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IN OUR NEXT ISSUE

Loudspeaker driver units. The fundamental parameters of moving-coil speakers will be examined and some new thinking introduced by Ted Jordan.

The first of a series of three articles on the design and construction of a high-quality tape recorder.

Details of an extra-versatile tone control.


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Brief extracts or comments are allowed provided acknowledgement to the journal is given.
How we made thyristors a commercial proposition for consumer products

Three years ago a Mullard design team was given the problem of developing thyristors for motor speed control in washing machines and drills. Thyristors offered important advantages over conventional power control methods, but at that time, production was confined to relatively expensive industrial devices. The high unit cost was essentially due to specialist production techniques.

Two Requirements The Mullard team set about designing inexpensive thyristors, together with triggering devices, for use on domestic mains supplies. Two current handling capabilities were identified as being necessary to meet the range of applications—6.5A for washing machines and other heavy current loads, and 2A for drills and lighter loads.

Within six months two consumer type thyristors, BT101 and BT102, had been developed for 6.5A applications, and they were soon in mass production. Now these devices, in the TO-64 stud-mounted metal encapsulation, are well established.

Low-cost Plastic After further design work, a new plastic device, the BT100A, was introduced to meet the lower current requirements. Plastic power device technology is highly specialised, and only intensive effort over many years has resulted in the highly automated manufacturing techniques which ensure extremely good reliability.

Computer Testing To cope with the necessary high rate of production, computer techniques were introduced to record test results and to allow automatic grading. The testing cycle was significantly shortened by the use of high-current pulses for directly heating the thyristor crystal. This is one of the best automated methods of testing breakdown voltages at the highest junction temperatures.

The result? A range of thyristors capable of meeting all the consumer-appliance manufacturers' current needs, and of improving both the efficiency of power-control and the usefulness of the units controlled. They offer consumer product manufacturers smooth, continuous and efficient power control.

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The Dehumanization of Broadcasting

Karl Marx, were he alive today, might have written that famous aphorism of his as: "Television . . . is the opium of the people". The fact that television is an opiate is generally blamed on the programme producers: the broadcasting engineers are inclined to take a superior, professional attitude and disclaim any responsibility for the material that is passed through their channels. Indeed some engineers, particularly in America, treat the programmes with open contempt. (The slang word “canned” used for recorded programmes is an implicit grouping of the creations of art and intellect with beer, soup, baby-food and other mass-produced commodities of a sloppy nature.) But it is too easy for the engineers to shelter in their sectarianism. They must become more aware of the effects of their work, their aims and attitudes, on the quality of what is broadcast. These effects may be indirect but are nonetheless real.

Anyone who has worked in mass-production industries will know that there is a strong pressure on designers to fashion their goods not so much for the convenience of the human customers as for the convenience of the production machinery. This, of course, increases manufacturing efficiency. If the resulting goods are not exactly what the customer likes he can always be persuaded to think that they are, by clever advertising. Equally it is well known that people must be continuously pressurized into buying goods which they may not really need, in order to keep the manufacturing plant fully loaded and hence economic—and, incidentally, to avoid unemployment and loss of consumers. The engineer, of course, has a vested interest in the design, manufacture and operation of the production machinery.

A similar situation is now developing in broadcasting. The mental and spiritual "goods" are becoming subservient to the broadcasting machinery, which is designed and operated by engineers whose main purpose is to achieve the most efficient distribution of canned, pre-digested, brightly packaged, expertly timed, second-hand experience to a mass audience.

At all costs the broadcasting machinery must be made efficient—and this seemed to be the cry at the recent International Broadcasting Convention in London (see p.484), where one of the main themes was the application of automation to broadcasting. One American contributor proudly remarked that the on-line computer programme for his computer-controlled broadcasting system had been “developed and documented to the point where it can be used as a general purpose program for any industry such as planning the production of manufactured goods.”

Automation is fine, in so far as it relieves people of monotonous work, reduces operating costs and improves the technical quality of the broadcast programmes. But experience from industry shows that it is also a means by which the human being is even more completely enmeshed and demoralized by the production machinery. He is not driving but being driven, as Charlie Chaplin showed in "Modern Times", and now his brain is involved as well as his reflexes.

Nevertheless, one speaker at the I.B.C., on being asked why he had expressed disquiet about too much automation in broadcasting, said “because it can be destructive of human initiative and art”. This speaker was an engineer. So there is at least one man who understands that the true work of engineers is not simply the perpetuation of engineering.
Elements of Linear Microcircuits

1. What a linear microcircuit is, how it is made and packaged

by T. D. Towers*, M.B.E.

What are these microcircuits that have revolutionized circuit design? In widest terms, they are a sort of supercomponent consisting of a number of circuit elements inseparably associated in a small package. In the ultimate they reduce the equipment to just fitting together a few prefabricated circuit blocks instead of designing a large complex of separate discrete components. No longer need the designer's job to just fitting together a few 'parts', he just buys a ready built microcircuit.

Linear and digital: the difference

There are two classes of microcircuits (often called integrated circuits or just i.cs): digital and linear. Digital circuits are designed for on/off switching applications and provide the equipment designer with a range of complete logic elements, such as AND, OR, NAND, NOR gates, flip-flops and some extremely complex computer-type sub-systems. Linear i.cs are for applications where the output is in some way proportional to the input, and they provide the designer with ready-made d.c., a.c., r.f. and wideband amplifiers.

Digital microcircuits became generally commercially available in the mid-1960s and have been exhaustively discussed in the technical press since then. Linear i.cs did not become readily available until much later, and are only now finding wide use. This series of articles is aimed at the newcomer to the linear field.

Linear microcircuits can be 'multiple-purpose' or 'single-purpose'. Multiple-purpose units are gain-blocks which can be externally pin-programmed to perform a large variety of different circuit functions (usually by fitting different feedback networks). The archetype of these is the operational amplifier. This is a very high gain d.c.-coupled amplifier with a response which is completely defined by feedback. It was the earliest linear microcircuit to become generally available and is the best known.

Most circuit designers prefer single-purpose microcircuits, which are complete in themselves and do not need additional circuits designed around before they can be used (as is the case with multiple-purpose linear i.cs). Fortunately, more and more single-purpose linear i.cs are coming on the market, ranging from a simple package of a matched pair of transistors up to a complete 100-W audio power amplifier.

Early developments

Before we look at current methods of microcircuit manufacture, it is of interest to look back over the past three decades at the landmarks in their evolution. Up until World War II, the normal methods of assembling electronic equipment was to mount all the heavier components on some form of chassis, and then interconnect them with point-to-point wiring, either directly or via tag boards. The first major move towards present-day microcircuits began with the miniature proximity fuses developed for the nose-caps of artillery shells in World War II. These radio-controlled fuses were closely packed assemblies using special valves, but the technique never spread into large scale commercial use because of the bulky valve needed for amplification.

The development of microelectronics really started with the invention of the transistor in 1948. This got rid of the large wasted vacuum space inside the valve, its inefficient heater and the need for a high anode voltage. Assemblies could now be much smaller, but they were still only scaled-down versions of the old point-to-point inter-wiring of discrete components.

In the late 1940s, Sargrove in England started a move away from point-to-point wiring. He pioneered a development in which a radio receiver was built on a small printed circuit board. The equipment was to mount all the heavier intercomponent wirings were printed and fired rather than separately mounted. This was one of the earlier experiments in the integration of circuitry, but in spite of it, point-to-point wiring continued unopposed.

Later printed circuit boards (more correctly printed wiring boards) became a commercial reality, and this form of integrated wiring provided another big step towards commercial microelectronics.

The 1950s also saw many different approaches to miniaturization, apart from assembling conventional miniature components on a small printed circuit board. They gave rise to names like C'ordwood', 'Tinkertoys', 'Micromodule' and '2D', which are now largely of historical interest only. Details can be found in books such as 'Microelectronics' by E. Keonjian. (McGraw Hill, 1963.)

All the 'tweaks' of microminiature assemblies developed in the 1950s were more expensive than the standard printed circuit board and they were only used in equipment where cost was not the governing element, military equipment for instance.

Today's microcircuits

In 1958 a development occurred which changed the whole face of things. Kilby of Texas Instruments came up with an interconnected assembly of resistors and transistors made by diffusion in tiny silicon chips. The true monolithic silicon integrated circuit (i.c.) was born. The first of these was a mesa-type r.l. (resistor transistor logic) bistable and it used only two chips interconnected by bonding wires in a single package.

In 1960 the celebrated Fairchild planar process for manufacturing transistors was developed which gave a strong impetus to

*Newmarket Transistors Ltd.
†Operational amplifiers were dealt with at some length by G B. Clayton in a series of articles which appeared in the February to December issues of Wireless World.

Fig. 1. Circuit of 1962 linear silicon integrated circuit (Texas Instruments SN521 operational amplifier).

†Some details of this development are given in an article 'Automatic Receiver Production' which appeared in the April 1947 issue of Wireless World.
the production of monolithic s.i.cs. Early units were the easiest-to-make digital types such as the 1961 Texas Instruments Series-51 r.t.f. But linear s.i.cs were not long in arriving. By 1962, the Texas Series-52 linear i.cs were on the market. Typical of these was the SN521 general-purpose single-chip 62dB differential amplifier the circuit of which is given in Fig. 1.

In the linear field, however, the general use of linear s.i.cs can be said to have started with the now well known Fairchild µA709 op. amp. which came on the market in quantity in 1965. Since then there has been a proliferation of multiple-purpose linear amplifiers, particularly of the operational amplifier type.

But the linear s.i.cs available by the mid-1960s did not get the immediate wide usage that their high technical specifications invited. This was partly because production was small and the cost was much higher than a designer could achieve by using conventional component circuitry. Also, run-of-the-mill circuit designers were not skilled at using wideband, high-gain operational amplifier building blocks for linear circuitry. They would rather have had low-cost single-purpose units.

In this climate, significant developments began along different lines. Techniques developed for producing prefabricated assemblies of resistors, capacitors and interconnections by printing on ceramics (thick film) or by evaporation on glass (thin film) were married to special miniature semiconductor devices suitable for attaching to such substrates. Out of this marriage came the hybrid active linear microcircuit, which had advantages over monolithics in some areas. The two main ones were that the hybrid could be fabricated economically in small batches and that single-purpose units could be made up readily.

By the end of the 1960s, many semiconductor manufacturers had gone into monolithic s.i.cs. Cheap standard multiple-purpose linear i.cs had become widely available, but there were not many standard single-purpose units around. You could get a special s.i.c. custom built, but you would have to use very large quantities for it to be economic. As a result, many custom hybrid houses had sprung up, using thick and thin film techniques, to serve the smaller-run equipment manufacturer who could not use the existing standard monoliths and was too small to have a special monolith built for him. Almost as a by-product, these hybrid houses also put on the market standard commercial single-purpose linear i.cs.

It is anybody's guess how the demand for linear microcircuits will divide itself up in the future between standard single-purpose, standard multiple-purpose, and custom-built units. One estimate is that in the 1970s linear applications will be met 50% by off-the-shelf single-purpose s.i.cs, 25% by multiple-purpose standards, and 25% by custom specials. As to how far the units will be monolithic and how far hybrid, again there is much doubt. The chances are that most multiple-purpose standards will be monoliths, most custom units hybrid, and single-purpose units a mixture of monolithic and hybrid.

No reference has been made so far to m.o.s.t. (metal oxide semiconductor techniques) microcircuits which use f.e.ts (field effect transistors) instead of bipolar transistors as the basic circuit elements diffused into silicon chips. They are cheaper to produce than bipolar monolithics, and have already found wide use in low-cost digital applications. However, they are not as yet well suited directly to linear applications and will not be discussed further here.

As to hybrid technologies, thin film is gradually being phased out for cost and technical reasons, and most hybrids are now thick film.

Monolithic silicon circuit manufacture

Manufacturing monolithic s.i.cs is a highly complex business and many books have been produced on the subject. If you are seeking detailed information, you should consult one of the standard texts, such as Motorola's 'Integrated Circuits—Design Principle and Fabrication', edited by M. Warner (McGraw Hill, 1965). In this article we will give only a sketchy outline of how s.i.cs are made.

The process starts with an ingot, usually 2in. (50mm) long and 25mm (1in) diameter, of highly refined single-crystal silicon, shown in Fig.2(a). The ingot is sawn up into thin slices of which one is shown at Fig.2(b), and the s.i.cs are made in these slices.

As shown in the enlarged view of a single slice in Fig.2(c), a large number of identical circuits are formed in a regular pattern. Various techniques are used, such as high-temperature diffusion of impurity gases into the slice, selective surface etching of photosist masking, formation of protective 'glass' (silicon oxide) surface layers, and deposition of metallic interconnections and lead bonding pads on the surface by vacuum evaporation (thin film) techniques. Depending on the area of the individual circuit in the pattern, a single slice typically produces anything from 200 and 2000 identical integrated circuits at the one time.

The slice is next scribed along the dividing lines between the circuits and broken up into individual units. A single circuit then finally appears as at Fig.2(d)—enlarged—in the shape of a square chip between 0.5mm (0.020in) and 1.25mm (0.050in) across with visible metallization on the surface.

This chip is packaged by bonding it face-up on a support such as the multi-lead TO-5 header shown in Fig.2(e), with the metallized bonding pads visible on the face. Connections are then made from the header leads to the pads by gold or aluminium wire about 0.025mm (0.001in) diameter. After being tested, the package is sealed. In the example shown, a metal top cap is fitted by welding round the rim.

From this necessarily brief summary, it should be evident that the basic element in a monolithic s.i.c. is a very small processed thin chip of silicon about the area of a grain of sugar. This makes it clear why high-power dissipation presents a major problem in s.i.cs, because of the difficulty in getting the heat away from the tiny chip. Normally, temperatures inside the chip must be kept below about 150 to 180°C and because of its small size it is hard to dissipate much power without exceeding this limit. This also explains why most of the commonly available s.i.cs have a power rating somewhere round 100 to 500mW (very much the same as a single transistor), and also why most of the high power linear microcircuits on the market tend to use the hybrid fabrication to be described below.

Thick film hybrid fabrication

The assembly of a thick film hybrid starts with a smooth ceramic (aluminium oxide) blank substrate, typically about 25mm
Just Microcircuit packaging; the problems

On this ceramic (which is an insulator) a matrix of passive circuit elements is screen printed and fired, just like the decorations on a piece of pottery, as shown in Fig.3(a). This produces an identical pattern of resistors, capacitors, insulating layers and metal interconnection runs and bonding pads (the last for attaching discrete components and external leads) in each cell of the matrix.

The large substrate is then scribed along the cell dividing lines and cranked up into individual small circuit substrates. One of these is shown enlarged in Fig.3(c). The next step is to attach any subminiature discrete components required, such as the transistor shown in Fig.3(d), and the final substrate preparation is the attaching of external leads shown in Fig.3(e).

After being tested, the hybrid circuit is encapsulated in some form of protective package, as shown in Fig. 3(f). It can be seen that the dissipating semiconductors can be dispersed over a relatively wider area than is possible in an s.i.c. chip so higher power dissipation is possible. On the other hand, it must also be clear that the overall package size will tend to be larger for hybrids.

The packaging of a microcircuit is of importance not only because it is all that the user sees of the device, but also because it has an important bearing on cost and reliability. For this reason, the rest of this article will be devoted to packaging aspects.

Microcircuit packaging: the problems

Just as with transistors, microcircuit packages are of two basic types, 'hermetic' (metal or ceramic and glass) and 'non-hermetic' (plastic). Non-hermetic are much cheaper than hermetic, but have not yet reached the stage where they can be regarded as satisfactory in extremes of temperature and humidity. Thus in high reliability applications, hermetic packages are the rule. Initially only hermetic packages were accepted for professional use, but recently plastics have improved so much that they are creeping in for the less demanding applications.

In commercial linear microcircuits, you will therefore find three grades in the market: (a) Entertainment or Consumer, suitable for use from 0 to 70°C and in low humidity environments (and almost always non-hermetic). (b) Industrial, suitable for use from -20 to +100°C and in medium high humidity (mostly hermetic), and (c) Military for -55 to +125°C and high humidity environments (until now always hermetic).

Unfortunately for the user, package standardization for microcircuits is a long way off. We are not yet in the comforting climate of transistors where you can take the same JEDEC standard TO-5 outline device from several different manufacturers and find that the case sizes vary by only a few thousandths of an inch and that the standard emitter-base-collector numbering of leads round the can obtained in every case.

For linear microcircuits at the time of writing there are over 700 different shapes, sizes and lead configurations available. In this chaos of packages offered, however, some trends are beginning to make themselves clear.

Monolithic s.i.c. packages show more standardization than hybrids because they have been around longer. But packages which have reached some acceptance for monoliths have had to be severely modified to encompass the generally larger hybrid element.

With regard to outlines, packages fall into four main classes: (1) low-power packages with leads to be inserted through circuit boards and soldered on the copper side; (2) low-power packages designed to be mounted directly on the copper side with leads attached flat to the metallization by soldering or welding; (3) medium-power packages with integral heat sinks for printed circuit board mounting; and (4) high-power packages designed for attachment to substantial metal chassis or heat sinks.

Low-power through-board-mounting packages

The most common low-power through-board-mounting microcircuit package is the dual-in-line, abbreviated to d.i.l. for the hermetic version and d.i.p. for the non-hermetic or plastic version. Fig.4(a) shows the main dimensions of the most common package, the 14-lead dual-in-line.

Variants of the package may have anything from 4 to 24 leads or more. The interlead spacing of 2.54mm (0.1in) in the line of leads is standard (to allow conductor runs between the lead lands on the board). The inter-row spacing of 7.62mm (0.3in) is standard for monolithic s.i.c.s, but, for the generally larger hybrid, other spacings such as 15mm (0.6in) are common.

Dual-in-lines are not easy to unsolder from circuit boards for servicing, and there is growing up another package style for through-board mounting which is easier to unsolder. This is the single-in-line, of which an example will be found in Fig.4(b). This s.i.l. can be thought of as half of a dual-in-line with the leads straightened into the plane of the device. It too, like the d.i.l., tends to use lead spacings of 2.54mm (0.1in), and is more common in hybrids than monoliths.

Historically the earliest monoliths were developed by semiconductor manufacturers and it was natural that they should package them in modified transistor cases. Fig.4(c) gives an illustration of the multilead TO-5 which may have anything from six to twelve leads. Because of the close lead spacing and the difficulty of removal from a printed circuit board, it is now not very popular with designers.

Low-power copper-side mounting packages

In these days of double-sided printed circuit boards and the demand for space...
saving, several packages have been developed for attaching to the copper side of the board. Two are fairly standard.

The flat pack shown in Fig. 5(a) was developed by Texas Instruments for their early s.i.c.s. With the general adoption of the dual-in-line package described earlier, users who wanted to mount them on the copper side of the board dressed their leads out flat as shown in Fig. 5(b). This gave rise to the ready-to-reflow dual-in-line modification which manufacturers are now prepared to supply.

**Medium-power microcircuit packages**

The packages so far discussed usually cannot dissipate more than a few hundred milliwatts. Other packages had to be developed for higher powers, particularly in the linear field. These tend to fall into two main groups: (a) items designed for powers up to about 5W without any special substantial external heat sinking, and (b) high-power packages capable of dissipating up to 50 or 100W.

In the first, medium-power, category, several packages will be met with. Semiconductor manufacturers, accustomed to standard two-pin TO-3 outline power transistors, developed a multi-pin version of this outline, of which Fig. 6(a) shows a typical example. On a printed circuit board this can dissipate up to about 2W (and on a substantial heatsink 10W).

Another transistor case used for medium-power microcircuits is the multilead TO-8 transistor package, of which Fig. 6(b) is an example. This has twelve pins arranged in a square, but a sixteen-pin version is also available. This package can dissipate up to about 1W in free air and about 2.5W clipped to a substantial heat sink.

![Fig. 6. Examples of medium-power linear microcircuit packages; (a) Modified multilead TO-3 power transistor package (2.5W); (b) modified multilead TO-8 intermediate power transistor package (1.2W); (c) modified dual-in-line with integral lugged heat sink (1W); (d) modified dual-in-line with integral heat sink for bolting to chassis (3W).](image)

A different approach to a medium-power package is the integral heat sink. Fairly typical of this is the package sketched in Fig. 6(c). This is really a dual-in-line with the leads dressed for reflow soldering and with a strip of metal inside extending from one end for better removal of heat from the chip. Permissible power dissipation can be increased by soldering the metal tongue to board metallization or some area of metal. Packages like these are typically capable of dissipations up to 1W.

The power dissipation capability of integral heat sink package can be extended by making provisions for bolting to a metal heat sink. One well known example of this is the chassis-mounting integral heat sink given at Fig. 6(D). This package is used for a linear monolithic amplifier with a power output capability of 3W audio, which has been widely marketed in the United Kingdom.

**High-power microcircuit packages**

Package design becomes a critical problem when we cope to linear i.c.s. capable of handling more than a few watts, whether they be monolithic or hybrid. At the time of writing no standard packages have been evolved, but the main features to be expected in such packages can be seen in the illustrative example of Fig. 7. This is a 50W high-quality audio amplifier. In the casing outline at Fig. 7(a), you can see that it is a fairly substantial package, 100 x 50 x 25mm (4 x 2 x 1in), with flanges for bolting to a chassis or heat sink. The terminals are stout pins issuing from one side of the package, to which connections can be made by soldering or by crimped-tag flying leads. The amplifier is of the quasi-complementary class-B type and the circuit used is shown in Fig. 7(b). The main power-dissipating elements are the two output transistors. Some expertise is required to mount these in the package to ensure the most efficient removal of the heat—quite a problem when you realise that the power transistor chips are asked to dissipate internally 30W apiece.

