box for the whole unit is made. Usually, however, it is possible to find a quiet spot within a few hundred kc/s of the nominal i.f., and this is the recommended procedure if interference is experienced.

![Fig. 11. Circuit diagram of the i.f. unit](image)

**ALIGNMENT OF THE RF. UNIT**

Having roughly ascertained that the oscillator is working in the correct frequency band—in the way previously mentioned—all that remains is to effect a careful alignment using a meter. Either phones or a small loudspeaker may be connected between C42 and B—, or an a.f. amplifier may be attached. A test oscillator or signal generator is required capable of giving a modulated output (preferably f.m.) over the range 85-100Mc/s. This is set to 87-5Mc/s, and connected to the aerial socket of the receiver; moderate output will be required, say 10mV. The volume control should be adjusted so that the receiver does not emit too much noise. Set the ganged capacitors to maximum (full interleaved) and rotate the core of the oscillator inductor (L2) until a signal is heard. If too loud reduce the signal generator output. Tune the oscillator for peak signal by means of the core. If the signal can be heard at two settings of the core, select the position corresponding to the smaller value of inductance.

Set the signal generator to 100Mc/s and the ganged capacitor to minimum. Adjust the oscillator trimming capacitance until maximum signal is heard. Next set the gang to the half-way position, and tune the signal generator for maximum output in the receiver. Rotate the core of the aerial coupling inductor and of the r.f. interstage transformer for maximum volume.

During the above procedure it will be found that when exact tuning with the signal generator is achieved the modulation disappears, unless the signal generator...
COMPONENTS . . .

Items marked * are not required if an emitter-follower output stage is employed.

**Resistors**

- R15 15kΩ
- R16 22kΩ
- R17 100Ω
- R18 2.2kΩ
- R19 22kΩ
- R20 15kΩ
- R21 100Ω
- R22 2.2kΩ
- R23 22kΩ
- R24 15kΩ
- R25 470kΩ
- R26 22kΩ
- R27 47Ω
- R28 1kΩ
- R29 470Ω
- R30 47Ω
- R31 6.8kΩ
- R32 33kΩ
- R33 1kΩ
- R34 1-8kΩ

**Capacitors**

- C18 1.5KpF
- C19 0-1µF paper
- C20 50pF
- C21 0-1µF paper
- C22 0-1µF paper
- C23 50pF
- C24 50pF
- C25 0-1µF paper
- C26 0-1µF paper
- C27 50pF
- C28 0-1µF paper
- C29 0-1µF paper

**Transformers**

- T4, T5, T6 I.F. transformers—see text
- T7 Detector transformer—see text

**Transistors**

- TR4 AF116
- TR5 AF116
- TR6 AF116
- TR7 OC75

**Diodes**

- D3 OA79
- D4 OA79

**Miscellaneous**

- SK2 Coaxial socket

---

**OFFICE WORK MADE EASY . . .**

Electronics is playing an important part in automation of office methods and it was evident from the Business Efficiency Exhibition, held at Olympia on 5–14 October, that the modern business establishment is finding new ways of speeding up office work and reducing the risk of error.

Among new developments there was the new electronic calculator, on show for the first time by Friden, which displays four rows of numbers and answers, including the decimal point and function signs, on a small c.r.t.

The decimal point can be positioned to give 0, 2, 5, 7, or 11 decimal place working, and any number of calculations can be made instantaneously by operating a simple ten-key keyboard.

The emphasis on quick and simple operation of dictating machines has been further enhanced by automatic tape threading and coupling to the take-up spool by the operation of a simple lever. The operator of one particular model, made by Philips, need not and indeed cannot touch the tape himself once the cassette is on the machine.

Another new dictating machine, developed by Grundig, uses foil, instead of the more conventional oxide coated plastic tape.

**This unique museum piece, thought to be the earliest idea of an acoustically operated chain driven dictating machine, was on the Aga stand at the B.E.E. Let us hope it does not cause redundancy among shorthand typists!**

---

**Fig. 13. The i.f. amplifier and detector response curve showing good (a) and bad (b) characteristics**

is frequency-modulated. However, a slight mistuning one way or the other will bring in the modulation sufficiently well for the output to be estimated. The following procedure, however, should be carried out with an f.m. signal, or failing this with an extremely small input. The latter can be achieved by attaching the aerial to the receiver—using the signal generator as a low-power transmitter. The signals when received should be barely above the noise level, so that the limiting effect of the ratio detector is at its minimum.

Alternatively, the broadcast stations themselves may be used for alignment, but this method is not as accurate and may take more time.