**Sockets for microcircuits**

In the early days of transistors, when designers were a little uncertain how to handle them, it was common to fit sockets for them on printed circuit boards. We see the same development with microcircuits, and there is a lot to be said for it.

Sockets for standard dual-in-line, single-in-line and multilead TO-5 packages are nowadays fairly readily available from electronics distributors. Apart from distributors, some firms specialize in the supply of microcircuit sockets, such as Jermy Industries in the U.K. and Augat or Barnes in the U.S.A. (with agents in the U.K.)

If you are buying microcircuit sockets, remember that they come in two types: "test" sockets specially designed for continuous repetitive use, and "production" sockets for once (or occasionally twice) use in equipment. Obviously production sockets will be cheaper than the test type.

**Availability of Linear Microcircuits**

From this preliminary look at the linear microcircuit field, it should be evident that nowadays the designer can look to a large, commercial armoury of such circuits around which to build his equipment. As later articles in this series will show, he will find linear i.c.s. for applications in frequencies from d.c. to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000).

The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000). The article next month will deal with what to expect to find linear i.c.s. for applications in frequencies from 1,000MHz to 1,000MHz, powers from 0.1mW to 100W and gains from 0dB to 120dB (X 1,000,000).
Circuit Ideas

**Loudspeaker transmit/receive switch**

In low-power radio transceivers it is customary to use the receiver output stage as the modulator when transmitting, a switch being used to disconnect the loudspeaker. The following circuitry allows this switching to be accomplished remotely without the use of a mechanical relay, and has been used in a four-metre portable transceiver in which all send/receive switching is accomplished electrically. The basic circuit is shown in Fig. 1 and has a very much lower insertion loss than any diode or other system that was investigated. The power loss is only slight with a 3Ω loudspeaker and is unnoticeable with a 15Ω load. Almost any transistors can be used but silicon planar devices give the greatest attenuation when the gate is off. Because of the fairly low reverse emitter-base breakdown voltage ratings of such transistors (about 5 to 6 V), some breakthrough occurs if the input voltage swing is greater than 12 V pk-pk. When one side of the input or output is referred to one pole of the supply battery the circuit of Fig. 2 can be used. If only one switched h.t. supply is available, for example that for the transmitter, the modification shown in Fig. 3 can be used. The diode ensures that Tr4 does not conduct when any audio peaks cause reverse breakdown current to flow into the base of Tr3.

D. A. TONG, Kirkintilloch, Dunbartonshire.

**High-stability constant-current source**

A convenient two-terminal constant-current source is a field-effect diode. Devices may be selected to have a temperature coefficient of less than 0.0005%/°C. However, the voltage coefficient of such diodes is typically 0.05%/V. This means that voltage variations may lead to larger errors in the constant current than temperature changes. A way of isolating the diode from voltage changes using an f.e.t. with its gate held at a constant voltage is shown. The f.e.t should be chosen to have a low \( V_T \) consistent with an \( I_{DSS} \) which exceeds the current passed by the current limiting diode. A 2N4340 or 2N4341 is suitable for use with the CL4710. The gate source voltage of a 2N4341 changed less than 10% over a 30V change in \( V_T \) giving a current stability of 0.0005%/V and 0.0005%/°C.

J. A. ROBERTS and J. R. JONES, Swansea.

**Cheap voltage reference**

The base-emitter diode of most silicon transistors can be reverse-biased and made to operate as a zener diode. At currents of about 1mA a positive coefficient of voltage with temperature is usually found which is greater in magnitude than the negative temperature coefficient of the same diode when forward-biased. By operating a transistor in an "amplified diode" arrangement the temperature coefficients of this diode and the zener can be made equal and opposite. With the two in series a very cheap temperature compensated zener diode can be produced which is the equal of most of the reference diodes available commercially for quite high prices. Using two 2N2484 transistors in a common heatsink a temperature coefficient of less than 10 p.p.m. over a ten degree temperature range can be achieved for 2mA current and 12V output. Resistors of the order of 10k have been used.

E. R. RUMBO, Chippendale, New South Wales, Australia.
High-power Amplifier

A design with a bridge output stage delivering 100W into 8Ω

by Ian Hardcastle*, M.A., & Basil Lane

Regular readers of Wireless World will recollect an earlier article of ours describing a simple 15-W power amplifier†. This article takes the design several stages further to provide an output power of 100W.

In attempting to upgrade the original design (reproduced in Fig. 1) two alternatives could be adopted, either to use 8Ω speakers and raise the supply voltage or to use 4Ω speakers and accept a very high output current.

Table 1 lists the requirements in detail and from the data sheets of the output transistor range (TIP29A to TIP36A) it can be seen that the supply voltage equals the breakdown voltage in the case of the 4Ω version, and for the 8Ω version the supply rail is well above breakdown. In addition if we are to retain the same pre-driver the supply voltage is also well above the breakdown of the BC212L used. Any alternative device used as a pre-driver would set a collector current requirement for this stage of around 20mA giving a power dissipation beyond the capability of the low cost small signal devices. In addition the stage gain would be reduced and by a chain reaction reduce the ratio of open loop to closed loop gain giving a high level of distortion. A way round this problem is to insert another set of drivers using a further pair of TIP29A/30A as shown in Fig. 2.

To ensure sufficient overall current gain around the quiescent point, resistors $R_1$ to $R_4$ are added to the configuration to increase the running current of the output stage to a point where the devices have developed useful gain. Since a 4Ω load is being employed the load coupling capacitor must be large and its current rating must be greater than 5A.

Finally the use of the 64-V rail means that the transistors are operating at and beyond the limits of their voltage ratings making the production of such an amplifier a risky business. Furthermore, the unregulated supply previously specified would be unsuitable since its off-load voltage could well rise too far. A fresh look at the design is obviously required.

**Argument for the bridge**

At the sort of power levels under consideration we are stuck with the output current and voltage requirements already mentioned and any attempt at reducing this (with say an 8Ω load) will only result in a prohibitively high rail voltage to provide the large voltage swings required. The reason for this is that the use of the capacitor coupling arrangement to the load limits these voltages to peak values of + or − half the supply voltage. What is required is an arrangement that eliminates the coupling

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* Texas Instruments Ltd.

**TABLE 1. Voltage and current requirements for 100 watt amplifier**

<table>
<thead>
<tr>
<th>load</th>
<th>r.m.s.</th>
<th>peak</th>
<th>pk-pk</th>
<th>r.m.s.</th>
<th>peak</th>
<th>power supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>8Ω</td>
<td>28.3V</td>
<td>40.1V</td>
<td>60.2V</td>
<td>3.53A</td>
<td>5.0A</td>
<td>90V</td>
</tr>
<tr>
<td>4Ω</td>
<td>20V</td>
<td>28.3V</td>
<td>56.6V</td>
<td>5A</td>
<td>6.0A</td>
<td>64V</td>
</tr>
</tbody>
</table>

of TIP35A/36A preceded by TIP29A/30A to give the base drive required by the output pair under peak output-current conditions. In turn, base drive for these devices, if derived from the existing pre-driver, would set a collector current requirement for this stage of around 20mA giving a power dissipation beyond the capability of the low cost small signal devices. In addition the stage gain would be reduced and by a chain reaction reduce the ratio of open loop to closed loop gain giving a high level of distortion. A way around this problem is to insert another set of drivers using a further pair of TIP29A/30A as shown in Fig. 2.

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capacitor without incurring the penalty of d.c. flowing in the loads.

Fig. 3 shows such an arrangement, where four output transistors are arranged as a bridge with the load connected across the d.c. null. If an anti-phase signal is applied to this configuration, on peak positive signals $T_{R1}$ and $T_{R2}$ are turned hard on, $T_{R3}$ and $T_{R4}$ are hard off, causing the full supply voltage to appear across $R_L$. With a peak negative input, $T_{R3}$ and $T_{R4}$ are turned hard on, causing the full supply voltage to again appear across the load but in the opposite direction. Taking another look at Table 1, we see that an r.m.s. voltage of 28.3V is required to produce 100W in 8Ω.

With the arrangement shown in Fig. 3, each half of the output stage only has to swing half of the required voltage. In this instance 14.15V r.m.s., 20.05V peak, or 40.1V peak to peak. This now allows the rail voltage to be lowered to 50V enabling the same transistor families to be used in the output stage as were employed in the original 15-W design. In addition, if at any time the power output of the amplifier needs to be raised, the rail voltage can be raised to achieve it. For example an 8Ω load with 60-V supply would provide an output power of up to 175W. Alternatively for a 4Ω load power in excess of 350W should be obtained.

Fig. 4 shows a block schematic of the arrangement to be used in this instance together with a full circuit diagram in Fig. 5.

Considering one half

Referring to Fig. 5, the left-hand power amplifier will now be described, similar arguments being applicable to the right-hand amplifier. Readers will recognize the configuration of the output stage, which is similar to that of the early 15-W design. The transistors TIP35A and TIP36A would be suitable for use in this 100-W version, the transistors TIP35A and TIP36A are hard off, causing the full supply voltage to appear across $R_L$. With a peak negative input, $T_{R3}$ and $T_{R4}$ are turned hard on, causing the full supply voltage to again appear across the load but in the opposite direction. Taking another look at Table 1, we see that an r.m.s. voltage of 28.3V is required to produce 100W in 8Ω.

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Fig. 3. Bridge output stage with the load across the d.c. null.

in which case they can be substituted without any modification. The latter transistors have a minimum current gain of 20 at 5A and hence a peak base current of 250mA is required. This is above the power dissipation capabilities of the smaller plastic encapsulated transistors which were previously used but the substitution of a pair of TIP29A and TIP30A will serve the same purpose without the need for heat sinks, since the demand is well within their free-air current and power ratings. The current gain at their peak collector current is at least 40, the peak base current required being about 5mA.

This particular type of transistor, when operated at low quiescent collector currents has a somewhat low current gain, and to obviate any difficulties likely to be encountered by variations in gain in such a situation, resistors $R_{9}$ and $R_{10}$ are used to shunt the base-emitter diode of the output transistors. Under quiescent conditions, the collector current of the drivers is now set at about 4.5mA giving them a current gain of around 100. A point not mentioned in the previous article dealing with the 15-W version, was the necessity for such resistors to be included to provide a path for the output transistors' collector-to-base leakage current. Readers who have built the 15-W version, will find it advantageous to insert resistors in a similar position, of value 1kΩ.

Two additional functions are performed by these resistors in both designs; they ensure thermal stability of the output stage and by providing a path for collector-base leakage, decrease the turn-off time of the transistors thus reducing high-frequency cross-over distortion and dissipation.

The familiar transistor-potentiometer biasing arrangement has been used again to supply the necessary inter-base voltage to the drivers, thus causing the output stage to operate in class AB, giving a nominal output quiescent current of 20 to 50mA. The pre-driver stage operates at a quiescent current of 10mA, this current being well within the current and power handling capabilities of the devices specified in the 15-W version. Referring to Fig. 1, the reader will see that a bootstrap resistor has been used as a constant-current sink, this resistor being connected between $C_4$ and $T_{R4}$. In this instance, at the cross-over point, the input impedance of the resistor tends to fall because the voltage on the collector of the driver transistor $T_{R4}$ changes more than the output voltage, thus a voltage imbalance occurs at either end of the resistor and the bootstrapping fails. An alternative providing a more satisfactory constant-current sink, is to replace the resistor by an additional small signal transistor suitably biased from a constant-current source. Such an arrangement is shown in Fig. 6 where the transistor $T_{R4}$ has a constant voltage at its base provided by a potential divider chain formed by the resistors $R_{91}$ and $R_{101}$, with diode $D_1$. The voltage developed by $D_1$ approximately makes the base-emitter voltage of $T_{R4}$ over a range of ambient temperatures and thus ensures that the voltage across resistor $R_{101}$, and in turn the current sink provided by transistor $T_{R4}$, remains constant with changes in temperature. An improvement in the cross-over distortion figures (still present in spite of the output stage operating in class AB) is obtained, since the constant-current sink is no longer dependent upon feedback from the output mid point.

This arrangement has been used for the 100-W amplifier for the reasons discussed above, and also because there is no output capacitor to transfer the output voltage from the output mid-point down to the earth rail. To provide such a point suitable for the connection of a bootstrap resistor, an extra capacitor and resistor would have to be inserted. All in all a comparison of costs between providing the additional transistor, or providing the capacitor-resistor arrangement shows that they are about equal, but the improvement in performance from using the transistor constant-current sink more than sub-
to its collector connected directly to the base. To complete the power amplifiers, a differential input stage was used in a simple amplifier with a gain of 11. In our original article several benefits were claimed for using the long-tailed pair as an input stage. These included low value decoupling capacitors and the potential preservation of a.c. feedback path to the emitter of Tr, R15, the driver transistor. Resistors R1 and R2 were reduced to a value of ten times this value would be required to allow operation of the base-emitter junction of which is partially shunted by R15, to reduce variation in the collector current of Tr, due to variations in the current gain of the driver transistor. Resistors R11 and R12, together with capacitor C1, provide an a.c. feedback path to the emitter of Tr1 and set the somewhat low a.c. closed-loop gain of 11. In our original article several alternative input stages were claimed for using the long-tailed pair as an input stage. These included a good stability of the d.c. level of output mid-point, and high input impedance to the load, resulting in a low d.c. output level. Under normal conditions the results of these changes due to temperature variations would be expected to be small, for example, a 20°C change will cause an output level shift of 40 mV and a change in gain of Tr7 and Tr8 from 60 to 300 will cause the output level shift of 400 mV. However, this is not really important since what we are interested in is any changes of voltage across the load creating a d.c. unbalance in the bridge, because at all costs large direct currents must be prevented from flowing in the load. However such currents are unlikely to occur since any temperature change affecting the left hand power amplifier will similarly affect the right hand power amplifier. Such changes in both amplifiers would simply result in a similar shift of output mid point voltage at both ends of the load, resulting in a cancellation of effect and the preservation of bridge balance.

The high impedance feature of the feedback circuits in the original design has become unnecessary in the 100-W version, since the closed loop gain has been made smaller.

The advantage of having low value decoupling capacitors is retained since resistor R15, is relatively large (470Ω) and needs only a 32µF decoupling capacitor to give a low-frequency -3dB point at 10Hz—once again comparing favourably with the 15-W version. If this arrangement were used in a simple amplifier with a gain of, say 100 where the feedback loop encompassed the whole amplifier, a capacitor of ten times this value would be required to give the same —3dB frequency. Despite the change of configuration from long tail pair to single transistor the input impedance looking in at the base of Tr1 is still high, due to the presence of the large in-phase feedback signal at the emitter. As the entire amplifier is d.c. coupled, the stability of the output mid-point voltage needs to be ensured by a d.c. reference provided at the base of Tr1. Two alternatives present themselves at this point. (a) To provide an independent potential divider bias chain for Tr7, and Tr8, the doubling up being necessary to allow compensation for individual variations in VBE of these two transistors together with the potential drop tolerance in R1, and R13. (b) To make use of the d.c. level present at the output of the phase splitter as a reference. The latter alternative represents a considerable simplification and has therefore been chosen.

Phase-splitter stage
Readers will note that the phase splitter used consists of a long-tailed pair formed by the transistors Tr1 and Tr2. Other
alternatives could have been used, such as a single transistor with equal collector and emitter resistors (see Fig. 7) one phase being taken from each output electrode. The preference for the phase splitter was set by the following considerations:

1. Voltage gain is obtainable from a long-tailed pair allowing a reduced voltage gain in the power amplifier and making a simpler design. In addition, a greater ratio of open to closed loop gain is obtained, giving lower distortion.

2. In the case of the single transistor, the impedance seen by each of the identical power amplifiers would be different since the collector output impedance of the phase splitter is higher than that of the emitter. The long-tailed pair shows no such disadvantage and provides identical drive conditions for both power amplifiers.

3. A single transistor phase splitter presents different d.c. levels at emitter and collector thus simplifying the problem of direct connection to the input of the power amplifiers. In the case of the phase splitter using a long-tailed pair, connection is made to collectors at the same d.c. level for both power amplifiers.

An examination of Fig. 5 reveals that the bias arrangements for the two halves of the phase splitter are different. Resistors \( R_c \) and \( R_e \) are of an order of ten times the value of \( R_b \) and \( R_e \). One of the main reasons for this difference is that the input to the phase splitter is fed to the base of \( T_b \), and it is necessary to preserve a high input impedance (to avoid loading the output of the pre-amplifier). The source impedance seen by transistor \( T_b \) when taking noise into consideration will be low, since \( C_{in} \), the input coupling capacitor and the impedance of the source acts as a de-coupling network across \( R_c \) and \( R_e \).

Provision of a network of similar impedance at the base of \( T_b \) would mean that the source impedance seen by \( T_b \) would be too high for minimum noise output, and additionally, radiated interference would be easily picked up by this device. The values chosen for resistors \( R_b \) and \( R_e \) provide the optimum low-noise condition, capacitor \( C_{in} \) being used to de-couple the bias chain at high frequencies to eliminate noise from radiation sources.

In most conventional long-tail pair arrangements efforts are made to see that both halves of the pair are balanced in their current, voltage, and impedance characteristics. In this way such an arrangement takes advantage of the inherent self-balancing of d.c. conditions available from such a configuration. Since in this version of the long-tailed pair we have an impedance imbalance at the base of each half of the long-tailed pair, gain changes in the transistors arising from temperature shifts is likely to result in a drift in the relative d.c. voltage levels of the two bases; this in turn appears at the output of the long-tailed pair and hence throws the power amplifiers into a state of imbalance. In practice, this effect is very small due to the selected high-gain characteristics of the transistors specified for \( T_b \) and \( T_e \). As an example, if a minimum gain transistor's gain doubles due to any changes in temperature, a differential change in the base voltage of \( T_b \) and \( T_e \) of about 120/4V can be expected. The resulting differential change in the output voltage of the whole amplifier is likely to be about 1.7 mV.

As already mentioned, the input impedance of the power amplifier is high and thus though it shunts the collector resistors of each half of the long-tailed pair this need not be considered when calculating the gain of the phase-splitter stage. Gain is calculated by the ratio of the collector resistors \( R_c \) and \( R_e \) to the emitter resistors \( R_b \) and \( R_e \) and produces a value of 15.3. Resistor \( R_e \) is used to connect the common phase-splitter stage to the positive rail. Since it is decoupled by \( C_{in} \), ripple and noise is prevented from appearing at the inputs of the power amplifiers. Since the power amplifiers themselves are highly hum-proofed, noise appearing at the output source is extremely low. One could argue that the de-coupling of \( R_e \) is not strictly necessary, since any hum appearing at \( R_b \) and \( R_e \) will be in-phase and will thus appear at the output of each power amplifier still in phase, constituting a null in the load. This condition would only be true were the voltage gain of each power amplifier equal. In practice this is somewhat difficult to ensure, and anyway the cost of the additional decoupling is small ensuring low noise as well as incidentally improving the high-frequency stability of the amplifiers.

A further consideration in the selection of the value of the collector resistors in the phase splitter, was the requirement to provide the appropriate d.c. level to allow direct coupling into the power amplifiers. This voltage is 28.5V allowing the mean d.c. level of the power amplifier output mid-points to be set at approximately 26.2V. Since a 50V supply rail has been specified, one might expect this output mid-point voltage to be nearer 25V, however, the output voltage of the power amplifiers cannot swing as close to earth as it can to the positive rail because the emitters of the current-sink transistor \( T_b \) and \( T_e \) are set at 1.5V.

As has already been stated it is undesirable for differences in the d.c. mid-point voltage levels to occur because of the resultant large direct currents flowing in the load. Component tolerances tend to create such a situation which is to a large extent compensated for by adjustment of the base voltage of transistor \( T_b \) using the potentiometer \( R_{V_b} \). This potentiometer allows the adjustment of the output mid-point voltage of the right hand power amplifier to the same level of the output mid-point voltage of the left hand power amplifier.

If low-cost wide-tolerance resistors are used throughout the system it may be found that the adjustment of \( R_{V_b} \) is insufficient to correct any imbalance in the output mid-point voltage. In such an instance, resistor \( R_{eb} \) should be reduced to 10k\( \Omega \) and a 4.4k\( \Omega \) potentiometer connected in series with it giving an additional adjustment to the left hand amplifier's output mid-point voltage.

**High-frequency stability**

Due to the high cut-off frequency of the transistors used throughout this design the whole amplifier has gain in the mega-
A complete amplifier. The four electrolytic capacitors used in the circuit are small enough to be wired directly to the Lektrokit board.

TABLE 3. Intermodulation Distortion

<table>
<thead>
<tr>
<th>Hz</th>
<th>V</th>
<th>Hz</th>
<th>V</th>
<th>(%)</th>
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<tbody>
<tr>
<td>1100</td>
<td>14.4</td>
<td>900</td>
<td>14.4</td>
<td>0.16</td>
</tr>
<tr>
<td>12k</td>
<td>14.4</td>
<td>9k</td>
<td>14.4</td>
<td>0.23</td>
</tr>
<tr>
<td>10k</td>
<td>24.0</td>
<td>1k</td>
<td>6.0</td>
<td>0.14</td>
</tr>
<tr>
<td>10k</td>
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<td>1k</td>
<td>24.0</td>
<td>0.14</td>
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<tr>
<td>10k</td>
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<td>120</td>
<td>6.0</td>
<td>0.15</td>
</tr>
<tr>
<td>10k</td>
<td>6.0</td>
<td>120</td>
<td>24.0</td>
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<td>1k</td>
<td>24.0</td>
<td>120</td>
<td>6.0</td>
<td>0.135</td>
</tr>
<tr>
<td>1k</td>
<td>6.0</td>
<td>120</td>
<td>24.0</td>
<td>0.146</td>
</tr>
</tbody>
</table>

The fact that the output stage can still overheat under long-term overload conditions. The value of this fuse should be 4A.