The procedure given in the above paragraphs should now be repeated, except that the aerial π-coupling should not be re-adjusted. Further repetition will give more accurate alignment, but it is seldom necessary to perform the operation more than three times in all.

If a meter is used for the alignment, it should be connected across the capacitor C33. The voltage developed, with an aerial input of 10µV, will be about 1V, but the response is highly non-linear and when the receiver is aligned the BBC transmissions may not give much more than this. Provided the signal generator output is kept as low as will give a reasonable meter deflection there should be no difficulty in achieving correct alignment.

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Some Practical Applications of the Geiger-Muller rate-meter are described by J. F. ROWLES

These simple experiments can be performed quite safely by any amateur interested in investigating the nature of radioactivity.

Last month instructions were given for the construction of a simple Geiger-Muller rate-meter. In this article it is proposed to describe a series of basic experiments that will give the user of the rate-meter an introduction to the nature of radioactivity.

Before beginning, it would probably assist if a few basic facts concerning the atomic particles emitted in radioactivity were mentioned. There are many particles that are emitted or can be emitted by an atom under different conditions. Here we are only concerned with natural radioactivity and will only consider alpha, beta and gamma radiation.

ALPHA PARTICLES
Alpha particles have the following properties:
Cause fluorescence; blacken photographic emulsions; produce ionisation in gases. They are easily absorbed by matter; deflected by magnetic and electric fields; and are emitted with large velocities.

The alpha particle has been shown in fact to be a helium nucleus, $^4\text{He}^+$ (a positively charged ion)

BETA PARTICLES
Beta particles have the following properties:
Cause fluorescence, though not as great as alpha particles; blacken photographic emulsions; cause ionisation, but to a lesser extent than alphas. They have much greater penetration than alphas; are deflected by magnetic and electric fields; and have extremely high velocities.

Beta particles, in fact, consist of electrons moving with extremely high velocities. They carry a negative charge.

GAMMA RAYS
Gamma rays were found to have the same properties as X-rays:
Unaffected by electric or magnetic fields; travel with the velocity of light; cause fluorescence; blacken photographic plates; cause a small amount of ionisation. They very easily penetrate matter; can be diffracted; cause interference; and can eject electrons from material.

The gamma rays are electromagnetic waves of shorter wavelength than X-rays. The wavelength of the rays emitted depends on the emitting material.

RANDOMNESS IN RADIOACTIVE DECAY
The randomness of radioactive decay is very easily demonstrated using the ratemeter and a radioactive source such as the luminous face of a clock or watch.

Set up the ratemeter with the luminous dial near to the G-M tube. It will be noted that the rate-meter needle does not give a constant reading but fluctuates to a certain extent, showing that the atoms of the source are not emitting at a constant rate, their emission being quite random.

INVERSE SQUARE LAW OF GAMMA RADIATION
Like light radiation, gamma radiation obeys the inverse square law. This states that the intensity of radiation observed is inversely proportional to the square of the distance from the source.

To verify this is simple, all that is needed is a gamma source and the ratemeter. A suitable gamma source

IMPORTANT NOTICE
R1 and R2 should be 2.7MΩ and not 2.7kΩ as given in last month’s article—pages 30 and 32.

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is radium shielded by thin aluminium sheet to stop the unwanted beta and alpha rays. A luminous clock or watch face can be used, but it is better to have a more concentrated source such as some of the luminous paint used by watchmakers. This paint can be purchased from a wholesaler in such goods, and is packaged in a small test tube (of the type known as semi-micro test tubes).

The method of testing the inverse square law is to take the count rate at varying distances from the source and to plot a graph of 1/distance squared against the count rate. (See Fig. 1.)

Alternatively, a logarithmic graph can be plotted of log distance against log count rate. Here the relationship is verified more exactly as the assumption of the inverse square law applying is not assumed but the power to which the distance has to be raised to satisfy the equation is arrived at from the graph. (See Fig. 2.)

A typical set of results will now be treated to give the graphs mentioned:

<table>
<thead>
<tr>
<th>Distance (Distance)²</th>
<th>Count Rate</th>
<th>Log Distance</th>
<th>Log Count Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.25</td>
<td>100</td>
<td>0.3</td>
</tr>
<tr>
<td>3</td>
<td>0.1</td>
<td>45</td>
<td>0.48</td>
</tr>
<tr>
<td>4</td>
<td>0.063</td>
<td>25</td>
<td>0.6</td>
</tr>
<tr>
<td>5</td>
<td>0.04</td>
<td>15</td>
<td>0.7</td>
</tr>
<tr>
<td>6</td>
<td>0.03</td>
<td>10</td>
<td>0.78</td>
</tr>
<tr>
<td>7</td>
<td>0.02</td>
<td>8</td>
<td>0.85</td>
</tr>
<tr>
<td>8</td>
<td>0.0156</td>
<td>6</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Mathematically, the inverse square law is expressed as

\[ R = \frac{k}{d^2} \]

R = Count rate

\[ d = \text{distance} \]

Taking logs,

\[ \log R = -2 \log d + \log k \]

Thus the power to which \( d \) must be-raised can be obtained from the log graph as above (data for these graphs were from actual records using the ratemeter described last month).