**Power supply**

It is just feasible that an unregulated power unit could be used to supply this amplifier, but it is important that under no-load conditions the voltage does not rise above 60V and at full power it does not drop below 50V. Large currents are drawn from the supply making these requirements difficult to obtain and most readers may favour a regulated unit. A suitable design is given in Fig. 9, where the 50V winding (rated at about 10mA) provides a supply which when rectified and smoothed acts as a constant voltage source. Resistor R, acts as a constant current source for the zener diode ZD, and the parallel arrangement of RV, and R, provides a supply which when rectified, smoothed acts as a constant voltage source.

TABLE 2. Performance Figures

<table>
<thead>
<tr>
<th>power output</th>
<th>100W</th>
</tr>
</thead>
<tbody>
<tr>
<td>power output 1h.d.(%</td>
<td>150W</td>
</tr>
<tr>
<td>frequency response (±10dB</td>
<td>10kHz</td>
</tr>
<tr>
<td>signal-noise ratio (R_s)</td>
<td>1kΩ</td>
</tr>
<tr>
<td>signal-noise ratio (R_s)</td>
<td>10Ω</td>
</tr>
<tr>
<td>input impedance at 1kHz</td>
<td>50kΩ</td>
</tr>
<tr>
<td>output impedance at 1kHz</td>
<td>0.08Ω</td>
</tr>
<tr>
<td>nominal input voltage</td>
<td>100V</td>
</tr>
<tr>
<td>power-supply current</td>
<td>3.5A</td>
</tr>
</tbody>
</table>
Avionics at Farnborough

Some impressions from the electronics show

Have you ever thought of all the things that occur when a modern aircraft is displaced slightly from its flight path by an air disturbance or for some other reason? As an airline passenger one is inclined to think only in terms of seating comfort and cabin service and to hope that the wings won't fall off or that engines won't pack up. It is interesting to look at the aircraft as a single unit, that is, to roll all the sub-systems into one.

The small disturbance mentioned above will cause a host of transducers of many types to give out a signal or to change their existing outputs. Innumerable gyro will measure the amount, rate and direction of the disturbance; accelerometers will measure the size and direction of the accelerations and decelerations involved in three dimensions; aneroid and other capsules will measure change in the earth's magnetic field relative to the aircraft, and so on.

This flurry of signals is fed to a number of digital, analogue and hybrid computers. Trains of pulses are generated during the computations, analogue signals change in phase and amplitude in such a way as to describe the amount and direction of the displacement, scores of small motors turn to either drive pointers or to assist in the calculations by turning a shaft which mimics the aircraft's angle in a particular plane.

As a result of all these actions the gyro compass now indicates the new heading (true or magnetic) and updates all the navigation computers which will provide a read-out of position; the outputs of the accelerometers are changed into signals representing velocity and to distance flown in a given direction for the navigation system; the doppler radar will be giving an indication of ground speed and drift from which true track can be computed; and signals will be fed to limited authority motors in the flying control system to cause the hydraulics to apply control surface movement to limit the size of the displacement. With automatic control the automatic pilot will apply control surface movement, after taking into account the flying characteristics of the particular aircraft, in such a way as to correct the displacement practically before it occurs. During even a disturbance these and many other actions occur. For instance, signals from different sources, but describing the same thing, are compared and an error signal may be generated to correct one of the sources.

Apart from these systems there is the radar blind-landing and communication equipment as well as the electrical, electronic, hydraulic, pneumatic and mechanical systems needed to control and monitor cabin pressurization, fuel management, undercarriage, flying controls, flaps, dive brakes, engines, temperatures, etc., etc.

All these systems have to be powered and the prime movers for this are of course the engines. The outputs of the engine-driven alternators have to be controlled in frequency and amplitude and distributed throughout the aircraft so a great deal of electrical equipment is required.

The preceding few paragraphs were presented so that the reader who is not familiar with aircraft systems could get some idea of how complex a modern aircraft is. Not all systems were mentioned and if a military aircraft had been taken as an example, instead of a civil one, the various weapon aiming systems would have increased the complexity by a very large factor.

Britain's avionic industry can design, develop and build all the systems necessary including the engines and the airframe for any aircraft that is technically feasible by today's standards if it had the money to do so. The only other countries to have such a complete capability are Russia and America. This lead cannot be maintained unless the industry designs and builds aircraft and at present its hopes are placed on perilously few products. Topping the list is of course the Anglo-French Concorde which stands to win £4,000M worth of export orders if it comes up to its design performance. There is also the Anglo-French Jaguar and the European Multi role combat aircraft (MRCA) controlled by an Anglo, German, Italian company called Panavia. There is the successor to the BAC one-eleven, the three-eleven, which is a short/medium haul jet airliner capable of carrying about 250 passengers which could be ready by mid-1975. About £200M is needed by BAC to get this project off the ground. Also awaiting money and policy decisions are two vertical take-off airliner projects the Westland WE.01/02 which employs a helicopter principle and the Hawker Siddeley H.S.141, a modified Trident with jet powered vertical take-off. If the British aircraft industry is to stay with the leaders it must have the money even if the costs are offset to some extent by Anglo-European co-operation. The benefits for the country in terms of exports could be enormous.

Not only can the British aircraft industry build aircraft but, as was...
exemplified by the static exhibition of Farnborough, our own electronics industry is fully capable of meeting all the demands likely to be made upon it for the equipment so essential to today’s aerospace technology.

At the show Marconi introduced a new computer called Myriad-3 which is designed around t.t.l. logic and is intended for handling radar data.

Myriad-3 is a parallel binary fixed-point machine with single address operation having a word length of 24 bits with facilities for double-length working. Extensive input/output facilities are available in the form of optional plug-in modules. Most single-length instructions take about 3.2μs and the more complicated instructions, such as multiply, take around 11μs. Storage capacity is up to 256,000 words and two types of store are available; a 32k word store with a 650ns cycle time and a 16k word store with a 1.6μs cycle time. Because the store timing is controlled from within the store unit, it is possible to have both types of store in a system, with the slower (and cheaper) store carrying less urgent information.

The basic machine comprises a number of modular ‘building bricks’. The main units are the central processing unit, store units, power units, operators’ control unit, programmers’/engineers’ control unit and a highway extension unit. A master peripheral unit, designed to accept standard control modules, accommodates the input/output control circuits for peripheral devices.

Among the many demonstrations on the Min-tech stand was the use of glass fibre light guides in an experimental optical communications system employing a gallium arsenide diode as the light source and an exhibit which showed how a c.r.t. and associated keyboard could be used on board an aircraft to communicate with a navigational digital computer.

Visitors to Farnborough were able to navigate their way round the airfield without moving from the Sperry pavilion. To do this, they went for a simulated run in a Land-Rover equipped with the Sperry Vehicle Navigator and Map Display which is currently being offered for airfield navigation duties.

The Land–Rover was driven in the normal way; the wheels revolving against a dynamometer to provide a speed input for a computer. Turning the steering wheel produced heading change inputs for the computer, in place of the gyro or flux-valve normally employed. A map display unit was mounted on the bonnet for the demonstration and the position of the vehicle was indicated by hair line cursors. A digital computer monitored the process.

The helicopter version of the Solartron Simfire seen at the exhibition is one of a family of direct fire weapon effects simulators developed as aids for combat training. The system has two basic roles. As a method of training helicopter pilots in making the best use of ground and cover to avoid ground fire; and as a means of assessing the vulnerability of helicopters to ground fire, for operational analysis purposes. A laser-beam projector is aimed by the operator at a helicopter target. When the operator ‘fires’, a stream of pulses is directed towards the target. Detectors on the helicopter receive the laser beam impulses and illuminate indicator lamps which show the pilot that he is under attack. The direction of the attack is indicated by a lamp to the pilot who can then take avoiding action. If the helicopter target is held in the centre of the beam for a period exceeding one second, the helicopter is ‘killed’.

Texas Instruments, as part of their Klixon range, were showing what they describe as a solid-state vane switch—a contradiction of terms if ever there was one. The device is designed to sense when a supply of cooling air is stopped or reduced in a piece of equipment. The sensing element is a positive temperature coefficient thermistor built into a probe.

Sperry were showing a c.r.t. display intended to replace a number of instrument panel dials. The c.r.t. displayed characters and symbols to give aircraft attitude, flight director information, altitude, airspeed and weapon aiming information either individually or as an integrated display.

Decca Navigator, who were rightly shouting about the recent order by America’s Eastern Airlines for the Omnitrac Area Navigation System, were also displaying a new back-projection navigation display.

Elliott Automation Radar Systems introduced a new nose radar of advanced design capable of terrain following, mapping, ranging, and air-to-air operation in strike aircraft while Elliott Flight Automation had on display a digital automatic flight control system for civil use.

Ultra Electronics were displaying a personal radio location beacon designed to replace the larger beacon now in service with the armed forces. Called Sarah-B the beacon is capable of twin-frequency working and it is built using thin film circuit methods. It measures 110 X 75 X 25mm and weighs less than 20 oz. Sarah-B transmits on a frequency of 243MHz and can be used for two-way communication over ranges up to 243 or 282MHz; battery life is in excess of 24hr.

That completes our quick glance at a small percentage of products that were on show at Britain’s biennial avionics supermarket at Farnborough.

Among the new items introduced by B.M.I. was a video map generator (Type VM101) which is designed to be an inexpensive adjunct to radar simulators or for use with real time radar displays for simulating stationary or moving clutter. It will also produce a video map. Patterns are generated by a flying spot scanner.

Elliott’s stand contained a vast assortment of equipment for both military and civil applications and the Digital Systems Department introduced an airborne display control unit. Facilities provided by this unit include alphanumerics, lines and circles with 10-bit angular and positional accuracy. Individual symbols can be made to flash or be made brighter, and several displays, each showing a different picture, can be driven simultaneously.

Plessey had an engine vibration monitor on show which was designed for Concord. The system consists of eight piezo-electric transducers, one mounted on both the fore and aft bearings of each of the four engines. An eight-channel display of the flight deck gives immediate indication of increased vibration, often the first indication of serious engine trouble. Another item on the Plessey stand was a stall warning unit for use on the Hawker Harrier. Intended for use when the aircraft is hovering, the unit senses an incipient stall condition and warns the pilot by shaking the rudder bar.

A personal survival beacon, Starbe 5, introduced by Burndept for military use. It allows two-way speech and a built-in test system.
London Broadcasting Convention

Some developments in broadcasting seen at the September convention

With over 80 technical contributions the biennial International Broadcasting Convention in London in September attracted 1000 delegates. Most of the papers were about television—the big stride nearly a year ago when the U.K. passed out of the 405-line monochrome age into the 625-line colour age overshadowing developments in sound broadcasting.

Audicial report in broadcasting was one of the major themes of the convention and a good 25% of the papers dealt with some aspect of automatic control of equipment, ranging from closed loop servos for particular operations (e.g. automatic registration of colour-separation images in television cameras) to a vast data processing system using several digital computers that controls the whole of the NHK (Japan) broadcasting network and even encompasses the audience. All this is becoming necessary, apparently, because of the increasing scope and complexity of broadcasting operations and equipment—saving time, saving cost, and saving inadequate—and, in turn, because of the excessive cost of training and using technicians for these operations. The subject has become so important, and the automation techniques are so varied and complicated, that we intend to make a special report on this aspect of the B.B.C. to be published in the November issue of Wireless World.

Satellite broadcasting has its problems, some of which have been discussed before. One, discussed by P. L. Mothersole, is that of mains isolation in television receivers; a problem when thinking in terms of adding a converter to receive satellite broadcasts (such an add-on unit would convert from f.m. to a.m. as well as frequency). But with a new receiver design a convenient way around this is to have an insulated winding on the line scanning transformer, at earth potential, providing the low-voltage supply that would be required for a converter. A possibility which Mr Mothersole foresaw is the use of a communal aerial and converter system. This would avoid mounting and aligning dish aerials in domestic installations, and could also help to keep cost down.

An interesting point touched on by J. Redmond, director of engineering, B.B.C., in his address was that of sound broadcasting from satellites in the h.f. band. A study has shown this to be technically feasible in the 21 and 26MHz bands. The satellite would probably be in a low-altitude orbit in such a scheme, because of the high power needed from a geo-stationary satellite—of the order of tens of kilowatts. A power in the region of 1kW is thought feasible for a low-orbiting satellite, and no doubt folding aerials would not present undue difficulties. Snag is the expense of maintaining orbiting satellites and with the limited number of sets able to receive 21 and 26MHz broadcasting authorities might feel there would not be much return for an outlay which could be as high as £10M p.a.

Speech clipping is used to increase the average modulation level in transmitters without overmodulation by reducing the peak-to-average energy ratio in speech waveforms. Normally this is done at speech frequency and results in trapezoidal waveforms. As well as imposing a linear phase response on the modulator this means a much wider bandwidth is needed and also power supply requirements would need to be increased. To avoid modifying older modulators to cope with the clipped speech, frequency translation can be used to ease filtering. The problem is of course that some harmonics of low-frequency speech signals in the clipped waveform are still within the speech spectrum and can not be filtered out. By modulating the speech signal on to, say, a 20kHz carrier (suppressed) and then clipping, filtering is made easy. This is because the highest upper-sideband frequency will be at, say, 25kHz—well away from the lowest first harmonic at about 40kHz. The signal is then demodulated in a product detector. With this kind of system, Radio Liberty (Federal Republic of Germany) has produced a clipper with harmonic distortion of less than 1%, even with an overload of 16dBm.

Studio acoustics. The well-known technique of making models to predict acoustic properties of concert halls has been applied to studio design and fault correction by the B.B.C. Pioneered by Spack at the University of Munich, this is the first time it's been used with a good signal-to-noise ratio—at least 50dB—allowing models to be listened to seriously. This method imposes severe constraints on experimental apparatus, severity depending on the scaling factor. Not least of these is the problem of air absorption, and to get the sound attenuation right a relative humidity of 3% is needed. The usual way of doing this is with silica gel but it takes several weeks to achieve the required dryness. In the B.B.C. experiments H. D. Harwood and A. N. Burd have reduced drying time to half a day for the first drying and to 15 minutes for subsequent drying by using an artificial zeolite.

Using a scale model of a studio reverberation time in the model agreed with that in the studio to within ± 10% throughout the whole frequency range, this difference being inaudible. The model was also a success subjectively in that addition of an 'orchestra', made from polystyrene backed with felt, to the model was clearly apparent in recordings made from the model. The problem in this case is to get tonal quality from the model occurred when this orchestra was added, as well as the expected change in reverberation time. On checking against recordings made in the real studio this change was also apparent and although there is no obvious theoretical explanation for this change the fact that the model predicted it is a very satisfying validation of the modelling technique.

Another interesting development in studio design is the realisation that reverberation time need not be independent of frequency. Absorbers needed to keep low-frequency reverberation time low (say 0.35s, the recommended value for talks studios) are expensive to make and install, bulky and make modifications difficult. Availability of a recently constructed studio with removable bass absorbers made experiments on how much bass r.t. could be increased possible. As a result of various subjective tests, it's now recommended that r.t. can rise to 0.4s at 500Hz, 0.47s at 125Hz and 0.74s at 62.5Hz. A discussion of new developments in television will be published in the November issue.

Domestic Receivers

New techniques seen at the London trade shows

Television

The design of domestic receivers is a compound of two elements: the available market and the available technology. To be more precise, the sales people are not interested in the electronic contents of the box provided the complete product is attractive for renting (and, to a smaller extent, owning); technical features, whether real or cooked up, are seen merely as fodder for sales promotion campaigns. The engineers have at their disposal new devices and techniques and would like to use them to the full in elegant, tidy circuits, but, being restricted by cost, usually end up with a design which to them is an unsatisfactory compromise.

What the engineers have in the back of their minds, as a sort of Volksfernsehempfänger, is a flat box containing pictures and containing nothing more than a few integrated circuits. We are certainly on the way towards this ultimate, leaving behind as we go valves, round tubes, monochrome pictures, hybrid circuitry, dual standards and discrete components. Meanwhile, in our present confused state of transition, there exist side by side monochrome and colour, hybrid and semiconductor circuitry, dual-standard and single standard, picture tubes of different sizes and shapes, single chassis and modular construction, together with a variety of “furniture” styles and electronic circuit techniques which seem like tricks because they are individual to particular manufacturers and not yet standard. In this confused situation it is difficult to decide what is “typical”.

To begin with the most obvious thing, the picture tube, the six main sizes available last year (19in, 20in, 22in, 23in, 24in and 25in) have now been supplemented by two more, 17in (monochrome) and 26in (colour). There are in addition the various portable battery sets with screen sizes of 12in and smaller. The range, however, is not as embarrassingly large as it seems, for the 19in and 23in monochrome tubes have been superseded by the 20in and 24in sizes respectively, and the 25in colour tube, though still being used in sets, is due to be replaced eventually by the 26in type. The 17in monochrome tube really takes the place of the 16in type that has been widely used in transportable and small “second sets”. Thus one sees a general up-grading in size all round. Monochrome tubes have deflection angles of 110°, colour tubes 90°; but colour tubes with deflection angles of 110° and, consequently, a few inches off their length, are available on the Continent and it is only a matter of time before they appear in British sets.

The distribution of valves, transistors and I.C.s in receiver circuitry varies considerably from maker to maker. British Radio Corporation and Rank Bush Murphy have all-transistor colour sets which are virtually the same as last year’s designs, and a new transistor colour receiver has been introduced by Philips. In the hybrid receiver circuits, colour and monochrome, it is common practice to use valves for the line and field scanning oscillators, for the associated output stages and for the sound output, but there is some variability with other stages. In a Decca single-standard monochrome chassis, for example, valves are also used for the 1st and 2nd i.f. stages, video amplifier, sync separator and line pulse discriminator. This design is, however, very much up with the times in having an integrated circuit, the Motorola MC1351P, for the sound intercarrier i.f. amplifier and f.m. detector (followed by a transistor a.f. output stage). Some current monochrome sets are still all-valve designs except for the u.h.f. tuner. Generally speaking the U.K. manufacturers are not bothering to put design effort into producing all-transistor monochrome circuits, which will only be found in the small imported portable sets.

Integrated circuits, last year restricted to the intercarrier sound and colour decoding functions* have now blossomed out somewhat, and in the new Philips colour receiver mentioned above there are four: (1) intercarrier sound; (2) stabilization for the tuner; (3) video pre-amplification, line gated a.g.c., sync pulse separation, noise protection for a.g.c. and sync channels; and (4) PAL switch, identity circuit and colour-difference demodulators. These devices are available from Mullard under the general type-number prefix TAA. But the general run of set makers is still rather wary about using I.C.s, mainly for the reason that, as distinct from the digital computer field, there is a lack of standardization and “second sourcing” in the manufacture and supply of devices.

Two noticeable trends in circuit design this year are the use of variable-capacitance diode tuning and the replacement of winding components by equivalent circuitry using transistors, resistors and capacitors. Variable-capacitance diode tuning on both u.h.f. and v.h.f. has been used fairly extensively for some time in Continental television tuners but this is the first time it has appeared in sets on the British market. Examples of the technique were seen in receivers by Philips, Ekco, ITT and Teleton. The reason why variac diodes, as they are called, have not been used here is a technological one and not, as might be thought, because U.K. makers were slow to appreciate the advantage of diode tuning. It is to do with the way in which channels are allocated.

In the U.K., u.h.f. channels are assigned to transmitters in groups of four. In most cases the four channels are n, n + 3, n + 6 and n + 10, or n, n + 4, n + 7 and n + 10, n being the lowest channel number for each station. For example: the channels assigned to Emley Moor are 41(n), 44(n + 3), 47(n + 6) and 51(n + 10). Those assigned to Winter Hill are 55(n), 59(n + 4), 62(n + 7) and 65(n + 10).

It will be seen that in each case the highest channel is spaced 10 channels from the lowest, which means that with the 8-MHz channel spacing laid down by the European frequency plan the highest channel is 80MHz away from the lowest. Now, for a receiver tuned to the lowest channel, the highest channel becomes the image frequency. This is because the agreed vision i.f. is 39.5 MHz. If the oscillator is tuned “high” as is usually the case, the image frequency is 39.5 Hz “on the other side of” (above) the oscillator or 79 MHz above the wanted station.

This figure is only 1 MHz short of the 80 MHz separation between n and n + 10 and a signal radiating at n + 10 if allowed to enter the pass band of a receiver tuned to

Push-button channel selector (left) and pre-set potentiometers (right) of the Philips varicap-diode tuner (Fig. 1), as used in the Philips G8 colour television receiver.
voltage swings than do colour-difference signals, which are matrixed with the luminance signal by the c.r.t. In the new Philips set referred to above, for example, matrixing is carried out in the decoder i.e. (4) at low level and the RGB outputs receive several stages of amplification through separate channels before being applied to the c.r.t. cathodes. This method relies on accurate setting of the grey scale for good monochrome reception and for this reason the colour drive adjustments are preset at the factory.