It can be seen that the power to which the distance had to be raised was not determined exactly as 2, but consideration of the errors involved in the experiment (mainly in taking the reading from the ratemeter) shows the result to be within the range of experimental error.

This may seem to be a high error, but the ratemeter was not designed to give extremely high accuracy, and it must be remembered that the needle of the meter flickers to some extent all the time, presenting a difficulty in determining exactly what the reading should be. Each experimenter will have his own idea of where the arithmetic mean of the flickerings lie.

**HALF LIFE AND ITS DETERMINATION**

In radioactivity the decay of a substance is exponential, it never being completely annihilated, hence to talk of its total active period is impossible; so the time taken for half the specimen to decay away by radioactivity is taken as a measure of its term of existence, this being called the half life.

Treating this mathematically, suppose a given sample of radioactive compound contains \( N \) radioactive atoms at some time \( t \), and the probability that each of these will decay in any one second is represented by a constant \( a \) (the decay constant).

Then the average number of atoms \( dN \) that decay in a time \( dt \) is given by,

\[ dN = -a dt \]

Integrating this over a time \( t = 0 \) to \( t = t \)

\[ N = N_0 e^{-at} \]

Where \( N_0 \) is the number of atoms present at time \( t = 0 \). The ratio \( N \) to \( N_0 \) is the fraction of radioactive atoms remaining unchanged after a time \( t \).

The decay constant, \( a \), is the fraction of the total number of atoms that decay in unit time (provided unit time is small enough). The units of the decay constant are reciprocal time, it usually being expressed as reciprocal seconds. Its value is constant and specific for a given nucleus.

Practically, this decay constant is not used, but half life, mentioned above.

At a time \( t = \frac{1}{2} t \), the number of atoms remaining, \( N \), equals \( \frac{1}{2} N_0 \). Substituting in the integral formula,

\[ \frac{1}{2} = e^{-at} \]

or

\[ \log e^{\frac{1}{2}} = -at \]

then,

\[ t \frac{1}{2} = \log e^{\frac{1}{2}} \]

or

\[ \log e^{\frac{1}{2}} = \frac{t}{2} \]

or

\[ \log e = \frac{t}{2} \]

or

\[ t = \log e \frac{1}{2} \]

**Fig. 1 (below).** This graph shows \( 1/\text{distance squared} \) plotted against count rate

**Fig. 2 (right).** A logarithmic graph of log distance against log count rate
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- Basic Computer Circuit
- Basic transistorised radio receiver using printed circuit
- A.C. Experiments
- D.C. Experiments

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PE 12.64.
The actual rate of decay of a specimen is equivalent to the rate of emission of photons or particles, since each atom gives rise to a particle and/or a photon of radiation. This rate of emission is therefore the same as the absolute rate of decay, represented by:
\[ \frac{-dN}{dt} \]

It is very difficult, however, to detect and record every single particle emitted from a radioactive mass, although it is possible to measure a constant fraction of that decay. This distinguishes between the count rate registered on the G-M ratemeter and the true rate of decay. The relationship between the two can be given as follows,

\[ C = K \left( \frac{-dN}{dt} \right) \]

Where K represents the overall efficiency of the detection.

The numerical value C may replace the true rate of decay in the integrated decay equation,

\[ C = C_0 e^{-\lambda t} \]

Hence,

\[ \log_{10} C = -0.4343 \lambda t + \log_{10} C_0 \]

The logarithm of the measured count rate, C, plotted against the time, yields a straight line graph of slope 0.4343λ, from which λ and hence t½ can be found. In practice it is easier to plot count rate on semi-logarithmic graph paper against the time, and read off t½ directly. (See Fig. 3.)

It can be seen from the above description and the graph, that to obtain a value for the half life of a substance, a graph from which the slope can be easily determined or from which the half life is directly obtainable, is essential. This means that this method can only be employed for the determination of the half lives of substances in which that period is practicably short (say, up to one year). Thus the substances that the amateur normally deals with (uranium and radium mainly) whose half lives are extremely long (1,000 years at least) cannot easily be treated in this manner to obtain values for the half life period.

For the determination of the long half lives a special technique is employed. Here the rate of decay and the number of atoms present in the specimen are determined separately, these together with knowledge of the Avogadro number for the specimen (the number of molecules in one gram molecule of a substance). The value of the Avogadro number is \( 6.02 \times 10^{23} \) molecules per mole. In the actual determination of the half life the quantities required are the decay rate, the weight of substance under examination (accurately in grams), the gram molecular weight (from tables), and the Avogadro number.

It must be remembered that the count rate recorded by the ratemeter is not the decay rate but a fraction of it, and before any determinations of half lives can be undertaken this relationship must be established.

A SIMPLE PIECE OF APPARATUS

It will be of great use if the following simple piece of apparatus is constructed and used when determining half lives. It consists of a short length of wood with mounts for the G-M tube and the source holder. No dimensions have been given as these depend on the size of G-M tube available. The tube is mounted through holes drilled in blocks of wood which are mounted in the positions shown in Fig. 4.

Once the relationship between count rate and decay rate has been determined for the apparatus it can easily be used for future determinations of half lives. The relationship can be determined in two ways: by consideration of the geometry of the arrangement and by experiment, assuming the half life of a substance.

Considering the geometry of the system, the source can be considered as a point source as the quantities used by the amateur are small. Referring to Fig. 5, the following measurements must be made:

1. The distance from the centre of the source to the G-M tube—"d".
2. The width of the G-M tube—"a".

Hence from the geometry of the figure,

\[ \tan \Theta = \frac{a}{d} \]

hence Θ can be found in degrees.

The constant relating count rate to decay rate is then 360/Θ, assuming that the specimen radiates equally in all directions.

Having determined the constant for the apparatus it can now be used to find half lives. The method is as follows.

The first consideration is the fraction of radioactive material in the specimen under examination. Consider a radioactive element, M, existing in a compound, MX, which is under examination. The fraction of M present is then the ratio of M to M - - X. A practical examination will now be given. In the compound radium chloride, the fraction of radium present is found as follows

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Therefore the fraction of radium present is
\[
\frac{226}{297} = 0.761
\]

A weighed specimen of the substance under examination is then taken and the weight of radioactive material present is found. The count rate observed from the specimen in the above apparatus is noted. The half life is then found as follows.

Let the count rate be \( C \), the constant of the apparatus be \( 360/A \), the weight of specimen taken \( W \), the fraction of radioactive material present \( 1/f \), and the Avogadro number \( L \). Let the molecular weight of the specimen be \( M \). Then,

\[
\text{Weight of radioactive substance present} = \frac{W}{1} \times \frac{L}{f} \times M
\]

True decay rate = \( \frac{360C}{A} \)

Number of atoms present in the radioactive specimen
\[
= \frac{W \times L}{1 \times M}
\]

The decay constant “\( a \)” therefore equals,
\[
a = \frac{360CfM}{AWL}
\]

\[\text{Fig. 5. Critical measurements in half life experiment set-up}\]

**A PRACTICAL EXAMPLE**

A practical example from the author's own records will now be given.

Source to tube distance = 10cm
Weight of radium taken = \( 5 \times 10^{-8} \) grammes
Diameter of G-M tube = 2cm
Count rate = 570/sec
Angle of acceptance = \( \tan^{-1} \frac{2}{10} = 11.3^\circ \)

Therefore,

\[
\text{Decay rate} = \frac{570 \times 360}{11.3} = 18,150 \text{ counts/sec.}
\]

Hence,
\[
a = \frac{18,150 \times 226 \text{ (M.W. of radium)}}{6.02 \times 10^{23} \times 5 \times 10^{-6}}
\]

The weight of radium taken was \( 5 \times 10^{-8} \) grammes

Hence,
\[
\log_{e} 2 \times 6.02 \times 10^{23} \times 5 \times 10^{-6}
\]

\[
t = \frac{18,150 \times 226 \times 60 \times 24 \times 365}{11.3 \times 6.02 \times 10^{23}}
\]

\[
= 0.593 \text{ grammes.}
\]

Hence, assay of material is 0.593 per cent of uranium 235.

**EXAMINATION OF RAIN WATER**

Readers will no doubt remember the consternation that was caused a few years ago by the discovery of radioactive iodine (I\(_{131}\)) in milk. The half life of this isotope is eight days so its presence can be easily detected by the first of the two methods described for determination of half lives. The iodine entered the milk via rain which fell on the pastures of cattle. The concentration of the isotope in the rain would be very small.