Colour television sets usually include a circuit for preventing the beam current of the colour c.r.t. from rising above a certain upper limit, the purpose being to save the tube's shadow mask from becoming overheated and consequently distorted in shape. In any case the shadow mask carries the major part of the beam current, and with certain types of picture content the electrical energy converted into heat could become excessive. Normally the beam current limiting is arranged as a form of automatic brightness control, but during operation this causes an error in colour saturation and also a loss of detail in the darker parts of the picture. To avoid this undesirable side effect, Decca, in their latest colour receiver chassis, have designed the beam limiter as a form of automatic contrast control. Fig. 3 shows how it is arranged. A potential proportional to beam current is derived from the cathode of the line output valve and this is applied through the vision detector and other circuitry (not shown) to a video emitter follower and then to the a.g.c. circuit. The direct voltage from the a.g.c. circuit is fed back to bias the first vision i.f. stage normally used for audio amplification, and so control i.f. gain in the back-to-back diode detectors for vision and intercarrier. Other circuit features noted: The B & O Beovision 3200 colour set has a circuit which automatically cuts out the colour sub-carrier notch filter in the luminance channel when the set is receiving monochrome transmissions. This colour set also has the unusual features of a separate high-frequency loudspeaker, and bass and treble controls. In the ITT CVCS colour receiver the saturation and contrast controls are mechanically ganged, and there are separate diode detectors for vision and intercarrier sound. The e.h.t. pulse winding on the line output transformer of the latest Decca colour chassis is underneath the primary winding instead of on top—a cost saving feature. Automatic line hold, dispensing with the usual manual control, is employed in the Philips and ITT colour receivers.

**Sound receivers and reproducers**

The mere appearance of integrated circuits in receivers is no longer a matter for surprise, but as the art of using i.c.s progresses makers may find alternative or novel uses. A case in point is the use of the TAD100 circuit in the new Dynatron amplifier and a.m./f.m. tuner (HFC91), announced earlier this year. This i.c. is intended as an i.f. amplifier, but in the Dynatron circuit the stage normally used for audio amplification is used instead as a d.c. amplifier feeding an a.m. moving-coil tuning meter. (Same meter acts as tuning indicator on f.m. straight from the discriminator.)

This tuner incorporates diode tuning on v.h.f. for four circuits, two back-to-back diodes each, with three pre-set potentiometers and another linked to the tuning scale. The scale covers 88-100MHz, giving greater spread than with 108MHz top
frequency, but the pre-set potentiometers extend to 108MHz, in anticipation of this model being sold in the U.S.A. and Canada. Supply voltage for the tuning circuits is regulated with a TAA550 i.e.c. between supply rail and ground. The three pre-set controls together with the displayed range allows a local station to be pre-set as well as the three national services, but we have seen some sets with four pre-set controls. (Incidentally, some local stations will be using 45° slant polarization with consequent benefits to car and 'picnic' radio reception—see p. 492.)

Interstation muting is achieved by switching back-to-back diodes in the signal path to the decoder from a d.c. amplifier following the discriminator (Fig. 4). Other features of this design are dual-gate f.e.ts in the f.m. tuner, four-i.c. Görler f.m.-i.f. amplifier, ceramic filter unit with the TAD100 a.m. i.f. amplifier, twin-T high- and low-pass filters and negative feedback tone controls in the pre-amplifier. Extensive use is made of BC148 transistors (11) with BC149S as low-noise input transistors. The audio amplifier is a conventional quasi-complementary circuit giving 45+45 watts into 3 ohms, or reduced powers into higher impedance loads, at low distortion (0.2%). It is typical of modern designs using silicon transistors which allow high voltage supply with consequent high-power output. A thyristor overload protection switch reduces output to a safe level when safe operating limits of the transistors are exceeded, lighting an indicator lamp and reducing the supply voltage to the pre-amp emitter follower. Price of this tuner amplifier is £165.

A notable trend in this kind of quality tuner is the omission of a ferrite aerial for a.m. reception—or at least provision of a separate coil pack for an exterior aerial. This was also noted on the new B & O Beomaster 1600 which, apart from the addition of f.e.ts and an f.m.-i.f. ceramic filter, is a re-styled version of the 1400. This new a.m./f.m. model, with a power output of 15+15 watts, and including two short-wave bands, costs £122. Another new a.m./f.m. tuner-amplifier from B & O is the Beomaster 1200. A new design, but along fairly conventional lines, it uses a cascode f.e.t. input circuit and diode tuning. Sensitivity is better than that of the 1600 (1µV for 26dB s/n ratio f.m., 7µV for 3dB s/n ratio a.m.) and power output is 15+15 watts. Price £108.

Latest Teleten tuner-amplifiers (made by Mitsubishi) acknowledge the difficulty in seeing vertical tuning scales in 'low-line' models by using a horizontal scale—in one case both types are used.

The Dynatron stereo decoder is fairly typical of current practice. Designers seem to have settled on the balanced switching demodulator, this only partially demodulating the L-R signal of course. Correction to give 40dB separation is made in a common-mode amplifier (one transistor in each channel with emitters bridged with a resistor). The Dynatron circuit has the added luxury of twin-T filters in each channel to reduce sub-carrier level.

First commercial amplifiers using a hybrid thick-film integrated circuit for the power amplifier are by Stanley Kelly, joint managing director (with Sidney Larhoit) of Kellar Electronics Ltd (Maryland Works, 9 Brydges Road, London, E15 1NA). One of the series of amplifiers is used in the new Kellar cassette tape recorders using the Dolby 'B' system for noise reduction above 2kHz. The system gives a signal-to-noise ratio improvement of 10-15dB (see p. 519). As well as using this system with the 25+25 watt cassette tape recorder, it will be available separately for reel-to-reel tape recorders (to be shown at the Audio Fair). We expect the Dolby 'B' separation to appear in equipment from various makers later this year—Decca, Rank and Metrosound are rumoured to be working on this.

The hybrid thick-film module used by Kellar—a Bendix circuit originally designed for industrial applications—has made possible a low-cost 15+15 watt amplifier. Marketed under the name Nova by L. L. Electronics at £33 and with low distortion (about 0.2%) this could be the best value for money in terms of watts per £ at this power level. The circuit uses a conventional quasi-complementary output stage and complementary driver with discrete transistors on the thick-film circuit. Module measures 20×45×80mm. A slightly larger 50-watt module is available, circuit is shown in Fig. 5, and will be used in an amplifier to be released shortly.

In designing the regulated power supplies for this amplifier, Stanley Kelly found that by using two series transistors (OC22s) each feeding one amplifier, instead of operating them in parallel, and arranging feedback from one side of a long-tailed pair circuit, he obtained a worthwhile increase in channel separation.

Another Nova Design, the 10+10 watt amplifier, currently using an AD161/2 output pair, is due for re-design around a Siemens TAA420 integrated circuit.

Another hybrid high-power amplifier is made by RCA (type TA7625) which operates from a split power supply and has a built-in limiting circuit. Among the new tape recorders there is a profusion of cassette machines and medium quality reel-to-reel types. Three models from Sharp are of particular interest, having servo control of motor speed: a cassette recorder with slider controls for setting the recording level (model RD423, price £57 10s) and two 5in reel-to-reel recorders with switched speed change (model RD513, price £39, and its push-button-control counterpart, the RD514, price £42). In each of these recorders the d.c. drive motor is in the collector circuit of a control transistor, the base circuit of which is fed from a generator coupled to the motor shaft. Speed change from 3½ to 1½ l.p.s. is accomplished by a switched resistor change in the bias circuit.

Sanyo now have three cassette recorder models available ranging in price from £19 15s to £99 15s—some of these have an f.m. radio too.

Along with several new tape recorders, ranging in price from £55 15s 7d to £157 14s, Grundig displayed the TK3200 three-speed battery recorder with a stick microphone priced at £178 3s. At 7½ i.p.s. the frequency response is said to be 40Hz to 16kHz and wow and flutter as 0.1%. Signal-to-noise ratio is claimed to be better than -48dB at 1½ i.p.s. Outputs are 500mV (into 15kΩ) with provision for driving an external 4Ω speaker with 2W or the internal speaker with 0.8W. This is a single channel recorder.
Mobile radio and amateur bands

I refer to the letter under the above heading which appeared in your September issue. The second paragraph implies that some unofficial arrangement exists concerning the 70-MHz amateur band. The Electronic Engineering Association seems unaware that the amateur service has been allocated frequencies between 70 and 71 MHz since 1956. Indeed, recent issues of your journal have carried news of propagation experiments by amateurs using these frequencies. It is implicit by the terms of the Radio Regulations that where the amateur service is the secondary user then this is subject to non-interference with the primary service.

The last sentence of the third paragraph of your correspondent's letter shows a lack of knowledge of the occupancy of the 420-450 MHz band. There are, of course, a number of amateur television stations using frequencies in this band, but, in addition, there are a far greater number of stations occupying the band for experimental work in connection with moon bounce, meteor scatter and satellite communication. Stations operating under the terms of the Amateur (Sound) Licence B are present in large numbers on both the 2-m and 70-cm bands.

The final sentence of the E.E.A. letter mentions "amateur associations". I would point out that the Radio Society of Great Britain is the organization recognized by the Ministry of Posts and Telecommunications as representing the stations of the amateur service in the United Kingdom. There are regular discussions between the Ministry and the R.S.G.B. concerning licensing matters and frequency allocations and we have no doubt that at the correct time the Society will be approached by the licensing authority.

J. A. SAXTON,
President,
Radio Society of Great Britain.

Crisis in microelectronics

Your September editorial draws attention to the difficulties of the integrated circuit industry, but the conclusion one should draw depends rather on one's viewpoint. The U.S. microelectronics industry obviously has-excess production capacity for the foreseeable future, and the present marketing situation cannot be changed rapidly. Dr. F. E. Jones cites import duties as a reason for British companies not manufacturing in the Far East. From a quick enquiry I get the impression that duty on radio components entering Britain is at most 17% which is not decisive in comparison with price differentials quoted in your Editorial, and nil from Commonwealth territories. So why not use Hong Kong? In addition, I feel that more could be done to establish the facts about American manufacturing costs and selling prices, unless it is the desire of the British i.e. industry to befog the issue. If American i.c.s which are packaged in the Far East are taken back into America on conditions which assume that the major part of the manufacture has taken place in America, then surely there is no doubt about the country of origin. But even if there is doubt about the country of origin in the manufacturing sense, it must be possible to establish the country in which the manufacturing company has its registered office. Before we worry too much about the difficulty of ascertaining the true country of origin, let us know at least the selling price in U.S.A.

If there is still a possibility of Britain joining the Common Market there might be a case for a European production facility. So far as concerns Britain as an isolated unit, however, the sensible thing might be to cut one's losses and abandon the whole of the British microelectronics industry as now understood. This sounds a rather staggering proposition, but surely the financial loss to be cut would be no greater than losses which have been cut on unsuccessful military development projects. When I say "the industry as now understood" I mean an industry producing logic units and simple linear amplifiers. These are the type of thing which can be bought cheaply from U.S.A., and so far as military strategy is concerned there could, well be either a factory operating under licence or an assembly and encapsulation plant in Britain. But I doubt however whether this is a serious concern: one plane load of integrated circuits could be enough to last for some time—longer than a nuclear war!

On the other hand, I think that large scale integration should be pursued in this country because by their nature large-scale integrated-circuit chips are usually tailored made for a particular purpose. It is no novelty for an industry to cut down on the manufacture of a basic product in order to progress to more advanced products.

Another point is that we must not be mesmerized by the idea of integrated circuits using present techniques, which are essentially collections of junction semiconductor devices. There may be a big future for solid state devices which do not depend on junctions, and Britain might have the chance to take the lead in this field. The Gunn effect has already been put to extensive use. The DOFIC appears to have faded into obscurity after a brief appearance, but perhaps there may yet be possibilities of developing it further. There is also the acousto-electric amplifier based on the interaction of electrons and phonons in materials such as cadmium sulphide. These may well play a large part in the future of electronics and should not be overlooked in a moment of panic about the marketing of devices which although scientific marvels to the layman can now be manufactured as a matter of routine.

D. A. BELL,
The University of Hull.

Class AB amplifiers

I am grateful to Mr. Mitchell for his letter in the September issue concerning my class AB amplifier, but there are some points which he makes which, I feel, should not pass without challenge.

In particular he states that a Darlington pair output stage has a lower mutual conductance than the output transistor on its own. While, in theory, this could follow from the fact that the second transistor imposes an impedance in the emitter circuit of the first, this situation does not arise under any but near zero source impedance systems, as I have illustrated in the previous letter. We worry too much about the difficulty of ascertaining the true country of origin, let us know at least the selling price in U.S.A.

If there is still a possibility of Britain joining the Common Market there might be a case for a European production facility. So far as concerns Britain as an isolated unit, however, the sensible thing might be to cut one's losses and abandon the whole of the British microelectronics industry as now understood. This sounds a rather staggering proposition, but surely the financial loss to be cut would be no greater than losses which have been cut on unsuccessful military development projects. When I say "the industry as now understood" I mean an industry producing logic units and simple linear amplifiers. These are the type of thing which can be bought cheaply from U.S.A., and so far as military strategy is concerned there could, well be either a factory operating under licence or an assembly and encapsulation plant in Britain. But I doubt however whether this is a serious concern: one plane load of integrated circuits could be enough to last for some time—longer than a nuclear war!

On the other hand, I think that large scale integration should be pursued in this country because by their nature large-scale integrated-circuit chips are usually tailored made for a particular purpose. It is no novelty for an industry to cut down on the manufacture of a basic product in order to progress to more advanced products.

Another point is that we must not be mesmerized by the idea of integrated circuits using present techniques, which are essentially collections of junction semiconductor devices. There may be a big future for solid state devices which do not depend on junctions, and Britain might have the chance to take the lead in this field. The Gunn effect has already been put to extensive use. The DOFIC appears to have faded into obscurity after a brief appearance, but perhaps there may yet be possibilities of developing it further. There is also the acousto-electric amplifier based on the interaction of electrons and phonons in materials such as cadmium sulphide. These may well play a large part in the future of electronics and should not be overlooked in a moment of panic about the marketing of devices which although scientific marvels to the layman can now be manufactured as a matter of routine.

D. A. BELL,
The University of Hull.

Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents
whole of its effective output swing. The mere fact that one or other of the output transistors is not completely cut off is not enough to satisfy this requirement.

Although I had not mentioned this point specifically in the article, the use of the amplifier in true class A does bring about a reduction in the distortion typically to below some 0.01%, at power levels below 15 watts, over the frequency range 100 Hz-5kHz, and the distortion content then decreases linearly with reduction in output signal magnitude.

My decision, in the design of the amplifier, to employ a variable resistor, as a source of bias, between the bases of the output transistors, rather than a more complex temperature compensation network was based partly on the convenience of adjustment of such a biasing system, as compared with, say, a string of diodes (two forward biased silicon diodes will, in fact, give almost the correct quiescent current, and this arrangement was used in some of the prototypes in use by friends) and partly on its lesser proneness to catastrophic failure than transistor "amplified diode" systems.

My curve B indicates the relative insensitivity of the single transistor output stage to variations in forward bias (and the choice of 200 mA quiescent current very much reduces thermal effects, even with an 8-ohm load!) as well as the excellent transfer linearity of such a system which contributes to the lower harmonic distortion figures obtainable with such an output stage in comparison with the more normal push-pull configurations.

Both Mr. Mitchell and Mr. Gibbs (letters, Aug. 1970) have taken me to task for my observation above being given an unexpected degree of prominence. Since I was, at this stage, reviewing the thought processes which had led to the choice of this output stage configuration, it would have been better if I had continued "and this type of stage was therefore chosen as the starting point for this design".

In the event, both the preliminary calculations and the initial experiments indicated that it was neither practicable nor desirable, from the point of view of linearity of operation, that the output stage should have a low source impedance and the solution suggested by Mr. Mitchell in his letter, that of a relatively high driver impedance with a low inter-base impedance, was the configuration which had been adopted in the final design.

In reply to the letter from Messrs Smith and Walker in the September issue I would point out that the total harmonic distortion was quoted at 1000 Hz, because this is the recommendation of the B.S. and DIN specifications. The t.h.d. figures, at full output, at 100Hz and 10kHz, are typically 0.04% and 0.06% respectively. At low frequencies the harmonic distortion is mainly influenced by the impedances of the power supply bypass capacitor and the decoupling and 'bootstrap' capacitors, and an improvement can be made, if necessary, by increasing the value of these. At high frequencies, the distortion content is mainly determined by the deliberate and necessary reduction in the open-loop gain, and feedback factor, required to maintain good reactive load stability, although the circuit layout and stray capacitances have some effect.

I apologise for the omission of the bandwidth limits for the noise figure measurements. These were effectively those imposed by the amplifier gain/frequency characteristics, as would be measured by a very wide bandwidth millivoltmeter. The use of a more restricted bandwidth, say 20Hz—20kHz, would allow an apparent improvement in the specified noise figure. (It is, in fact, quite inaudible.) However, on looking through back numbers of Wireless World I find that other authors have been equally remiss in omitting measurement bandwidths when quoting noise levels. This point will, perhaps, be noted in the future.

I regret that the measurement parameter "square wave transfer distortion" was not accompanied by some further explanation. In practise, transfer distortion is measured by comparing electrically the waveforms at the input and output of the system under test, and then expressing the error arising in the transfer as a percentage of the input waveform, as measured on an r.m.s. calibrated voltmeter such as that used for conventional t.h.d. measurements. Any convenient waveform may be used for this purpose.

Typical values for transfer distortion with conventional audio amplifier designs using a 10kHz square wave and a resistive load range from 0.2% to 10%. Square-wave transfer errors as high as 30% are fairly common under reactive load conditions, and this, in conjunction with the relatively high distortion levels sometimes found at low volume levels, may account for much of the so-called 'transistor sound'. Unlike harmonic distortion, transfer distortion with reactive loads may worsen as the amount of negative feedback is increased.

J. L. LINSLEY HOOK,
Taunton,
Somerset.

**Sine-wave power oscillator**

The basic requirements for any circuit are that it should be comprehensible, designable and as simple as possible. The old rule, simplify and add lightness, still applies. Mr. Armer's circuit (August p.402) and his explanation, do not seem to satisfy this.

It is rather easier to examine this circuit if the earth point is moved: indeed it is probably easier to use it if a second variation is adopted. Fig. A shows the circuit rearranged for conventional analysis, and Fig. B shows it with the collector of the transistor at an a.c. earth. In both circuits the tuning capacitor has been transferred to be in parallel with only the larger part-winding, simply to make the circuit look conventional.

Before discussing how it works, let us look at the numbers. $L_1$ is tapped to give
400 mH in the one part, 200 mH in the other. The total inductance is thus \(200 \times (1 + \sqrt{2})\) mH, or 1.16 mH. This tunes with \(C_1 = 0.05\) \(\mu\)F to 21 kHz. It would seem that the frequency is not determined, as Mr. Armer suggests, by \(L_1\) and \(L_2\) in parallel. They are, in fact, in series, to give the reactance plot shown in Fig. C.

The feedback path when neither the diode nor the base emitter junction are conducting very much is a low-pass half-section with a cut-off frequency of below 1 kHz and an impedance of about 75 ohm. When either diode is conducting it reduces to an inductance of about 180 \(\mu\)H, to give a 90 \(^\circ\) phase shift.

The load for 13 W must be in the region of 10 \(\Omega\). The reactance of \(C_1\) is about 160 \(\Omega\), so that the \(Q\) of the circuit is very small indeed. Furthermore the value of \(L_1\) (\(L_2\)) for the 400 mH section would seem to require a ferrite core of some 30 cm\(^3\) volume.

In a push-pull circuit \(L_1\) would be identified as a constant current supply choke. Here its value is just low enough to avoid really awkward high voltages as the transistor is cut off, provided that the cut-off is slow, and thus lossy. What Mr. Armer means by the statement that the base current controls the collector current while the transistor is saturated I cannot understand. The only way this can be done is by limiting emitter current and drawing much of it off into the base. But 2 A base current?

Mr. Unsworth ("1000:1 Attenuator"—same page), in offering us an output of 0.768 V, appears to neglect the fact that the 8 should be significant. He obtains his 0.7-0.8 V across a \(R\) which is loaded by roughly 100 \(\Omega\). Thus if we look at the first step, nominally 0—0.1 we shall have, in fact, 0—0.099. Moreover, \(V_{out}\) must be loaded by something like 5000 \(\Omega\)—I have not worked it out—if the system is to be plausible.

T. RODDAM, London.

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**R.S.G.B. Exhibition**

Where have all the experimenters gone?

Seduced by sales talk every one!

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Not so long ago under the heading of "Components, Complacency" we urged manufacturers to turn a sympathetic ear to the component needs of the home constructor. It would seem, however, that as far as the amateur radio enthusiast is concerned we should not have wasted the ink and the paper. There were only seven entries from the whole amateur radio fraternity for the home constructed equipment competition held at the recent R.S.G.B. Exhibition. A lamentable turnout.

Is it true that the ham of today does no more than gossip on the air while twiddling the spun aluminium knobs and peering at the gleaming Perspex dials of a shiny piece of commercially constructed equipment? If so the frequency bands allocated to amateurs are being wasted and should be reallocated to a more deserving cause.

Today's home constructor has never had it so good. He can obtain at reasonable prices sophisticated components which were not even available to industry a few years ago. Is it that today's amateur does not want to risk his money on experiment? Or are the days of trial and error design done?

The winner of the Horace Freeman award for home constructed equipment this year was George Goldsmith, from Jersey, with a finely engineered communications receiver for the amateur bands. It employed both valves and semiconductors and incorporated three crystal filters. Sensitivity was 0.4 \(\mu\)V for a 10 dB signal-to-noise ratio. Other prizewinners were M. F. Taylor, of Reading, with a 2-m transceiver and J. R. Jessop, of Pinner, with a linear amplifier. This year the John Rouse Trophy was not awarded as there was not a single entry from the under-16 age group, a necessary qualification for this award.