Investigation of radioactive material in rain first necessitates the concentration of the rain water. For this a special kettle reserved for the purpose should be used. About a gallon of rain water is collected. The kettle is filled with this water and boiled almost to dryness; it is then refilled and the process repeated until all the rain water collected has been concentrated (a gallon is the minimum for usable results).

The concentrate should be of the order of 50 to 100cc. This is then transferred to a conical flask of 250cc capacity where final concentration is carried out. The final volume should occupy about a half of one of the semi-micro test tubes.

The radioactivity of the specimen is observed over a period of time and a graph of count rate against time is plotted. One reading a day at the same time each day will be sufficient. If the graph adopts an exponential form, the half life of the radioactive material present can be found. Since the half life is peculiar to a particular nucleus, the substance present can be identified.

The specimen of rain water for concentration must be concentrated as soon as possible after it has fallen.

The above article by no means exhausts the possibilities of the use of the ratemeter, but it is hoped that it will serve as an introduction to radioactivity enabling the individual to devise his own experiments and lines of research.
IMPORTANT DATE

Perhaps it is not altogether irrelevant for me to mention the General Election. After all this did take place on the same day that Practical Electronics made its debut (yes, 15 October 1964 was certainly a date of importance!). Furthermore, electronics played a notable part in the election proceedings, both during the campaign as candidates vied with one another to appear the more foresighted in technological matters—the words electronics and automation are now very much part of the politician's stock-in-trade—as well as after the poll when some of the largest and fastest computers in the country were mobilised by the BBC, ITV, and the Press to analyse the results.

But was it lethargy on the part of the Elliott 803 in the BBC studio or inefficiency of the humans feeding this robot which produced the state of affairs where one commentator was able to obtain the answer on his slide rule in much shorter time than previously?

A BIASED VIEW?

It is not, I trust, insularity on my part that makes me favour our term "valve" as opposed to the trans-Atlantic "tube". The latter word has always seemed to me a pretty inapt title for this important electronic device. All the more surprising that it was adopted by the Americans who generally have a gift for concocting imaginative and colourful terminology.

Actually I seem to remember reading sometime ago an admission by an American writer that the English term valve was a more appropriate choice than tube. The reason put forward in support of our word was rather odd though. It was suggested firstly that "valve" is synonymous with "amplifier", and secondly that all valves (or tubes) are amplifying devices.

What does this word valve in its general sense suggest to you? Do you think of, for example, a small lever or screw device controlling a large flow of liquid in a pipe line—if so then this is in truth an amplifier.

Or do you visualise an object which is essentially a one-way device—such as the pneumatic tyre valve? Coming back to the electronic valve, the one-way interpretation fits the envelope perfectly. On the other hand, the amplifier idea is logical all right when applied to triodes and upwards, but unfortunately excludes the humble diode.

SWEET AND LOW

Have you noticed how widespread the use of built-in background music is becoming? I really do mean "have you noticed". The sound that is nowadays being disseminated in many public places, shops, and restaurants is indeed of a very subtle character. It is far, far removed from the brash and forthright "music while you work" variety.

This background music is played more or less continuously and is designed not to intrude, but to be just audible. One may be hardly aware of the music—but sure enough it is doing its stuff on our subconscious mind!

Maybe it is all good therapeutic treatment, inducing calm into worried minds, and so aiding our digestive processes as we imbibe. Stores and supermarkets presumably find it commercially rewarding. The casual shopper, without realising exactly what is going on, finds himself loath to depart from the comforting relaxing atmosphere, but lingers among the wares.

A WEIGHTY MATTER

According to the theory put forward by an archaeologist, Stonehenge—that monumental array of stone circles on Salisbury Plain—is a neolithic age computer, and was probably used to calculate the movements of the Sun.

Solid state, without a doubt.

EXTRACTING THE FI

You may have your own ideas regarding the ethical or artistic aspects of this form of sound distribution. At any rate we can admire the technical expertise that has been applied to the planning and recording of programme material.

Musical items are carefully selected—strident sounds or heavily accented rhythms are out. During the recording session amplitude compression is introduced, for it is essential that the sound level should remain constant throughout.

I suppose the engineers responsible for these recordings have their own particular problems and have no doubt evolved some ingenious circuits for their purpose. Perhaps it would be a trifle unfair to describe their end product as no fi.

But why employ all those musicians and then pass their recorded performance through an electronic mangle? Far more sensible to give the job to a computer, since this is an obvious case for synthesised music.

J.V. PREDICTS

Fashions do change, of course, and already I can see the next step: "Instal 'NOVOX' Ultrasonic Background System for that tranquil atmosphere . . . your clients will appreciate this aid to concentration when contemplating the menu or pondering over that special purchase . . . " etc., etc.