The exhibition itself is still affectionately known as the R.S.G.B. Exhibition, rather than by its somewhat pretentious title (International Radio Engineering and Communications Exhibition). This year it sprouted the additional title Radiocom 70 as well. Attendance was just over 7000; about 800 less than last year. This may have been due to the show being held in August instead of later in the year as in the past. We do not question the value of the exhibition which, as a meeting place for the electronics-radio fraternity, is almost second to none. It is patronized by all types of people from home constructors and amateurs to engineers and academics. It is a pity that working equipment demonstrations were so thin on the ground this year. There were many bargains in surplus equipment to be found even though one exhibitor admitted that the exhibition gave an opportunity to get rid of a "pile of junk".

The Ministry of Posts and Telecommunications had a display which illustrated how interference can spread in large urban areas and the problems incurred in tracing, measuring and suppressing it. This year the Radio and Space Research Station had a stand which showed the work they are doing in the field of propagation of radio waves over a very wide band of frequencies.
News of the Month

Ceramic stores for information displays

Some interesting work currently being carried out at Bell Labs in America has resulted in a sort of re-usable slide for projection purposes. Images stored on the slide can be erased and replaced with a new image at will. At the present stage of development the device, or 'ferpic' as Bell Labs call it, would only be suitable for use in displays of written text and figures which do not require to be quickly altered. Not a great deal of information has been released but it does not take a great deal of thought to see that if the speed can be increased and if the devices can be manufactured at reasonable cost the ferpic could have a bright future.

The material used in the construction of the ferpics was first announced by an American concern called the Sandia Corporation. The device is a sandwich. A transparent substrate is flooded with light in the presence of a reversed electric field; the plate is then ready to store another image.

Bell Labs is exploring this device in the hope of obtaining efficient, low-cost solid-state information displays with features that are difficult to obtain in present display systems. Because the image store in the ferpic device can be projected, very large displays can be obtained. Also ferpic slides can retain images for a long time without electrical power, fading only slowly.

Slant polarization for local radio

Certain B.B.C. local radio stations will be using slant (45°) polarization instead of horizontal polarization. This follows successful tests by B.B.C. research department engineers in Kingswood and Nottingham areas†. Reception in cars and in the open air with vertical aerials will be improved through the effective increase in transmitter power equivalent to about 6—9dB, at least doubling signal strength on average. Hitherto, satisfactory reception with vertical aerials has been largely a matter of luck. As a consequence, horizontal roof aerials will give a reduced signal—about 70% or —3dB. If necessary, this could be recovered by slanting the aerial (clockwise by 45° when looking at the transmitter) but the national v.h.f. services, not using slant polarization, would suffer a loss.

Stations using slant polarization are: Manchester—95.1MHz; and early in 1971 Blackburn—96.4MHz; Derby—96.5MHz; Leicester—95.05—95.2MHz and Nottingham—94.8MHz.

B.B.C. make the point that some roof-level aerials may not be correctly oriented for the local station and some adjustment may be needed for best results.

Mullard’s golden jubilee

As part of their Golden Jubilee celebrations Mullard Ltd. are to stage a 3-week public exhibition in the Electronics Centre of their London headquarters, Mullard House, Torrington Place, London, WC1E 7HD.

The exhibition will trace the history of Mullard’s golden jubilee—over the past 50 years. The exhibition opens on October 5th, and will run until October 24th, opening every day (except Sundays) between 10.00 and 18.00 (21.00 on Thursdays). Admission will be free. Later, the exhibition, probably in a modified form, will tour Mullard establishments throughout the country.

The main window of the Electronics Centre will contain examples of vintage electronic equipment contrasted with their modern counterparts and supported by displays of Mullard components used in their manufacture.

Within the Centre one of the main attractions will be a radio transmitter built and operated by Mullard ‘hams’. Some of the company’s earliest valves will be used

†Spencer, I. G. Tests of mixed polarization for v.h.f. sound broadcasting, B.B.C. Engineering, July 1970, pp.4-12.
in its construction. It is also hoped to show part of the original 2LO transmitter used by the B.B.C. for its first public broadcasts.

Another main feature will be entitled 'Mullard Through the Decades': This will show electronic products and their components of each era, beginning with the first Mullard high-power transmitting valve. Displays in the 'Today' section will feature many working exhibits including a microwave oven. Another section will provide a glimpse of some of the likely future applications of electronics. The exhibition will also include a section where visitors can test their skill and reflexes in various electronic games.

I.T.A. completes 405-line network

The coming into service of a local v.h.f. relay station at Newhaven, Sussex, on August 3rd marked the completion of the I.T.A. network of 405-line v.h.f. television transmitting stations. No further additions to this network, which operates solely in Band III, are currently envisaged. All I.T.A. station building plans are now concentrated on the rapid expansion of the new 625-line network of u.h.f. transmitters. Since the original opening of the first I.T.A. Band III station at Croydon, south-east London, on September 22nd, 1955, the 405-line network has expanded steadily and now comprises 47 transmitting stations, of which 20 are manned, and 27 remotely controlled. The network provides television coverage for approximately 98.7% of the population of the United Kingdom.

Want to use a satellite?

The National Aeronautics and Space Administration is offering the use of six satellites which have long since fulfilled their original task but are still operational. The six spacecraft are: OGO-1 (Orbiting Geophysical Observatory), ten experiments still operational, highly elliptical orbit 111,000 by 39,000 miles, inclination 58°; OGO-3 similar orbit to above; Explorer-31 (direct measurements explorer) with five operational experiments and Explorer-33 (Interplanetary Monitoring probe) orbit 410,600 by 109,000 miles, orbit period 32 days; finally the orbiting solar observatory satellites OSO-3 and OSO-4 are also available.

Interested scientific bodies should contact Code SG N.A.S.A. Washington D.C. 20546.

As a matter of interest the oldest satellite still transmitting useful information is the Canadian Alouette-I which was launched on September 29th 1962.

Apollo colour TV camera

Under a $196,500 contract R.C.A. will deliver two colour television cameras to the National Aeronautics and Space Administration which can be used under the extreme lighting conditions found on the moon. The cameras, which weigh ten pounds each, not only operate in dim lighting conditions but they can be pointed directly at the sun without sustaining any damage!

The cameras employ silicon intensifier tubes, the imaging surface being made up of almost 400,000 silicon diodes. The colour system (525 lines per frame and 60 fields per second) is as used in earlier Apollo missions with a colour filter wheel arranged so that monochrome pictures corresponding to the red, blue and green brightness levels are transmitted sequentially for recombination at the ground station.

A lamp, which simulates the brightness level of the sun, being pointed directly into the lens of the new Apollo TV camera.

European component standardization

A ‘Harmonized System for Electronic Components’ is being introduced in Western Europe in which a set of common specifications and quality assurances will remove all technical barriers to inter-country trading. The system is similar to, and fully compatible with, our own BS 9000.

Agreement has already been reached on all the major aspects of the Harmonized System and at the invitation of the Tripartite Committee for Standardization, the Comité Européen de Coordination des Normes Electrotechniques (CENELEC), which comprises all E.F.T.A. and E.E.C. countries, has accepted overall responsibility for launching the system in these countries.

The responsibility for the quality assurance aspects of the Harmonized System is to be handled by an independent committee known as the Electronic Components Quality Assurance Committee (ECQAC). It is hoped that the system can be introduced on a world-wide basis later.

Radar base at Lahr

On August 18th Marconi handed over a radar base to Brigadier General R. E. Mooney who was acting on behalf of the No. 1 Canadian Air Group. The
Announcements

"Compendium of Degree Courses 1970", providing information about more than 279 sandwich, full-time and part-time courses, is available from the Council for National Academic Awards, 3 Devonshire Street, London WIN 2BA.

The following courses are to be held at Hendon College of Technology, London N.W.4, "Thyristor applications", six lectures commencing 12th October; "Electronics for non-electrical engineers", fourteen lectures commencing 13th October; "Construction and operation of digital computers", sixteen lectures commencing 15th October. Fees are £3.00 and £6.00 respectively.

Two-day and three-day colour television training courses are being conducted at the Thames Hotel, Bridge Street, East Molesey, Surrey, by Electronic & Colour Television Training Ltd, of 180 St Johns Road, Woking, Surrey. Fees £15 and £20.

Coincident with next year's Electronic Components Show at Olympia (May 18-21) an Electronic Components Conference is to be held at the Royal Garden Hotel, Kensington, under the auspices of the Electronic Components Board.

Truvox Ltd, which became part of the Racal group with the acquisition of Controls & Communications Ltd, has franchised its distribution and their range of audio products will not be available in future. The service department will continue to operate from Hythe, Southampton, providing an advisory service, repairs and a supply of spare parts.

Philips and Brown Boveri.—An agreement has been reached between Philips' Telecommunicatie Industrie, of Hilversum, Holland, and Brown Boveri & Company Ltd, of Baden, Switzerland, by which the two companies will co-operate in the manufacture and development of sound broadcast transmitters.

REMO is the brand name of a new company, Rectifier Modules International Ltd, of Remo House, Rye Street, Bishops Stortford, Herts. The range of products will begin with three basic types: e.h.t. rectifiers and modules, encapsulated rectifiers and rectifiers to meet British Post Office specifications.

Mobile Radio Communication

Congestion of bands: Proposals for improving the service

The number of private mobile radio licences in the U.K. which at present stands at about 85,000, is likely to double every five years according to figures given at a conference on mobile communications arranged by the Society of Electronic & Radio Technicians. Sectors of the frequency spectrum allocated to this mode of communication are already saturated and equipment manufacturers and users are desperately seeking means whereby they can increase the number of available channels.

Speaking before 130 delegates at the conference at Brunel University, Uxbridge, J. R. Brinkley, of S.T.C. suggested that one way out of the dilemma would be to extend the present u.h.f. mobile band (450-470 MHz) to 420-512 MHz. This would entail, at the top end of the extended band, sharing television channel 21 in Band IV. Channel 21 has been assigned to 15 B.B.C. TV transmitters including three high-power stations at Rowridge (I.O.W.) Divis (N. Ireland) and Sandy Heath. Mr. Brinkley pointed out that the TV band was fixed by international agreement. There would be great difficulty in sharing this band with mobile radio. Undeterred Mr. Brinkley asserted that frequency sharing with TV broadcasts had been successful in America in three densely populated areas. The situation in the U.S.A. is somewhat different to the U.K. in that densely populated areas in the U.S. are more widespread than in this country. These areas are each served by a large number of relatively low-power transmitters. Therefore there would be little likelihood of interference from a mobile operator sharing the frequency of a TV station located several hundreds of miles away, but unused in his own area.

In the U.K. on the other hand, an attempt is made to saturate the whole island with television signals, with most of the area covered by 8 high-power transmitters.

Users as a whole, however, cannot be unaware that v.h.f. television Bands I and III may be phased out of use for the existing programmes and the two broadcasting organizations are expected to present a convincing case for retention of the v.h.f. bands for broadcasting before their charters come up for renewal in 1976. Otherwise industry will have its sights firmly fixed on this substantial sector of the frequency spectrum. The threat by mobile radio to amateur frequencies was pointed out in "World of Amateur Radio", in the July issue.

The conference posed the question, whose need is greater, mobile radio or television? That which may not necessarily have to be made because several delegates spoke of new technologies, or the updating of old ones, which can provide a greater number of effective communicating channels within the existing frequency allocation. There is, for example, the possibility of reducing the u.h.f. channel spacing (currently 25kHz) to 12.5kHz. This would virtually double the number of available channels but an increase in noise would result from a reduction in deviation ratio.

Frequency modulation is in general used on u.h.f. but systems might be improved by changing the modulation characteristic. E. W. Crompton of the Home Office (police and fire services) described work his department was currently carrying out on double sideband diminished carrier amplitude modulation (d.s.b.d.c.m) which has the desirable feature of concentrating most of the transmitted energy in the sidebands and not in the carrier as with conventional a.m. and f.m. A more complex detector than the simple diode demodulator would be required but the post detector circuits could be relatively simpler than in the conventional reciprocal rectification. He had played a tape recording of speech from the output of a d.s.b.d.c.m receiver with a 1kHz signal input. Noise was virtually absent but the intelligibility of the speech left much to be desired. Mr. Crompton postulated that more than one information channel could be accommodated in a single transmission by quadrature modulation of a subcarrier, in the same way that colour TV systems carry chrominance information, and the use of synchronous detection.

A system was described for dialling from a vehicle into a private telephone exchange and another for using the mobile radio as a data link. This latter can provide information on the location of up to 1000 vehicles by a hyperbolic system employing four fixed stations disposed round the vehicle movement area. By measuring the phase shift of a 2.7kHz audio tone and collecting 600-2700 -band data in a small computer at the base terminal, the system is capable of giving the positions of up to 2000 vehicles per minute.

1 Macario, R.C.V. "How Important is Detection" Wireless World, April 1968.
Electronic Building Bricks

5. The electronic circuit

by James Franklin

In order to transmit and process information, say in a television set or a computer, we must provide means for moving the electrons which we are using to represent the information. In Part 3 we looked at the general nature of this movement—conduction. The medium most widely used for electron conduction is one in which the process can take place most freely—a metal—and which is also reasonably cheap, which means copper. A path for electron conduction is called a circuit, and the simplest form of electronic circuit is a continuous loop of wire as shown at Fig. 1. Almost all "electronic building bricks" are elaborations of this.

To cause the free electrons in a conducting path such as Fig. 1 to move, circuit, 2 volts will move twice as many electrons in a given time (cause twice the current to flow) as 1 volt. There is a very precise scientific definition of the volt, but most people know from experience the relative strengths of different "voltages" by what can be "driven" by them—41 volts from a torch battery, 9 volts from a transistor radio battery, 12 volts from a car battery, 240 volts from the electricity supply mains—and these give some practical idea of the e.m.f. presented by the volt. (Anything above about 50 volts will give you a nasty jolt!)

Fig.2(a) shows how a source of e.m.f. is inserted into the Fig.1 circuit to cause the free electrons in the metal to move. The insertion of the e.m.f. source breaks the loop of wire, but the electrons flow through the source, as indicated by the dotted lines. We may also insert some electronic component or device in the circuit, as indicated. The flow-rate of electrons (current) in the whole loop containing the e.m.f. source and the component can be measured by inserting a meter as shown at (b)—and, of course, to allow the current to continue to flow this meter must not break the circuit. Such a meter for measuring current will be calibrated in amperes (Part 3) or, for small currents, milliamperes (thousandths of an ampere).

As will be seen from other articles in Wireless World, circuits are normally drawn in a simplified form by the use of symbols. To draw the physical form of the wires and components, as was done in the early days of radio, would be extremely laborious for the more complex circuits, and in any case is unnecessary, except sometimes as an aid to the construction of equipment. All the essential information about the functioning of electronic circuits and systems—and this is what we are really interested in—can be given in the simplified, generalized form known as a theoretical circuit diagram (or just "circuit diagram"). Thus the simplified form of Fig.2(b) is shown at Fig.3. It will be seen that this takes no account of the physical size or shape of the wire, the source of e.m.f. or the meter. We have a generalized representation that could mean any type of conductor (e.g. areas of metal film), any type of e.m.f. source (battery, rotating generator, thermo-electric device, electrostatic machine) and any shape or size of meter. Thus with the removal of non-essentials, our attention is concentrated on the functional aspect.

It will be seen that diagram Fig.3 contains some extra information, the + and — signs on the e.m.f. source. Without going into the full meaning of electrical "positive" and "negative", it is sufficient to say at this point that these signs on this particular source indicate (a) the direction in which the electrons are made to move round the loop by the e.m.f. and (b) the fact that this direction is always the same. A source of e.m.f. producing such a uni-directional current is called a direct-current (d.c.) source—a practical example is a battery—and the positive side of this source is identified as that towards which the electrons travel.

Another type of e.m.f. source used in electronics causes the electrons to flow alternately in opposite directions. This type of flow is called alternating current (a.c.), and the theoretical circuit symbol used to represent an a.c. source—which might be a power-station generator or a laboratory testing instrument (oscillator)—is shown in Fig.4.

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1 Named after Alessandro Volta, (1745-1827), Italian physicist and inventor of the electric battery, which was originally known as a Voltaic pile.
Personalities

Professor A. L. Callen, O.B.E., Ph.D., D.Sc. (Eng.), Pender professor of electrical engineering, University College, London, is to receive from the Paul Instrument Fund Committee the sum of £10,717 over three years for the construction of a wide-band microwave impedance bridge of high accuracy, using a new and very precise absolute impedance standard. Professor Callen, who graduated at Imperial College, London, in 1940 and was for six years at R.A.E. Farnborough, occupied the chair of electrical engineering at Sheffield University from 1955 until his appointment to University College in 1966.

George Millington, M.A., B.Sc., F.I.E.E., who recently retired from the Marconi Company, has been appointed consultant to the Director of Radio Technology of the Ministry of Posts and Telecommunications. Mr. Millington is well known for his studies of radio-wave-propagation phenomena and was at one time international vice-chairman of the C.C.I.R. study group investigating the problems of ground-wave propagation. A graduate of Clare College, Cambridge, he joined Marconi's in 1931 and headed the company's propagation section for many years.

W. F. Hawes has been appointed general manager for marketing by Pye Telecommunications Ltd. Mr. Hawes, who is 49, was formerly overseas marketing manager and succeeds J. C. Turnbull who has become managing director of the recently formed Pye Business Communications Ltd.

Alec Kravis, O.B.E., who is 51, has been appointed sales manager of the Radio Communications Division of Marconi Communication Systems Ltd. He has been with the Marconi Company since 1950 and was at one time project co-ordinator in Research Division for advanced communication and radar projects. In 1964 he was appointed project co-ordinator for space communication studies, and when Marconi

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won the contract for the first British military satellite communication stations Mr. Kravis was made project manager. After the completion of this project he became manager of administration and technical services in the Research Division, and since 1967 has been in the Computer Division, as deputy manager.

Donald W. Morrison, B.A., who joined the Sprague organization earlier this year as special assistant to G. V. Tremblay the president of Sprague World Trade Corp., has been appointed managing director of Sprague Electric (U.K.) Ltd, of Yiewsley, Middx. From 1960 to 1967 Mr. Morrison was director of marketing and general manager for the Far East of A.M.F. International after which he spent two years as regional manager for Europe with the American Air Filter Co.

Alan Hall has joined Marconi Communication Systems Ltd as sales manager of the Specialized Components Division at Billericay, Essex. After studying at Sheffield University Mr. Hall, who is 45, served in the Royal Signals from 1945 to 1948. He worked as a sales engineer with Solarton Electronic Group and with Microwave, then as assistant to the technical manager in the Electronic Component Division of Johnson Matthey at Burslem, and latterly as sales manager for Oxlaby Developments Co. Ltd, of Ulverston, Lancs, Mr. Hall is an amateur radio transmitter using the call G3UWA.

The appointment of John S. Walker as managing director is announced by Cosmocord Ltd, of Waltham Cross, Herts, manufacturers of Acos electro-acoustic products. Mr. Walker has been associated with the electronics industry for nearly 20 years. He was until recently with De La Rue Instruments, before which he spent 10 years with Texas Instruments Ltd, where he was in turn responsible for the application laboratories and for research and development.

Ernest M. Hickin recently joined Microwave Associates Ltd where he is now responsible for co-ordinating all the technical activities of the Luton-based subsidiary of Microwave Associates Inc., of Burlington, Mass. Mr. Hickin was previously for six years with GEC-AEI Telecommunications Ltd at Coventry as chief radio engineer, Transmission Division, having earlier been responsible for transmission research at the GEC Hirst Research Centre, Wembley. He is vice-chairman of the I.E.E. South Midlands Electronics & Control Section.

J. D. Rhodes, B.Sc., Ph.D., an authority on microwave selective linear-phase filters, has been appointed design consultant to the Valve & Microwave Group of Ferranti Ltd at Dundee, Scotland. Dr. Rhodes, who is 26, is a lecturer in the Department of Electrical and Electronic Engineering at Leeds University, where he graduated and obtained his doctorate. He then spent one year as a post-doctoral fellow before going to work for Microwave Development Laboratories Inc., Natick, Mass., U.S.A. There he was engaged upon general research and development into microwave techniques with the emphasis on linear-phase and elliptic function filters. During 1969, Dr. Rhodes returned to Leeds to take up his present post at the University.

J. E. Diggins, M.B.E., who joined Racal in 1963 as an electronics engineer at Bracknell, is appointed deputy managing director of Racal-BCC Ltd, the largest company in the Racal group. In 1966 he headed a team of engineers whose task was to develop a new h.f. mobile radio-telephone. The project was so successful that a separate company was formed, named Racal-Mobilcal Ltd, and production transferred to a new factory in Reading. E. T. Harrison is managing director of Racal-BCC Ltd, in addition to being chairman and managing director of the

Group. Following Mr Diggins appointment G. J. Lomer has become general manager in addition to being technical director of Racal-Mobilcal Ltd. D. C. Elsberry, formerly chief inspector and quality assurance manager of Racal-BCC, Bracknell, becomes production director of Racal-Mobilcal and E. Phillips, formerly production manager of Racal-Mobilcal becomes chief inspector and quality assurance manager of Racal-BCC Ltd.

The appointment of J. O. M. Jenkins, M.Sc., as applications engineer for digital integrated circuits is announced by Siliconix Ltd, of Swansea. After graduating in electrical engineering at the University of Swansea, Mr. Jenkins, who is 30, went to the Steel Company of Wales in 1961. In 1966 he relinquished his appointment to study for his Master's degree at Cranfield Institute of Technology following which he joined Mullard, Southampton, to work on the development of integrated circuits.

James A. Scott, appointed sales manager of K. W. Electronics Ltd., Dartford, Kent, was previously assistant to the sales manager of the radio navigation ails division of Standard Telephones & Cables Ltd. After studying at Oxford Technical College Mr. Scott, who is 41, joined the Scientific Civil Service at the Atomic Energy Research Establishment at Harwell. Following transfer to the Overseas Civil Service he held executive positions in the security services radio branch and in the civil aviation department in Kenya, until the independence of that country. He held another appointment in Kenya, and now operates in this country with the call G3CMI.