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A word or two now about practical resistors as used in electronic equipment. Last month we mentioned that wire wound resistors are not usually made in values greater than 100,000 ohms. In fact, the kind of resistor most commonly encountered in electronics is of the carbon fixed value variety.

Wire wound resistors have rather limited and specialised applications: they are used whenever a precise value of resistance is required; also as "voltage droppers" in power supply circuits, where high currents and voltages are involved. And of course, wire wound resistors suit our requirements perfectly in the present series of experiments.

One important thing to remember. All the basic laws that we are demonstrating for ourselves in this series of experiments hold good for all types of resistors — no matter whether they be made of wire, or of carbon or any other substance.

Last month we showed a group of typical wire wound resistors. This month our photograph shows a selection of carbon fixed-value resistors. These are the kind of components you will constantly be handling as you become involved in building electronic devices. A word or two about their characteristics — physical and electrical — will not be out of place at this stage.

There are two main types; carbon composition and carbon film.

Carbon composition resistors consist of a rod of carbon black or graphite. Connecting wires are wrapped around the ends of the rod and the latter is given a protective coating of paint. This type is known as non-insulated.

There are also insulated composition resistors. These are made by enclosing the rod of resistive material in a plastic moulding or ceramic tube. The connecting wires emerge straight out from the ends of the tube.

The film type of resistor is made by depositing a thin film of a carbon mixture upon a glass or ceramic tube or rod. The rod is encased in moulded plastics or in a ceramic tube. Outwardly, these resistors resemble the insulated composition type.

Most carbon resistors are colour coded. This colour code indicates the value in ohms and sometimes provides additional information. You will find the Practical Electronics Colour Code Calculator (presented with our first number) an extremely useful tool. If you have access to an assortment of resistors, it is a good idea to practice reading off the colours of a randomly selected component. Take our word for it — this will be to your benefit in the future.

RESISTORS IN PARALLEL

Our next exercise is to find out what happens when we connect resistors in parallel, that is, side by side instead of end to end. To do this you will need to connect the "shorting wire" of the last experiment to points A and C of the resistor and the slider contact to point B (see Fig. 2.1). You will find that the slider can be moved along the resistor from end to end and the bulb will now light all the time. Why is this so?

To enable you to understand quite clearly the present circuit arrangement, we have drawn an "intermediate" diagram: imagine the end A of the resistor bent back so that it nearly touches end C (Fig. 2.2), as you move the slider from the central position towards one end you are reducing the resistance of that branch and so increasing the current flow. The circuit is shown in its final and conventional form in Fig. 2.3.

As the bulb lights now at all positions along the resistor, it follows that the total resistance must be much less than the original short section (11cm) measured in the first experiment. Once again, we can calculate the value of the total resistance using a formula:

$$\frac{1}{R_{\text{total}}} = \frac{1}{R_1} + \frac{1}{R_2}$$

Your resistance element has an approximate value of 75-80 ohms and hence you can mark the baseboard into divisions of, say, 5 ohms each. By setting the slider at any random point you can now read off the value of resistance either side of it. If the slider is set at 20 ohms (R1), the remaining resistance (R2) will be 60 ohms. Substituting these values in the above formula we get

$$\frac{1}{R_{\text{total}}} = \frac{1}{20} + \frac{1}{60} = \frac{3}{60} = \frac{4}{60} = \frac{1}{15}$$

$$R_{\text{total}} = 1/\frac{15}{1} = 15 \text{ ohms.}$$

We would like you to work out half a dozen calculations (one has already been done for you!) taking the value of R1 as 5 ohms, 10 ohms, 15 ohms, etc. and make a small list showing the values of R total, R1 and R2. You should find that the value of R total goes from 17\frac{1}{2} ohms down to nearly 1 ohm.

You will see from this list that, when R1 is much smaller than R2, the total resistance or equivalent
resistance is nearer R1 in value than R2. This can be very important in electronic circuits when you have a component with a resistance of perhaps 1,000 ohms in parallel with another component of 1 megohm.

Let's do another calculation to show why:

\[
\frac{1}{R_{\text{total}}} = \frac{1}{1,000} + \frac{1}{1,000,000} = \frac{1,001}{1,000,000}
\]

Thus

\[
R_{\text{total}} = \frac{1,000,000}{1,001} = 1,000 \text{ ohms approximately.}
\]

You can see then that if the value of one resistance is very high you can ignore it and consider only the value of the small one.

SECOND RESISTANCE ELEMENT

Now it is necessary to add the second resistance element to our apparatus. Here we use a 1,000 watt (1 kilowatt, or kW) fire element. Push the spare plastics knitting needle through the vacant hole in one of the wooden support pieces, thread it through the coiled element and insert in the hole provided in the second support. Ensure that the turns of wire are evenly spaced along the length of the needle.

You may be wondering at this moment: what is meant by a kilowatt?

The basic unit of a watt is the unit of power that is the rate of doing work. To calculate the power in an electrical circuit you must multiply the voltage by the current; this is shown by the formula:

\[ W = V \times I \]

where \( W \) stands for watts, \( V \) for volts, and \( I \) for current in amperes.

If you are unable to measure the voltage but know the resistance then you can use a second formula, which is

\[ W = I^2 \times R \quad \text{(or } W = I \times I \times R) \]

A third form of the equation is

\[ W = \frac{V^2}{R} \quad \text{(or } W = \frac{V \times V}{R}) \]

If you look at the list of components in other articles in PRACTICAL ELECTRONICS, you will notice that resistors are quoted at \( \frac{1}{4} \text{W}, \frac{1}{2} \text{W}, 1 \text{W}, \text{etc.} \) This is as important in electronic circuits as having the correct value of resistance (in ohms). Say, for example, you had a resistance of 100 kilohms and a voltage of 300V, then the current flowing through it would be

\[ \frac{300}{100,000} = 0.003 \text{ amperes or 3mA.} \]

Working out the power as above \((W = V \times I)\) would give

\[ 300V \times 0.003A = 0.9W \]

You would thus need a resistor rated at 1 watt and if you used one of perhaps \( \frac{1}{2} \) watt or \( \frac{1}{4} \) watt then it would quickly overheat and break down. This heat is caused by the current flowing through the resistor and we use this to our advantage in electric fires, water heaters and electric light bulbs.

The higher the wattage rating of a carbon resistor, the larger its physical size. Refer to the photograph: the two smallest sized resistors are \( \frac{1}{4} \text{W} \) types, the next pair are \( \frac{1}{2} \text{W} \), and the other two \( 1 \text{W} \) and \( 2 \text{W} \) respectively.

Now to return to the experiments. If you have the two fire elements or coils wound on the needles you can experiment on your own by connecting them in different ways, shorting out sections of them and calculating the value of resistance in circuit. The 1kW coil will have a resistance between 50 and 55 ohms

so you can mark out the base board in equal sections and measure off the resistance values direct.

You may also like to see the effect of increasing and decreasing the voltage to 6 volts and 3 volts respectively by substituting other batteries for the present 4½V supply. If you increase the voltage you will need more of the resistance in circuit to get the bulb just glimmering as compared with the amount needed with the 4½V supply. Obviously then you will have less resistance in circuit when a 3V battery is used.

We have used a bulb to indicate that current is flowing through the circuit and our next project is to make a simple type of meter that also tells us current is flowing. Many of you may have seen and used meters at school and know that there are many different types to measure voltage, current, resistance, etc. Next month we will show you how to make a simple meter that you can set up with your battery and use for approximate measurements in later experiments.

SHOPPING LIST

<table>
<thead>
<tr>
<th>Item</th>
</tr>
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<tbody>
<tr>
<td>One 1,000 watt electric fire replacement element.</td>
</tr>
</tbody>
</table>
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COMPLETE AND SEND ORDER FORM OVERLEAF!
ULTRASONIC REMOTE CONTROL continued from page 118

Pack the space between the transducer and the wall of the top cap with foam rubber. A piece of \( \frac{1}{8} \)in thick material, cut into a strip measuring approximately \( \frac{1}{8} \)in \( \times 4 \)in should serve this purpose adequately. Other similar material may be used, the important factor being to wedge the transducer firmly and centrally within the case.

Returning now to the bottom end of the case, first check that the battery can be accommodated inside, and recessed at least \( \frac{3}{4} \)in from the bottom edge. If not, the transmitter assembly must be pushed gently upwards, but without, if possible, disturbing the transducer.

Solder a \( \frac{1}{2} \)in long lead (red coloured sleeving) to the metal strip which makes contact with the metal rim of the case. Fit the battery, base foremost, inside, ensuring that the blue and red leads are not trapped. These two battery leads should extend about \( \frac{1}{2} \)in from the bottom of the case; cut off any surplus and solder these leads to the battery press stud connectors observing the correct polarity, i.e. red for positive, blue for negative.

Fit the connectors to the battery terminals and carefully push down the looped ends of the leads.

From a piece of stout cardboard, cut out a disc approximately \( \frac{1}{4} \)in diameter. Place this disc over the battery before screwing on the end cap. This cardboard insulating disc is essential, since the spiral spring connector in the end cap will be connected to the positive side of the battery when the cap is screwed home. The insulating disc prevents the spring coming into contact with the negative battery terminal—this should happen the battery will be shorted.