J. R. Tillman, D.Sc., Ph.D., M.I.E.E., deputy director of research at the Post Office Telecommunications Headquarters, London, has been appointed a visiting professor in the Department of Electrical and Electronic Engineering of the City University, London. Dr. Tillman joined the Post Office Research Station in 1936 and was appointed deputy director of research there in 1965.

B. A. Pain, B.Sc., is appointed managing director of Booker Bowmar Ltd and its subsidiaries Reliance Controls Ltd and Bowmar Instruments Ltd. A graduate of California State Polytechnic College, Mr. Pain, who is 37, has relinquished his appointment, operations manager with Spectral Electronics Corp., of Southern California. He succeeds L. M. Butler who has gone to California to become president and general manager of another Bowmar company.
The whole equipment has been built into a standard case (Olson Type 75B) with the power supply assembled on the back panel (4½ in x 1½ in). This was mounted at one end on a hinge so that it could be opened out, but this proved to be quite unnecessary and would not be done in a second model. It is mentioned merely because the hinge may be evident in some photographs.

All other parts are mounted directly or indirectly on the front panel, which is of the same size as the back panel. Connection between the two is made by an 8-way cable terminated by an 8-way connector. Another identical connector is screwed beneath the box which contains the marker oscillator and the two joined together by short lengths of No. 16 wire. The cable is long enough to enable the front unit to be withdrawn from the case and turned over, and it can then be disconnected by slacking off eight screws.

In this way good screwed connections are obtained and, by using two connectors, there is no possibility of making wrong connections on rejoining them as there would be if wires were disconnected independently.

Components are not critical and an indication is given of a supplier of certain parts which have been used in the model described. Only one component is really important—the Motorola 1N5145—and this was obtained from Celdis Ltd. (37/39 Loverock Rd., Reading, Berks, RG3 1ED). The photographs show most of the constructional details. The marker oscillator is built on a piece of plain Veroboard with a 0.1-in matrix of holes and measuring 2½ in by 2½ in. The variable capacitor used (Home Radio type VC20, Jackson U101/SS, 25pF) is a split stator type of 25pF each half; only one half is used. It is screwed to the Veroboard, on which the other parts are mounted in the usual way. A long 6BA screw for mounting to the box is fixed in each corner of the board and nuts are run on, not only to fix the screws to the board but so that the spacing of the underside of the board from the case can be adjusted.

The screening case for it is a metal box measuring 3½ in x 3½ in x 2½ in (Home Radio Type 127). This must have four holes drilled in its bottom to take the four screws from the Veroboard. A ½-in hole must be drilled in one side as a clearance hole for the capacitor shaft extension and in the same side four 6BA holes for the screws by which the box is attached to the front panel. It is mounted with spacers so that the box lies ½ in behind the panel. It is desirable to tap the holes in the side, since this saves getting nuts on to the screws in rather awkward positions. An extension of the capacitor with the usual metal coupler inside the screening can.

A further hole in the bottom is fitted with a grommet to take two power-supply leads and the twisted pair for the r.f. output. One connector is screwed to that side of the can which is at the bottom when it is mounted on the front panel.

The main assembly is on a piece of plain Veroboard, again with a 0.1-in matrix of holes and measuring 3½ in x 6½ in. It is held to the panel by brackets. The layout is not critical but all connections within a tuned circuit should be kept short.

Printed circuits do not lend themselves to all well to development work and instead we used plain Veroboard with Cir-Kit for "wiring", for it permits easy alteration. It proved very successful, and we retained it in the final model. Cir-Kit comprises copper strip and is available in widths of ½ in and ¾ in. It is coated on one side with an adhesive and a paper backing to prevent it from sticking together. A piece of the required length is cut off the roll, the backing paper is peeled off and it is placed on the board in the required position and pressed firmly down. The ½ in was used only for the earth, 17V and 70V lines, the ¾ in being used for everything else.

It works very successfully as long as there is no push or pull on it which tends to separate it from the board. A component on the top of the board, therefore, should not be spaced from the board but should rest on it and its leads should be bent over flush with the board on the under side, so that the component and its leads tend to clamp the Cir-Kit strips to the board. It is wise to let a lead cross the copper strip and project a little on the other side. If it should be necessary to remove a component a knife blade can then be slipped under the projecting wire while the soldering iron is applied and the lead bent up without disturbing the copper strip.

The adhesive softens with heat and this can cause trouble when unsoldering a lead from a very small piece. It is then sometimes easiest to pull out the copper strip while it is hot and replace it with a new piece.

Connecting leads and any components on the under side of the boards should be
attached only at places where the leads from parts on the top of the board are providing a firm anchorage for the strip to the board. In other places, a connecting lead should be anchored to the board by enlarging two holes, passing the lead through one from bottom to top and then through the other from top to bottom.

It is worth while to check all components before mounting them, including semiconductors. Using the Model 8 Avometer on the ohms range most diodes and base-emitter junctions show from about 400 Ω to 2k Ω in the forward direction and appear to be open-circuit in the reverse direction. Other ohmmeters may give very different resistance values, but as long as the resistance in the forward direction measures much less than in the reverse direction there is a presumption that all is well. This applies to zener diodes as well as ordinary types, and also to the varactor diode.

**Setting-up**

Until further notice the vision-sound switch is to be in the vision position. No i.f. amplifier need be connected. Connect a voltmeter across R11. Turn R22 for zero a.c. drive to TR. Check that as R20 is rotated the voltage across R11 can be varied from almost zero to 70V. Set R20 for about 20V.

Disconnect the voltmeter and connect the c.r.o. between earth and the junction of R6, R10 and D3. Turn up R22 to apply a.c. drive to TR. Use the linear timebase of the oscilloscope and synchronize it to the waveform (50Hz). The waveform should at first appear sinusoidal but, as the amplitude increases, it should more and more tend to very rounded positive half cycles with peaky negative half cycles. If the amplitude is too great or the bias on TR3 is wrong, or both, there will be flats on the bottoms of the negative half cycles. This occurs when D3 conducts it and it shows that the safety circuit is functioning. Adjust R20 and R12 for the maximum possible amplitude of the waveform without overloading. This will be about 50V p-p.

It is important to realize that the oscilloscope is connected to a high impedance point (about 0.4 MΩ) with the result that unless the oscilloscope is of much higher impedance the voltage measured by it will be a good deal less than the true voltage. If R is the input resistance of the oscilloscope, the voltage indicated by it should be multiplied by 1 + 0.4/R. We used an oscilloscope of 1MΩ input resistance and measured on it a maximum of 38V p-p, making the true voltage 53V approximately.

Connect the c.r.o. to the "Output to c.r.o. Y-amp" socket and set its Y sensitivity to about 1V, or a little less, for full vertical deflection. Connect its X-input to "Output to c.r.o. X-amp" socket. Connect the signal generator to "Input from s.p.". The signal generator should have an open-circuit output impedance of 75Ω and an open-circuit output of at least 200 mV. Set it at full output at 36.5MHz. Turn R19 to maximum. Set the internal marker oscillator control so that the variable capacitor vanes are fully unmeshed. Set the core of L4, so that its top is a little below the top of the former.

There may now be visible on the trace anything from none to three markers. If there are three the largest will usually be from the internal marker oscillator and the next from the signal generator. This may be checked by adjusting their controls independently; the markers will then move along the trace independently. The third marker is much smaller in amplitude and is always about half-way between the other two. Also it moves when either of the other markers is moved and in the same direction, but at half the rate. It arises because a frequency equal to the sum of the two marker frequencies is generated in the D4 circuit and it beats with the second harmonic of the wobbly oscillator. Its frequency is precisely half way between the two marker frequencies and it is useful in adjusting for linearity, for this third marker should be precisely half way between the other two markers on the trace.

For the moment we are concerned only with the marker at 36.5MHz provided by the signal generator. If it is not visible adjust R20 to bring it on to the trace, and in any case adjust this control to bring this marker as nearly to the centre of the race as possible.

Unless the phase adjustment is by chance set correctly, each marker will be double. Adjust "Phase" to make the markers on the forward and return sweeps coincide.

Check that increasing the marker frequency makes the marker move along the trace to the right. If it moves to the left, reverse the leads to one of the 7-V transformer secondaries.

Adjust the signal generator towards 30.5MHz while watching the trace. The marker may disappear from the left-hand end of the trace before this frequency is reached or it may not have reached the end at this frequency. In either case adjust R20 to bring the 30.5-MHz marker precisely to the end of the trace. This is when the end of the trace comes to the middle of the marker, so that only half of the marker is visible.
Now turn the s.g. towards 42.5MHz. There are now several possibilities. The marker may disappear beyond the right-hand end of the trace at some frequency above 42.5MHz. If it does this readjust $R_{19}$ and $R_{22}$ so that when the s.g. is set in turn to 30.5MHz and 42.5MHz the marker is precisely on the left and right hand ends of the trace respectively.

If the marker stops before 42.5MHz is reached, it may still be possible to make it reach the end while still keeping 30.5MHz at the other end, just by adjustment of $R_{19}$ and $R_{22}$. More likely, however, the third possibility will be that the marker will stop before 42.5MHz is reached but, while its left-hand half will be undistorted, its right-hand half will be drawn out into an oscillation for the rest of the trace. If this happens unscrew the core of $L_t$; a little and repeat the process.

Having obtained a sweep covering 30.5MHz to 42.5MHz, calibrate the internal marker oscillator against the signal generator. It is sufficient to do this in 1-MHz steps. It is convenient to use the blank half of the dial with the slot of an adjacent screwhead as an indicator, and place a pencil mark on the dial for each calibration point.

Set the s.g. to the required frequency and turn the dial of the marker oscillator to superimpose its marker on that provided by the s.g. When the two are nearly equal in frequency a low-frequency oscillation will appear right across the trace and it will disappear at a very critical setting. This is that the marker will stop before 42.5MHz is reached but, while its left-hand half will be undistorted, its right-hand half will be drawn out into an oscillation for the rest of the trace. If this happens unscrew the core of $L_t$, a little and repeat the process.

The calibration is easily checked in this way at any time, and if the marker is needed at any frequency in between the calibration points it can be set there by reference to the s.g. When the marker is calibrated, the setting up procedure is very much easier because a marker can be set at each end of the range, and it is unnecessary to be continually turning the signal generator from one end of the range to the other, possibly by a tedious slow-motion control.

Set the internal marker oscillator so that its marker is off the trace. Set the s.g. to 36.5MHz and adjust the core of $L_t$ for maximum amplitude of the marker. Check that the amplitude is about the same at 30.5MHz and 42.5MHz and is about 70% of that at 36.5MHz. Readjust the core if the amplitudes at the two ends are not almost the same. The adjustment is not critical.

The next step is to check the linearity. This is done with the aid of the third marker set in the s.g. and the internal marker to 30.5MHz and 40.5MHz and see that they lie precisely on the two ends of the trace; slight readjustment of $R_{19}$ and $R_{22}$ may be needed because of temperature drift. Measure the distance of the small centre marker to each of the two end markers. The two distances should be the same. If they are not adjust the core of $L_t$ very slightly and readjust $R_{19}$ and $R_{22}$ and measure the distances again. If the distances are more nearly equal continue adjusting the core in the same direction, each time readjusting $R_{19}$ and $R_{22}$ until they become equal. Of course, if the first adjustment to the core makes matters worse, it needs adjusting the other way.

As an example, it was found in one instance that the distance of the centre marker to the left was 35 arbitrary units, whereas the distance to the right was 32 units. About one turn only of the core was needed to bring the distances to equality.

The wobbulator is now set up on vision and can be used with an i.f. amplifier to depict its response curve. Proper alignment of the vision amplifier with its trap circuits must be achieved before any attempt is made to align the inter-carrier sound channel.

There are certain traps for the unwary in doing this. The first is a short-circuit on the mains supply! Never for one moment forget that the normal television receiver is live to the mains. To avoid the risk of shock, damage to equipment and even to obtain proper operation of equipment, there is really no alternative but to use a double-wound 1:1 ratio mains transformer to feed the television set. It is certainly the only safe thing to do. Otherwise the i.f. strip must be removed from the set and operated from a separate power unit containing a transformer.

Most television sets are designed to operate with the video detector giving an output of 2V to 4V. Care should be taken to see that the peak-to-peak output with the wobbulator is of this order. However, the input from the wobbulator must never be so great that overloading occurs. It is essential that the connection of the video output to the wobbulator should not cause feedback in the i.f. amplifier. A well-screened lead is necessary and it is sometimes better to take the output from a video stage than from the detector itself. In the case of the Wireless World Colour Television Receiver it was found to be best, and certainly most convenient, to use the sync separator feed. This is a long screened cable which plugs into the sync separator board, and so it can just be unplugged and plugged into the wobbulator. The r.f. output from the wobbulator must be by coaxial cable and its length

General view of the power supply unit.

Here the markers are at 34MHz and 40MHz and half way between there is a very small marker at 37MHz. This arises from the sum of the main markers (74MHz) beating with the second harmonic of the wobbly oscillator.

Taking the output from the luminance delay line of the W.W. Colour Television Receiver results in an inverted trace.

The normal input coupling time constant of the oscilloscope is 0.25 sec. These photographs show the result of reducing it, at (a) to 0.04 sec and at (b) to 0.001 sec. Notice the double trace in the vertical direction in (a) and the gross distortion in (b).
should be as short as possible. It is not practicable to match the cable perfectly at each end. At mid-band only about 4ft. of cable is needed for a quarter-wave section. It is well, therefore, to arrange the apparatus so that the cable is no more than 2ft. long if possible. It is not often practicable to feed into the tuner of the television set, so that the first i.f. circuit, which is normally in the tuner, can be in circuit. It is useful, therefore, to have a dummy tuner built to the circuit of Fig. 1 to connect the wobbulator to the i.f. strip. The cable from the dummy tuner to the i.f. strip must, of course, be the same length as that from the real tuner to the i.f. strip in the receiver.

Very often additional attenuation to that provided in the wobbulator will be needed. This is conveniently obtained from Belling Lee coaxial attenuators, which are available with attenuations of 3, 6, 12, 18 dB; they plug into each other and to the normal cable plugs and sockets. It is particularly convenient to have three 6-dB (L729/6) types available. Whenever possible one should be between the wobbulator and the dummy tuner. This is the point at which the cable has its greatest mismatch, because of the tuned circuit in the dummy tuner, and this mismatch is greatly reduced by introducing an attenuator at this point. Even when there is sufficient range on the internal attenuator, it may pay to include a 6-dB attenuator at the cable end, and use a step or two less internal attenuation.

For the sound channel the overall picture including the discriminator is obtained by feeding the a.f. output of the sound detector to the "Input from i.f. amplifier" socket. For the alignment of the early circuits, however, it is advisable to make up an a.m. detector to the circuit shown in Fig. 2 and to take the output from this. It is connected to the collector of the last sound i.f. transistor, for instance.

To operate the wobbulator on sound, set the vision sound switch to sound. Set the s.g. to 39.5MHz, and then set the marker oscillator to zero beat with it. This can be done even if there is no visible marker on the trace, because near the proper setting the low-frequency beat between them extends over the whole trace. It is necessary to do this because the calibration of the marker oscillator does not hold when it is switched to sound. It produces 39.5MHz when it is set roughly to the 40.5-MHz calibration point. If one wishes one can put on a special 39.5-MHz point for sound, but it is so easy to set the marker against the s.g. that it seems unnecessary. The change occurs because there is a change of loading on the marker oscillator between the two positions of S1.

Turn the "Mid-band frequency control" R20 fully clockwise (if it is wired so that on vision a clockwise rotation shifts a response curve to the right) and then gradually back until the sound response curve appears. This is the correct one. If it is turned further another of less amplitude will appear, and if one goes on turning others will come into view, and there may even be several overlapping ones. The first and, usually, largest is the proper 6-MHz inter-carrier beat between 39.5MHz and 33.5MHz in the vision i.f. detector. The second occurs between 39.5MHz and 36.5MHz, when the separation is 3MHz, and it is the second harmonic of this produced in the detector which passes through the sound i.f. amplifier. The others occur for separations of 2MHz, 1.5MHz, 1.2MHz, 1MHz and so on, with the third, fourth, fifth and sixth harmonics.

By adopting the above procedure the right setting is easily found and the spurious responses cause no trouble. Notice, however, that the proper response will not always be the largest. If the sound trap in the vision i.f. amplifier gives more attenuation than usual, the second response may be larger than the proper one.

On both vision and sound an increase of marker frequency moves the marker to the right. On vision a clockwise rotation of R20 moves the response curve to the right on the trace, but on sound it moves it to the left. This could be avoided by extra switch contacts to reverse the leads to R20 but did not seem worth while. Temperature drift is normally to the left on vision and to the right on sound.

One thing must not be overlooked. It is usually necessary in some way to put out of action any a.g.c. system of the amplifier under test and the way of doing this will depend on the receiver design.

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**Coil data**

Details of windings: L1 10t; L2 10t; L3 1t; L4 14t; L5 1t; L6 2t; L7 10; and L8 2t.

Formers are Neosid 722/1 with terminal bases 5027 and Neosid long screw cores 4 x 0.5 x 12.7. The former diameter is 0.8 in. with an available winding length of 7 in.

Except L8, all coils are wound with No. 24 enamelled wire; L4 is wound with No. 32.

In every case the start of the main winding is next to the point for sound, but it is so easy to set the proper frequency coverage from being obtained.

The pin spacing of the bases does not fit the hole spacing of Veroboard. It is advisable, therefore, to make a metal-template so that the Veroboard can be drilled in spite of the existing holes. The base is fixed to the board by putting small washers or loops of wire around four of the pins and soldering.
A YIG Radiometer and Temperature Controller

Solid-state device for temperatures of 100-250°C

by I. J. Kampel*

The radiation pyrometer or radiometer provides a convenient way of measuring surface temperature where more conventional sensing elements may not be employed. The system to be described also utilizes an experimental solid-state optical modulator—the YIG—and in so doing eliminates the bulky and inconvenient motorized chopper unit normally associated with such systems. Use of this new electro-optical component therefore answers the need for a sensing head requiring no maintenance, and provides a rugged, miniature solid-state construction.

All bodies emit electromagnetic radiation, the amount of radiant energy being dependent upon their temperature and emissivity. The maximum theoretical emission at any temperature is given by a black-body radiator, and the "emissivity" factor determines the ratio of emittance by a body to the emittance of a black-body at the same temperature.

The Stefan-Boltzmann law states that the total spectral emittance of a black-body is directly proportional to the fourth power of its absolute temperature. The radiometer—or radiation pyrometer—utilizes this principle. Emitted radiation is measured, and this is then equated to source temperature. A control is normally provided to allow for emissivity factor corrections.

While the disadvantage of temperature measurement by radiometer lies in the need for approximate evaluation of source emissivity, the system does offer unique advantages over more conventional techniques. The infrared sensing element represents the perfect measuring transducer: it in no way affects the object being measured since it is non-contacting. This particular versatility also allows the remote measurement of moving bodies. As measurement is by means of a photoelectric as opposed to the more common thermoelectric principle, a fast response may be realized. Many control systems do not require an absolute temperature indication, and in such cases the controller may be used without prior determination of source emissivity.

For accuracy, and the convenience of a.c. amplification in radiometer systems, it is normal to chop the incoming radiation with a rotating segmented chopper-disc. The size of such a disc with its associated driving motor has necessarily led to rather bulky sensing heads in previous equipments, however the YIG solid-state optical modulator removes such size restrictions. The total absence of all moving parts has also eliminated the need for servicing.

YIG Modulator

Unbalance in electron spin of inner orbital electrons induces a magnetic moment in a crystal of yttrium iron garnet (YIG); it is therefore said to be ferrimagnetic. Magnetic domains of identically orientated magnetic dipoles form and take up a natural alignment. These domains exhibit Faraday rotation; in the presence of a magnetic field the plane of polarization of transmitted plane-polarized radiation is rotated through an angle proportional to the magnetic field strength. Faraday rotation is also proportional to path length through the material, and is inversely proportional to the wavelength of radiation.

The high transmission of YIG in the spectral range 1.1-4.5µm is enhanced by the use of an anti-reflection coating. Its usefulness is limited by the rapid deterioration in Faraday rotation with increasing wavelength. The polarizing material normally employed in the modulator also limits the spectral response to about 2.3µm. Lead sulphide is the most suitable detector material to employ in radiometric applications due to its similar spectral response characteristic.

*Mallard Ltd.
Current passing through a coil situated around the material provides the required magnetic field, with lines of flux lying parallel to the path of the traversing radiation. A square-wave current drive provides a suitable modulation of the plane of transmitted plane-polarized radiation, and by further passing this radiation through another polarizer—known as the analyser—an intensity modulation is derived. This principle is illustrated by Fig. 1.

A sectional diagram of the sensing head is shown in Fig. 2. Overall dimensions are 2cm diameter by 3cm length.

A glass lens is used to focus incident radiation on to the element of a 139CPY chemical lead sulphide detector. In the path of this radiation is situated an experimental YIG modulator; this was housed within a modified Ferroxcube transformer pot core which served to provide a low reluctance path for external flux, so minimizing direct electromagnetic pick-up at the detector. Polarizer and analyser are located on the outer faces of this housing.

The plane of polarization of the analyser is situated at 45° relative to the polarizer. This requires a ± 45° rotation of the plane-polarized radiation for full theoretical modulation, and this is approached by employing a true a.c. drive current in the YIG coil. A greater modulation depth for a given drive power may be achieved with this method than by any other.