SETTING UP

Place the transmitter so that its transducer is looking directly at the receiver transducer, and the two are not more than a couple of feet apart.

Connect an ohmmeter to the relay contacts, and connect the receiver battery.

Switch on the transmitter. Rotate the core of T1 until the relay operates, as indicated by zero reading on the ohmmeter. Withdraw the transmitter further from the receiver while making adjustments to T1 in order to obtain the optimum tuning point.

When the receiver is correctly adjusted, the relay should pull in at a current not exceeding 5mA with a d.c. supply of 4.5V.

The receiver should respond at a distance of at least 20ft from the transmitter. This range can, however, be increased upwards to 100ft if OC44 transistors are used in the first three stages of the receiver (TR3-TR5) and simple cones are placed over the transducers. Paper cones tapering out to about \( \frac{1}{4} \)in are quite effective for this purpose.

COMPONENTS . . .

<table>
<thead>
<tr>
<th>Resistors</th>
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<tbody>
<tr>
<td>R1 8.2kΩ</td>
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<tr>
<td>R2 1kΩ</td>
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<tr>
<td>R3 5.6kΩ</td>
</tr>
<tr>
<td>R4 22kΩ</td>
</tr>
<tr>
<td>R5 1kΩ</td>
</tr>
<tr>
<td>R6 2.2kΩ</td>
</tr>
<tr>
<td>R7 5.6kΩ</td>
</tr>
<tr>
<td>All 3W carbon</td>
</tr>
</tbody>
</table>

<table>
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<tr>
<th>Capacitors</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 3,300μF silver mica</td>
</tr>
<tr>
<td>C2 0.015μF disc ceramic</td>
</tr>
<tr>
<td>C3 0.1μF disc ceramic</td>
</tr>
<tr>
<td>C4 22μF elect. 25V</td>
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<tr>
<td>All 3W carbon</td>
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<table>
<thead>
<tr>
<th>Transistors</th>
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</thead>
<tbody>
<tr>
<td>TR1-17 OC71 (7)</td>
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</table>

<table>
<thead>
<tr>
<th>Miscellaneous</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL Relay: 400Ω 5mA</td>
</tr>
<tr>
<td>T1 H.F. transformer (Osmor type QHF9)</td>
</tr>
<tr>
<td>XI, 2 Transducer (Gulton type 1404)</td>
</tr>
<tr>
<td>BY1 9V battery, Ever Ready PP3 or Exide DT3</td>
</tr>
<tr>
<td>BY2 9V battery</td>
</tr>
<tr>
<td>Two miniature coaxial plugs</td>
</tr>
<tr>
<td>Veroboard : one piece ( \frac{4}{8} )in ( \times \frac{4}{8} )in; two pieces ( \frac{1}{4} )in ( \times \frac{1}{4} )in</td>
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</tbody>
</table>

Note: The Gulton transducers, the reed relay, and other essential components can be obtained from:

DTV Group, 126 Hamilton Road, West Norwood, London S.E.27

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<tr>
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<th>TAPE RECORDERS, TAPES, ETC.</th>
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<tr>
<td>Recorders. S.A.E. with enquiries: REDWATT ELECTRICAL, 41, Denmark Street, Wakefield, Yorks.</td>
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<td>A number of suitably qualified candidates will be required for training, leading to permanent and pensionable employment. (Normally at Cheltenham but with opportunities for service abroad or appointment to other U.K. stations).</td>
<td>SITUATIONS VACANT</td>
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<td>Applicants must be 19 or over and be familiar with the use of Test Gear and have had Radio/Electronic workshop experience. They must offer at least &quot;O&quot; level GCE passes in English Language, Maths and Physics, or hold the City and Guilds Telecommunications Technician Intermediate Certificate or equivalent technical qualifications.</td>
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<td>Pay according to age, e.g. at 19 £722, at 25 £929 (highest pay on entry) rising by four increments to £1,067.</td>
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<td>Prospects of promotion to grades in salary range £997—£1,634.</td>
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<td>Annual leave allowance of 3 weeks 3 days, rising to 4 weeks 2 days.</td>
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<tr>
<td>Normal Civil Service sick leave regulations apply.</td>
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<table>
<thead>
<tr>
<th>MFD</th>
<th>Volts</th>
<th>Price</th>
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<tr>
<td>1.00</td>
<td>500</td>
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<td>1.00</td>
<td>1,000</td>
<td>1/6</td>
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<td>2.20</td>
<td>10,000</td>
<td>15/-</td>
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