System description

Output from the radiometer takes the form of a moving coil meter; output from the controller may either be a simple audible warning, or a change-over relay, but various operational modes may be selected to give this considerable flexibility.

A chemical lead sulphide detector was employed since this had a suitable spectral response, and was available in the small size of a TO-5 encapsulation. The system to be described is suitable for a black-body temperature range of 100-250°C, covered by two ranges; the addition of higher temperature ranges would be straightforward. An emissivity control covering the range e=0.1 to e=1.0 was provided.

Two integrated circuits are used to modulate the YIG coil with a true a.c. square-wave current at a frequency of 400Hz as shown in Fig. 3. This frequency is sufficiently high to avoid mains pick-up problems, and low enough to allow optimum performance from a lead sulphide detector having a somewhat slow response.

A quadruple NAND gate (FJH131) is interconnected to form a square-wave generator, where external 1-μF capacitors set the periods as in a conventional multivibrator. Since the resistive component of the time-constant is contained within the integrated circuit, however, this is liable to production spreads and will introduce some spread in frequency. (See Fig. 3).

A dual buffer gate (FJH141) provides the required current drive to the YIG coil. The coil is d.c. coupled and driven in push-pull mode. The voltage amplitude from this integrated circuit is also dependent upon production tolerances, and R_p is adjusted on test to give a coil current of approximately 20mA (33-680 typical). A capacitor in parallel with the coil reduces the spike caused by fast current switching in the inductive load.

Modulator and detector leads should be adequately screened from one another in order to avoid pick-up problems.

Pre-amplifier Circuit

Detector resistance varies with ambient temperature. Since responsivity is approximately proportional to the square of this resistance, it is necessary to provide some correction. By biasing the detector in a constant voltage mode and utilizing the signal current, the output obtained is inversely proportional to the square of detector resistance and a much improved temperature stability is achieved.

An f.e.t. is used to provide detector bias, and was found preferable to a transistor, introducing far less current noise than the latter. The complete circuit is shown in Fig. 4. Noise from the zener diode is eliminated by decoupling the gate of the f.e.t. A second f.e.t. is used in a compound arrangement with a transistor to provide initial gain; this is also a low noise configuration. A voltage-dependent resistor in the transistor emitter allows a greater drain resistance for improved loop gain. A further gain of 10 or 100 is provided by the following virtual-earth amplifier, the gain being selected by the range switch.

![Fig. 3. Drive circuit for the YIG.](image)

![Fig. 4. Low-noise preamplifier circuit with compensatory detector bias.](image)

![Fig. 5. A simple coherent filter.](image)
A simple coherent filter is formed from two complementary germanium transistors as shown in Fig. 5. These effectively form a dynamically synchronized narrow-bandwidth filter. A gating waveform is taken from the YIG drive circuit and applied to switch these transistors in anti-phase. The output from the pre-amplifier is fed into the circuit, and is used to charge the 125-µF capacitor through one or another of the 10-kΩ resistors.

The two transistors are switched in synchronism with the signal, and earth alternate sides of the capacitor so that a d.c. charge builds up which is proportional to the signal waveform. Any noise or spurious signals present at frequencies other than the modulating frequency average to zero. An output is taken from one side of the charge capacitor for further a.c. amplification.

It is important to ensure a true 1:1 mark-space ratio for optimum performance from the coherent filter. It will be obvious that drift of the chopping frequency will in no way affect performance. The transistors are connected in an inverted manner to minimize leakage current and breakthrough of the gating signal.

An operational amplifier (TAA811) is used to provide a further stage of variable gain and an emissivity control. The configuration of Fig. 6 will provide a linear emissivity scale calibration between 0.1 and 1.0 provided that the potentiometer is truly linear (selection normally required). Voltage gain will be 100 at \( e = 0.1 \), and 10 at \( e = 1.0 \).

The radiometer section of the instrument terminates in a peak detector circuit and is shown in Fig. 7. The 1-µF capacitor charges to a d.c. potential proportional to the signal amplitude. This is fed to a moving-coil meter and provides the temperature indication. The zener diode is a protective device for the meter.

The d.c. level on the charge capacitor is also monitored by the controller circuitry. Provision is made to switch the meter to a variable d.c. potential independent of the signal: this greatly facilitates initial adjustment of the controller.

**Temperature controller**

Totally independent adjustable maximum and minimum limits are provided, and either or both may be used. In the “basic” mode, if the meter pointer crosses either limit, the relay or audible warning switches on; hence the output does not distinguish between maximum and minimum (although the meter indicator will). In the “cycle” mode, the relay or audible warning switches on when the pointer exceeds the maximum limit, and will remain on until the lower limit has been crossed.

Thus by using both limits in this mode, a cycling controller is available between preset temperatures. By using only one limit in this mode, a one-shot function is available provided that the initial state has been correctly set.

The input to the control circuit is taken directly from the output of the radiometer circuit, and responds either to a d.c. potential set by the signal waveform, or a potential manually set on the “meter-set” input from the coherent filter.

---

**Fig. 6. Main amplifier with emissivity control.**

**Fig. 7. Radiometer output circuitry.**

**Fig. 8. Temperature controlled circuitry.**
control; the latter considerably eases the accurate setting of limits.

Two integrated circuits (IC₁ and IC₂, Fig. 8) monitor the input voltage, and both their outputs will be at 0V until a limit has been crossed. When S₁ is closed the maximum limit is set by adjusting Vₓ to a suitable level. If Vₓ exceeds Vᵧ then IC₁ output rapidly switches to +30V. When S₂ is closed, the minimum limit is set by adjusting Vᵧ to a suitable level. If Vᵧ falls below Vₓ then IC₂ output switches rapidly to +30V.

With S₃ in the “basic” position, the input of IC₁ is referred to +15V. The output of IC₂ is normally at 0V. If either limit is crossed, the anode of either D₁ or D₂ will be taken to +30V, and the + input of IC₁ will follow; thus the output of IC₁ will then switch to +30V.

Hysteresis circuit

With S₃ in the “cycle” position, IC₃ forms a hysteresis circuit, and the output voltage will switch to +30V if IC₃ output goes +ve, and will remain there until the output of IC₂ goes +ve, whence it returns to 0V.

When the output of IC₁ switches to +30V, the base of the output transistor rises from 0V to a little above +15V, and either the audible warning or the control relay will operate. The choice is selected by S₂.

A second small centre-zero meter (+100μA) may be used to give a constant indication of the control state under all conditions. The pointer will be centred until a limit is crossed, and will deflect when a limit is crossed, the direction of deflection being indicative of maximum or minimum.

The picture shows the temperature of a silica tube being measured while undergoing a production process. The chopper and temperature sensor form the small unit held in the operator’s left hand and pointed at the hot part of the silica tube.

The 1970 International Audio and Music Fair, to be held from 19th to 24th October at Olympia, London, differs from previous fairs of this kind (in this country) in that there will be a programme of “presentations” sponsored largely by the audio press. The full list is given below.

It will be seen that Wireless World is sponsoring five lecture-demonstrations. Each session will be given by a well-known Wireless World author, who will relate engineering principles and procedures to the performance actually given by items of audio equipment. The lecturers will be Arthur Bailey, Peter Baxandall, Jack Dinsdale, John Linsley Hood and Ted Jordan. Tickets for each of these sessions will be available at the Wireless World stand at the Fair on the day of the lecture.

**Tuesday, 20th**

2.0 Types of recorded sound quality
by John Crabbe (Hi-Fi News)
Different musical and acoustical balances to be found on modern recordings will be discussed and demonstrated.

4.0 The progression of electronic music synthesizers
by Dr. Robert A. Moog
The inventor of the Moog Synthesizer will demonstrate the instrument used for the famous “Switched on Bach” LP.

6.0 The heart of hi-fi
by J. Dinsdale (Wireless World)
The important features of modern amplifier circuitry and specifications will be explained and demonstrated.

8.0 Cassettes and cartridges
by W. Woyda (Precision Tapes)
Cassette and 8-track cartridge formats will be described in detail and several recently released recordings will be played in both media.

**Wednesday, 21st**

2.0 Power levels, distortion and the enjoyment of music
by P. J. Baxandall (Wireless World)
The inventor of the Baxandall tone control will discuss the technical requirements of hi-fi equipment and relate them to musical enjoyment.

4.0 How good is your gramophone?
by John Borwick (The Gramophone)
The lecturer will play a selection of records and suggest how these can be used to assess the performance of record reproducing equipment.

6.0 Both sides of the record
by Joan Coulson (EMI Records)
All kinds of music on record with glimpses behind the scenes.

8.0 The progression of electronic music synthesizers
by Dr. Robert A. Moog (See Tuesday)
Thursday, 22nd

2.0 From cylinders to 78s to today
by G. Child (formerly of Decca Records)
A short history of the gramophone record with a display of vintage players and examples of records old and new.

4.0 Audio facts and fallacies
by A. R. Bailey (Wireless World)
The well-known designer examines hi-fi ideas and terminology.

6.0 Personal appearance of Sir Arthur Bliss
The Master of the Queen’s Musick will introduce excerpts from the first recording of his “Pastoral” and “Knot of Riddles” to be issued in October by Pye Records.

8.0 Stereo for beginners
by Clement Brown (Hi-Fi Sound) A simple introduction to the subject of stereophonic recording and reproduction.

**Friday, 23rd**

2.0 Cassettes and cartridges
by W. Woyda (Precision Tapes)
(see Tuesday)

4.0 How good is your gramophone?
by John Borwick (The Gramophone)
(see Wednesday)

6.0 Little and good
by J. L. Linsley Hood (Wireless World)
An illustrated examination of the related subjects of power and quality in sound reproduction.

8.0 The funny side
by Donald Aldous (Hi-Fi News & Record Review) A light-hearted look at the record repertoire—"in the groove, but out of the rut".

**Saturday, 24th**

2.0 Sound sense
by E. J. Jordan (Wireless World) This well-known loudspeaker designer will talk about sound reproduction aims and play some recorded examples.

4.0 The funny side
by Donald Aldous (Hi-Fi News & Record Review) (see Friday)

6.0 Types of recorded sound quality
by John Crabbe (Hi-Fi News) (see Tuesday)

8.0 Live pop recital
presented by New Musical Express Throughout the Exhibition there will also be a programme of semi-technical films.

The well-known designer examines hi-fi ideas and terminology. A light-hearted look at the record repertoire—"in the groove, but out of the rut".
Active Filters

14. Bandpass types

by F. E. J. Girling* and E. F. Good*

It has already been shown that low-pass filters can be made up from one or more feedback loops containing integrators, simple lags, or a mixture of the two. The band-pass counterparts of both integrators and simple lags are tuned circuits tuned to the chosen centre frequency. Consequently band-pass filters may be made by substituting such tuned circuits for the lags and integrators of suitable low-pass models, and the method is described for synthesis by factors and for active-ladder synthesis. A brief discussion of stagger tuning is also given.

A symmetrical band-pass characteristic may be considered as a transform of a low-pass characteristic, and all the methods of design used for low-pass filters may be carried over into b-p filter design, the most important being (a) by factors, (b) as a ladder structure. The nature of the transformation has been described in Part 2, and if, for clarity, frequency for the l-p model is designated by the upper-case letter \( \Omega \), and for the b-p counterpart by the conventional \( \omega \), an algebraic statement of the transformation is

\[
\Omega = \frac{\omega - \omega_0^2}{\omega} = \omega_0 (\omega / \omega_0 - 1).
\]

This produces, Fig. 1, a b-p characteristic in which the bandwidth, \( \omega_1 - \omega_2 \), between any two points of equal amplitude, and of equal but opposite phase shift, is equal to \( \Omega_1 \), the bandwidth from zero to the corresponding point on the l-p characteristic. The b-p characteristic is centred on \( \omega_0 \) in the sense that \( \omega_0 = \sqrt{(\omega_1 \omega_2)} \), i.e. \( \omega_0 = \omega_0^* / \omega_0 \).

Realisation by factors

Since resolution of a l-p characteristic into 1st- and 2nd-order factors provides a basis for the design of a b-p filter as a cascade of non-interacting simpler b-p sections, transformation of the l-p factors to b-p provides a basis for the design of the corresponding b-p filter as a cascade of non-interacting simpler b-p sections.

1. 1st-order

The frequency response function for 1st-order l-p response (a simple lag)

\[
G(\omega) = \frac{\omega}{1 + j\omega / \omega_0}
\]

2. 2nd-order

The 2nd-order l-p response may be defined

\[
G(p) = \frac{1}{1 + pT (1-p)}
\]

which rearranges into

\[
G(p) = \frac{1}{1 + \frac{pT_0}{Q} \left( \frac{pT_0 + 1}{pT_0} \right)}
\]

The familiar form for "tuned-circuit" response. (\( T_0 = 1/\omega_0 \)). The transformation may be considered, therefore, to consist in replacing \( pT \), where \( T = 1/\omega_0 \), by

\[
Q \left( \frac{pT_0 + 1}{pT_0} \right)
\]

Physically this means, for example, that a differentiator (say the capacitor of a Blumlein integrator) has an integrator placed in parallel with it.

Fig. 1. Corresponding b-p and l-p responses: for any pair of points on the b-p curve and the corresponding point on the l-p curve \( \omega_0 - \omega_2 = \Omega_1 \) and \( \omega_1 \omega_2 = \omega_0^2 \).

Fig. 2. Relationship between (a) a damped tuned circuit and a simple lag, (b) an infinite-Q tuned circuit and an integrator.

Fig. 3. Misalignment of tuned circuits of different Q gives an unsymmetrical loop response, which shows in the Nyquist plot.
loop closed—although bandwidth and shape factor \( q \) are affected. In practice there may be errors in \( q \) as well as in centre frequency, but the effect of error is still likely to be more tolerable than in a loop containing one infinite-\( Q \) circuit. It appears, therefore, that the preferable 1-p model for a b-p filter is the loop with two equal lags.

The properties of such a loop have been considered in Part 4, and the important result obtained that closing the loop increases both \( q \) and bandwidth by the factor \( \sqrt{A_0+1} \), where \( A_0 \) is the loop gain at zero frequency. For two equal lags the open-loop \( q \) is \( 1/2 \). To obtain a closed-loop value of \( q \), therefore,

\[
q = \frac{1}{\sqrt{A_0+1}} = 2q
\]

i.e. \( A_0 = 4q^2 - 1 \) \hspace{1cm} (11)

and for a closed-loop bandwidth \( \omega_b = 1/T \), the open-loop bandwidth, which is also the bandwidth of the individual lags, must be \( \omega_b/2q \), i.e. the time constant of the lags must be \( 2qT \). This is shown in Fig. 5(a).

Now the bandwidth of a tuned circuit is \( \omega_0/\omega_b \). So for the tuned circuits of Fig. 5(b) to have the same bandwidth as the lags in Fig. 5(a)

\[
\omega_0 = \frac{\omega_b}{2q}
\]

i.e.

\[
Q = 2\omega_0/\omega_b \hspace{1cm} (13)
\]

It is now convenient to define a measure of the relative sharpness or selectivity of a 2nd-order band-pass circuit, \( Q \): \( Q = \omega_0/\omega_b \). \hspace{1cm} (14)

This is comparable with the definition of \( Q \) for a single tuned circuit, although now \( \omega_0 \) is the nominal bandwidth equal to the corner frequency of the corresponding 2nd-order l-p circuit, and the \(-3\)dB bandwidth only for the particular case of \( q = 1/\sqrt{2} \).

Making this substitution in eqn. (7) gives

\[
Q = 2qQ_b \hspace{1cm} (15)
\]

and substituting for \( Q \) in eqn. (6) then gives the transfer functions of the elementary tuned circuits of Fig. 5(b)

\[
G(p) = \frac{1}{1 + 2qT} \hspace{1cm} (16)
\]

Comparison with the transfer functions of the simple lags of Fig. 5(a)

\[
G(p) = \frac{1}{1 + 2qT} \hspace{1cm} (17)
\]

shows that the transformation may be considered to be the replacement of \( pT \), where \( T = 1/\omega_b \), by

\[
Q_0\frac{p (pT_0 + 1)}{pT_0} \hspace{1cm} (18)
\]

Transfer functions for corresponding 1-p and b-p 2nd-order sections may therefore be written

\[
1 + \frac{1}{q} pT + p^2T^2
\]

\[
1 + \frac{1}{Q_0} \frac{p (pT_0 + 1)}{pT_0} + Q_0^2 \frac{p (pT_0 + 1)}{pT_0} \hspace{1cm} (19)
\]

though the method of synthesis just described does not depend on explicit statement of the b-p transfer function.

The rule for 1-p to b-p transformation given above, expression (18), is only apparently different from the rule given for 1st-order sections, expression (9). By dividing by \( T = 1/\omega_b \) both reduce to the basic rule: i.e. \( p \) is replaced by

\[
Q_0 = \frac{1}{T} \frac{p T_0 + 1}{p T_0} \hspace{1cm} (19)
\]

Equation (15) and the well known relationship expressed by eqn. (5) provide the basic theory for the design of any symmetrical (all-pole) band-pass filter as a cascade of active 1st- and 2nd-order band-pass sections.

It is also worth noticing for future reference that because of the identity

\[
p T_1 \times p T_2 = T_3 \times p T_3 \times p T_3 \hspace{1cm} (22)
\]

where in the present case

\[
D_1(p) = 1 + p T_1/Q_1 + p^2 T_1^2 \hspace{1cm} (23)
\]

\[
D_2(p) = 1 + p T_2/Q_2 + p^2 T_2^2 \hspace{1cm} (24)
\]

two tuned circuits in tandem may be replaced by a low-pass circuit and a high-pass circuit also in tandem.

3. Higher-order filters

The general pattern for a higher-order filter realized as a cascade of sections designed as above is \( n \) tuned circuits all tuned to \( \omega_0 \) and connected in \( n/2 \) feedback pairs, or when \( n \) is odd \( (n - 1)/2 \) feedback pairs with one single tuned circuit. The feedback pairs form the 2nd-order sections, and the \( Q \) factors of the constituent tuned circuits and the degree of back coupling are chosen to give the required closed-loop bandwidth and \( q \) (shape factor). Similarly the \( Q_b \) of any single tuned circuits (the 1st-order sections) are chosen to give the required bandwidth.

Butterworth filters are a special case, as the nominal bandwidth of each section is equal to the \(-3dB \) bandwidth of the complete filter. So \( Q_0 = Q_b = \omega_0/\omega_b \); and for \( n \) odd the \( Q \) factor of the single tuned circuit is also equal to \( \omega_0/\omega_b \). But the \( q \) of each 2nd-order section is different, and, using eqns (15) and (12), the \( Q \) factors of
the constituent tuned circuits and the loop gains must be calculated as follows:

\[
Q_1 = 2q_1Q_p, \quad \text{loop gain} = 4q_1^2 - 1, \\
Q_2 = 2q_2Q_p, \quad \text{loop gain} = 4q_2^2 - 1, \quad \text{etc.}
\]

Thus the block diagram for a 3rd-order Butterworth filter, which needs only one feedback pair (with \(q = 1\)), may be drawn as in Fig. 6. Values of \(q\) for \(n = 10\) were given in Part 9, Table 6.

In general, however, both \(q\) and bandwidth will be different for each factor, as they are for the factors of an l-p filter, e.g. Table 8 of Part 9. The parameters \(q\) pass straight over into the band-pass design. The parameters \(T\) are inversely proportional to the nominal bandwidths of the factors \(\omega_n\), and consequently directly proportional to the band-pass parameters \(Q_B\) (or \(Q\) for a 1st-order factor). As a b-p response repeats itself on the other side of \(\omega_n\) it will show twice as many ripples as the l-p response, e.g. Fig. 7.

### 1/nth-octave filter

The bandwidth of a b-p filter is often specified as a fraction of an octave (2:1 frequency ratio), especially when it is one of a bank of filters required to divide a broad spectrum into a number of relatively narrow contiguous bands.

If the filters all have the same relative bandwidth, and the first one is centred on \(\omega_n = 1\), the nth filter will be centred on \(\omega_n = 2\), Fig. 8. Consequently

\[
x^2 = 2^2, \\
QB = x - 1 = 2^{2/2} - 1
\]

from which the figures shown in Table 1 may be calculated. The last row corresponds to one filter for each note of the equally tempered scale. Sometimes of course, the relative bandwidth is made different from the spacing between adjacent filters. This is so for B.S.3rd-octave filters, which have a band width much less than the pitch between centre frequencies.

From the first column of Table 1 the \(Q\) factors required of individual tuned circuits may be calculated via eqn. (15). Thus for 3rd-order Butterworth response \(Q\) factors equal to \(2QB\) are needed. This gives a guide to the type of circuit needed.

### Circuits

The most powerful type of active tuned circuit is the two-integrator loop, especially when high \(Q\) is needed. In its ordinary form (Parts 7 and 8) the circuit uses three amplifiers, and two circuits may be put together as in Fig. 9 to form a feedback 2nd-order band-pass section. With the usual balance of component values shown each tuned circuit gives a peak gain of \(QB\), not 1 as assumed in Fig. 5 for example. So the "gain" of the feedback path must be divided by \(QB^2\) to compensate, and unless \(Q\) is very low the feedback resistor may have an inconveniently high value. This can be avoided by using a resistor of moderate value fed from a potential divider as shown inset. It may also be helpful to make the feedback variable over a small range. This will allow some adjustment of bandwidth, although not without varying \(q\) simultaneously.

The ease with which both tuning and \(Q\) can be adjusted in a two-integrator loop can also be made use of. Thus each tuned circuit can be individually adjusted to the centre frequency, allowing components of relatively broad tolerance to be used, or perhaps the nearest preferred value. Similarly
Fig. 11. Building up a 3rd-order b-p response. On the right, corresponding l-p responses.

in a 3rd-order filter tilt in the passband can be corrected by adjusting the tuning of the single tuned circuit. If only a single resistor (or T) is varied, a is varied with a0, but for a small range of adjustment this is likely to be unimportant. In any case it is quite easy to adjust Q also.

Probably most active band-pass filters at the present time use a balanced parallel-tee network (see Parts 10 and 11). Fig. 10 shows a circuit for a 2nd-order filter which was designed for 3rd-octave bandwidth approximately. The tuned stages use the Sallen-and-Key type of connection and are arranged as low-pass x high-pass, which also usefully multiplies the forward gain by Q². An untuned input stage puts the necessary sign reversal into the loop, and allows adjustment of overall gain without affecting the tuned stages. Adjustment of the feedback is also provided, but if the required combination of bandwidth and q is not obtained the damping of one or both stages must be adjusted.

As the bandwidth is over 20% of the centre frequency, a reasonable tolerance on the time constant of the tees is ±1%. To ensure that each twin tee is well balanced, however, so that the expected value of Q is obtained, it is advisable to make each up from matched pairs of components as explained in Part 11 (June). As a b-p system is not required to pass zero frequency, the amplifiers do not need to have low zero drift; and as Q is only moderate, the internal gain need not be very high. The amplifiers can, therefore, be quite simple—though they can be high-gain types provided they will give the required output at the highest frequency with low distortion.

The attenuation of a 2nd-order Butterworth filter is given by (1 + x⁴)², where x = actual bandwidth/3dB bandwidth. So 20 dB is obtained at x = 99 = 3.155; 40 dB at x = 10 approximately.

An advantage of the parallel-tee circuit is that zeros are easily added. Thus a 3rd-order b-p filter can be built up as in Fig. 11. The 2nd-order loop contains a l-p and a h-p stage, and these are given zeros (a) and (b) by feeding a fraction of the input to the other tee (Part 11, Fig. 11) so that an open-loop response as (c) is obtained. If this is symmetrical it can be represented by the transfer function of the corresponding l-p response (d) of the form

\[ 1 + k²p²T² \]
\[ 1 + pT/2 + p²T² \]

and the amount of feedback calculated which will give a l-p response such as (e) and to the b-p circuit an "over-coupled" response (f). The hole in the middle can then be "filled up" with a single tuned circuit (g) corresponding to a simple lag (h).

A suitable model is a 3rd-order Darlington filter, Fig. 12(a). Being a symmetrical network it can be divided into two halves with Zin(1) = Zin(2) and its transfer function may be written down as \( \frac{1}{1+T} \) the product of the transfer functions of the subnetworks so formed, Figs 12(b) and (c). These are:

\[ 1 + pC R \]
\[ 1 + p^2L_L C_L \]
\[ 1 + pL_L/2R + p^2L_L(C_L + C_K)/2 \]

and can act directly as l-p models for the single tuned circuit and the 2nd-order loop of the active b-p filter, the required bandwidths and q being obtained by comparing these transfer functions with transfer functions written in standard form, \( \frac{1}{1+T} \) and \( \frac{1+T^2}{1+T^2} \) (1 + q²T²)

Parallel-tee stages can be given variable tuning (Part 11); but this usually requires extra amplifiers, and the short-circuited-output time constants of the two tees must still be equal. So the practicability of a parallel-tee filter, or bank of filters, depends very much on the cost and difficulty of obtaining accurate components for the parallel-tee networks. As the price of gain comes down, therefore, the preference is likely to go to circuits which, while needing more amplifiers, have less severe requirements for passive components.

Active ladders

The first stage in preparing a design for a band-pass active ladder filter has already
obtaining the required spread of T by the same value of C for all the integrators, by applying 11Q8, and all of the second set by the ratios of the first set of integrators may be multiplied by Ti/T0. The loop gain of the minor loop is changed from T, (say) to T0. It will still be practicable to use the linkages between the tuned circuits feeding them, which is bad for dynamic range; and the elementary tuned circuits which they form with those integrators would be likely to have a lower Q factor than need be, since if the zero-frequency gains of the integrators are equal the best performance is obtained with Ts equal.

This condition is obtained by making the T0 of each integrator = T0, and readjusting the ratios of the tuned circuits so that all loops have the same loop gain as before. If the T of one of the integrators in the forward path is changed from T1 to T0, the signal voltage at its output is multiplied by T0/T1. The loop gain of the minor loop, the elementary tuned circuit, has simultaneously been restored to its former value by changing the T of the other integrators in that group. So the ratios of bandwidth/bandwidth/centre frequency, say 1/QB; and in general equal, are all roughly equal to 1/co02. Compensation in all other paths including the T1 integrator is effected by introducing a multiplying factor T0/T1, which may in practice mean multiplying one or more resistances by T1/T0, Fig. 13.

The ratios T0/T1, T0/T2 etc., although not in general equal, are all roughly equal to 1/QB, and the ratios T0/T1, T0/T2 etc., roughly equal to QB. And, if more convenient, all the Ts of the first set of integrators may be multiplied by 1/QB, and all of the second set by QB, as this will bring them near enough to each other to give good performance. The scaling factors to be introduced into the linkages between the tuned circuits will now all be 1/QB. It will still be practicable to use the same value of C for all the integrators, by obtaining the required spread of T by variation of R.

After scaling, a filter with a relatively narrow pass band (QB > 1) is seen to consist of n two-integrator loops, where n is the order of the l-p filter used as model, loosely coupled together. This points to a rough analogy between a coupled-tuned-circuit filter and a ladder b-p filter, in which the loose coupling needed for a relatively narrow bandwidth is obtained by making the reactances of the shunt branches much smaller than those of the series branches.

The analogy may be put to use in a 3rd- order b-p filter as shown in Fig. 14. RV1 is placed so that the symmetry of the system is preserved and allows simultaneous adjustment of the loop gains of the two intermeshing feedback loops. As it is increased from a low value the response changes from single-peaked through a maximally flat response (Butterworth), to the over-coupled type of response, Fig. 15. Ideally the three peaks have equal height. This depends on the central tuned circuit having infinite Q. If it has appreciable damping the outer peaks are lower than the middle peak and may become only shoulders. Compensation can be made by applying to the central stage regeneration or positive feedback.

Other types of tuned circuit can be used in place of the two-integrator loops, provided the inside ones have high Q (approaching infinity). Fig. 16 shows a 3rd-order filter using parallel-tee circuits. By making use of the identity expressed in equ. (22), and by making the middle stage sign-inverting and the outer stages not, the feedback loops have been closed in the right sense, without the use of separate inverting or adding stages. So the filter is economical in amplifiers, using only one third as many as the previous circuit. But although the equally terminated structure is some help against the effects of mistuning, the Q factors of the tuned circuits are still very dependent on accurate balance in the twin-tee networks, and at least twice as many capacitors are needed.

Electronic tuning

An all-integrator circuit lends itself to electronic tuning (voltage-controlled) tuning (Part 8, Fig. 11). The electronic switches are equivalent to accurately ganged potentiometers, and the effective T of each integrator in series with a switch varies inversely with the mark/period ratio.
therefore, that the tuning range found practicable will be smaller, and that in compensation deterioration of bandshape at the lowest frequency will also be less.

Once again we are indebted to Dr R. L. Ford for showing that the versatility of the active filter does not end here and that it is possible to vary bandwidth independently of $\omega_0$. To do this it must be possible to increase the effective value of $R_1, C_2, L_3, \ldots$, for transmission round the larger loops, while leaving the tuning of the minor loops unchanged. The switches are therefore placed as shown in Fig. 17. Operation of switches $k_2$ varied the bandwidth, operation of switches $k_1$ varied the centre frequency, operation of both sets simultaneously gives the constant-$Q$ type of tuning. If zeros are introduced by adding linkages as described in Part 13, these also move under the action of the switches, as their positions also depend on the effective $T$s of the integrators.

**Stagger tuning**

Consideration of symmetry shows that when two tuned circuits are staggered to give a 2nd-order b-p response they must be of equal $Q$, and that the centre frequency of the combined response is the geometric mean of the centre frequencies of the two factors. Hence the pole positions are as shown in Fig. 18, and the normalized responses may be written:

$$G_1(\omega) = \frac{1}{1 + jQ(\omega - x)}$$ (27)

$$G_1(\omega) = \frac{1}{1 + j\omega x}$$ (28)

The product gives an expression for the overall gain, and from this by substituting $\Omega = \omega - 1/\omega_0$, which is equ. (1) when $\omega_0 = 1$, the frequency-response function for the corresponding 1-p response is obtained as

$$G(\Omega) = \frac{1}{1 + Q^2/S^2 + jQ\sqrt{1 + 1/4S^2} - Q^2/\omega_0^2} \Omega - Q^2\omega_0^2$$ (29)

If $S$ is defined by

$$x - 1/x = 1/S$$ (30)

$$x + 1/x = 2\sqrt{1 + 1/4S^2}$$ (31)

So equ. (29) becomes

$$G(\Omega) = \frac{1}{1 + j\Omega/Q, - \Omega/Q,\omega_0^2}$$ (32)

and comparison with

$$G(\Omega) = \frac{1}{1 + j\Omega/Q_0, - \Omega/Q_0,\omega_0^2}$$ (33)

gives

$$q = 1 + Q^2/S^2$$ (34)

$$\omega_0 = 1 + Q^2/S^2$$ (35)

So, for example, if $S = Q$, the bandwidth obtained is $\sqrt{2}/Q$, i.e. $\sqrt{2}$ times the bandwidth that the tuned circuits would have if not staggered. For the general case where the overall response is centred on $\omega_0$

$$\omega_0 = \frac{Q_0}{\Omega_0}$$ (36)

Now $\omega_0/\omega_0$ is the parameter $Q_\alpha$. For brevity let $B = Q_\alpha$. Equin. (36) may then be written

$$Q = 2qB$$ (40)

The above results may be used to analyse the performance of a b-p filter and a 1-p filter in tandem, using the identity already given, equin. (22). Thus equin. (34) shows that for very great staggering ($4S^2 \ll 1$ and $S^2 \ll Q^2$) $q \rightarrow 1$, but that for $Q > 1$, as $S$ increases $q$ falls, until for no stagger $q = \frac{1}{2}$. Stagger tuning is not a good practical method of making a filter, as obtaining a flat pass band depends so much on balancing one slope against another (e.g. see Ref. 1, Fig. 10.16). But the analysis is of theoretical interest as it gives the resonant frequencies and $Q$ factors of a b-p system.

**REFERENCE**

Current Generators

Some circuit techniques used to design discrete component and integrated circuit current generators

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Good approximations to voltage sources are commonplace in electronic circuits and are widely used in equipment design. Familiar examples are the low impedance d.c. power supply and the "follower" circuit in all its guises (cathode, emitter, etc.)

Less well known, but often very useful, are current source circuits or current generators. These are required in the measurement of semiconductor d.c. characteristics when a specified current is caused to flow between the terminals of a device and a breakdown voltage observed. Also a current source is required for the linear charging of a capacitor to produce an accurate linear sawtooth voltage waveform in timing applications. Such a scheme has the advantage over a conventional "Miller" circuit of producing no initial jump and not requiring a floating clamp.

Review of fundamentals

The first quadrant characteristics of an ideal controllable current generator are evident from Fig. 1(a); these are:

(i) Infinite I.f. incremental resistance for $V > 0$.

(ii) The d.c. current is dependent on only one chosen variable $\lambda$. This parameter could represent the effect of variation in a circuit resistance, current, voltage, charge, applied pressure, or radiation intensity, etc. The practical situation corresponding to Fig. 1(a) is shown, exaggerated for clarity, in Fig. 1(b). Curve (1) is now only approximately straight over a region between two arbitrarily defined points $A$ and $B$ being limited beyond these points by physical mechanisms such as voltage saturation and breakdown. The incremental output resistance at point $P$, $r_o = \frac{\partial V}{\partial I} = 1/\partial I$ is not infinite and may be a function of $\lambda$ and $V_e$ depending on the precise nature and spacing of the curves. Furthermore, $\lambda$ may not represent only the effect of one variable. It is desirable that the variable at our disposal, e.g. resistance, is dominant, and that there is a relative insensitivity, calculable in magnitude, of set current $I$, and resistance $r_o$ with respect to the other variable parameters. In most cases of practical interest the disturbing functions are temperature and rail voltage variation.

Before passing to specific circuit realizations and assessing to what extent they succeed in satisfying the ideal criteria discussed above, it is worth noting that current generators may be simply paralleled. One easily-ment requirement is that the common load resistance is much less than the $r_o$ of each source.

Basic circuit schemes

One of the simplest and most frequently encountered current sources is that shown in Fig. 2(a), in which $D_2$ is a zener diode (preferably temperature-compensated) operating in the breakdown region.

Normally $V_z = \delta_1, \delta_2$, and $\delta_1 \approx \delta_2$; hence if $\alpha = \text{common-base current gain of } T_{R_1}$, then for $B V_{ZB} > V > (V_z + \delta_2)$,

$$I = \frac{\alpha V_z}{R_e + R_f}$$

$$r_o \approx \frac{1}{\alpha I} = f(I)$$

Potentiometer $R_f$ is the controlling variable. This may be manually operated or mechanically driven, or might represent an f.e.t. operated in the pre-pinch-off region. The main disturbing influences are variations of temperature ($T$), and change in $V_z$. The latter produces a change in $V_z$ because of alteration in zener current; this may be reduced by replacing $R_f$ by a similar current source using a p-n-p transistor. Since $\alpha$ and $V_z$ are weak functions of $T$, $I$ is not sensibly dependent on this variable. Sometimes the lower limit of the voltage range is unacceptably high.

If a negative rail is available then the simple arrangement of Fig. 2(b) is useful. The stability of $I$ is directly dependent on $-V_1$ for this configuration.

For the case where a negative rail voltage is not available the circuit of Fig. 3(a) may be used. This has been used by the author

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to obtain the maximum input voltage range in a long-tailed pair differential comparator. 

$T_{2}$ is a germanium transistor whilst $D_{1}$ is a silicon diode.

It follows that, for $V_{o} > V_{S}$ in the upper limit of the voltage range,

$$I = a(62 - 6,)(E_{r} + R_{v})$$

$$1/h_{re} < r_{o} < 1/h_{re}$$

$V_{o}$ and the actual value of $r_{o}$ both depend on $(E_{r} + R_{v})$ and the incremental resistance of $D_{1}$.

Assuming a logarithmic volt-amp. relationship for $D_{1}$, a $x 4$ change in $V_{o}$ causes a change in $I$ of about $10\%$ for $62 \approx 0.6\ V$ and

$$\delta_{1} \approx 0.2\ V.$$  

Because of the larger value of $I_{CB}$ for germanium transistors and the fact that $|dV/dT| \neq |dI/dT|$ there is an increased temperature sensitivity for this configuration compared with that of Fig. 2(a).

To obtain the output characteristics, shown in Fig. 3(b), on a curve tracer (Tektronix 575) $R_{B}$ is removed and the rest of the circuit treated as a transistor—the emitter of which is the junction of $D_{1}$ and $R_{v}$—subject to base current drive in the common-emitter configuration. The logarithmic relationship between applied current and $V_{o}$ causes two effects which are visible on the photograph.

In the first place the curves become almost parallel to the voltage axis at points successively shifted to the right by a small amount. This occurs because the saturation condition $V_{CB} = 0$ is a function of drive current.

Secondly, the characteristics are unequally spaced in the vertical direction.

In a practical circuit a selected value of $R_{v}$ corresponds to a particular base current step. The vertical spacing thus gives a measure of the effect of $R_{v}$ tolerance on circuit performance. For predictable behaviour it is arranged that $(V_{o}/I_{o}) > (I/\beta)$ where $\beta$ = common emitter d.c. current gain of $T_{2}$. The results were obtained using an OC139 for $T_{2}$ and a low cost 1N4148 for $D_{1}$. $R_{v}$ was set at a convenient value: in cases where $R_{v}$ is dispensed with, a closer tolerance on a fixed $I_{o}$ may be obtained by using a well-specified diode, such as the 1N3595, for $D_{1}$.

If the magnitude of the minimum voltage across the terminals of the current source is not a problem the output resistance of the circuits in Figs. 2(a), 2(b) and 3(a) can be increased by employing a field-effect operated in the common gate mode (see Fig. 4(a)). The output resistance is now $r_{o}^{'},$ where

$$r_{o}^{'} = r_{o} + (\mu + 1)r_{o}.$$  

$$\mu = f.e.t.\ amplification\ factor.$$  

For this scheme to be successful the f.e.t. must be a "normally-on" type working in the current saturation region.

A mathematical treatment of the d.c. circuit conditions is not difficult and a pictorial representation conveys the information most appropriate to a practical design. Curve (a) represents the base-emitter characteristic of $T_{2}$. The load line for $R_{g}$ intersects this at $I_{o}^{*}, \delta_{1}$. Curve (b) shows drain-source current, $I_{DS}$, as a function of source voltage. Since $r_{o}$ is large relative to the impedance seen looking in at the source the actual source voltage, $V_{s}$, is found at the point on curve (b) corresponding to $I_{o}^{*} = I_{o}$. Clearly it is required that $V_{s} > \delta_{1}$ if $T_{2}$ is not to saturate.

**Exploitation of the matching principle**

One result of modern monolithic i.c. technology is the close parameter matching and temperature tracking of components of the same type fabricated on the same semiconductor slice. This feature is widely exploited in circuit design, giving rise to some arrangements which would not normally be encountered when using discrete components.

In Fig. 5(a), two transistors $T_{1}, T_{2}$ having an emitter area ratio $1:m$ respectively are made in close proximity on the same wafer. $T_{1}$ is given a collector-base strap in order to function as a diode. The circuit has been variously described as a "compound diode-transistor structure" and "current mirror".

Ignoring base width modulation effects in $T_{2}$ and the difference in power dissipation in the two devices—both legitimate assumptions for small values of collector-
emitter voltage—it follows (see Appendix 1) that,

\[ I = mI_b/(m+\beta+1) \]  

or

\[ I \approx mI_b \]  

for the usual case \( \beta > 1 \) and \( m \ll 1 \).

The effective current gain of the combination is \( \beta^* = I/I_b \approx m \). Gain precision has thus been obtained at the expense of gain magnitude—a familiar feature in feedback systems.

Equation (6) is true provided \( T_1 \) functions as a “well-behaved diode”: in the present context this means a logarithmic current-voltage characteristic whatever the current level. Now the collector-base region of \( T_1 \) is, in fact, \( < 0 \) by \( \approx R_{mb} \) where \( R_{mb} \) is the collector saturation resistance: it is thus necessary to use low \( R_{mb} \) devices, obtained for example by employing an n-

buried layer technic, in order that equation (6) be valid.

Fig. 5(b) shows curve tracer results obtained using two matched devices of an SL303A (Plessey): in this case \( m \approx 1 \). Since \( m \) is a function of device geometry \( I \) is independent of \( T \) to a weak, calculable, extent. For the same approximations used in obtaining equation (6) (a) it is simply shown that, at constant \( I_b \),

\[ (1/I)(dI/dT) \approx (1/I^2)(dI_b/dT) \]  

In fact the application of local heating to the TO-5 header (via a Thermoprobe) caused no noticeable shift in the characteristics on the scale used over a 50°C temp. range. However equation (7) must be used with caution since in a circuit \( I_b \) is not always fixed. If it is obtained by taking a resistor, \( R_b \), from the collector of \( T_2 \) to a constant positive rail voltage, \( V_1 \), then \( R_b \) and \( \delta_1 \) both vary with \( T \). This means that, in principle, by suitable choice of a discrete component \( R_b \) variation of \( I_b \) with \( T \) can be made to almost cancel variation of \( \beta \) with \( T \). One shortcoming of the current mirror so far described is the noticeable output resistance at the collector of \( T_2 \): this is not unexpected since as far as collector circuit of \( T_2 \) is concerned the transistor is connected in the common-emitter configuration with only a small incremental resistance between emitter and base.

At low current levels a resistance in the emitter lead of \( T_2 \) gives negative feedback and a consequent increased output impedance: for this case,

\[ R_e = (V_T/I) \log_e (I_b/I) \]  

where \( V_T = "thermal voltage" = (KT/q) \).

This approach permits the design of current sources in the mA range: this avoids the necessity of large values of \( R \) and the resulting expensive use of chip area in monolithic circuits.

The technique is not really suitable at current levels of a few milliamperes because \( R_e \) becomes very small; this means a significant output impedance improvement due to feedback, and a significant lack of precision in \( I \).

High output impedances for currents in the milliamp range can be achieved by using the circuit of Fig. 6(a). This scheme—which might be termed the “enhanced current mirror”—is a modification of Fig. 5(a), and appears to have been first used by Wilson.4 Analysis, in Appendix 2, shows that if all the devices have equal emitter areas,

\[ I = I_b[1 + [2/(\beta \beta + 2)] \]  

Fig. 6(b), which should be compared with Fig. 5(b), shows the increased output impedance occurring in this circuit.

To obtain the trace an SL303A was used: this contains two matched transistors (\( T_{1}, T_{2} \)) suitable for use in a long-tailed pair and a third transistor (\( T_{3} \)) suitable for use in its current tail. Fig. (7) shows results for a specially supplied device in which the area ratio of the matched transistors used in the circuit of Fig. 6(a) is 1 : 3.

Feedback amplifier schemes

Some of the limitations of the simple current generators so far considered may be overcome by using circuits having a large amount of negative feedback. This condition is easily met if plenty of gain is available. Such gain is readily and cheaply obtained with i.c. operational amplifiers. The input stages of these amplifiers will, incidentally, almost certainly contain a current-mirror type of current source functioning as an emitter or common-emitter load.

Fig. 8(a) shows the arrangement of a class of precision current generators in which a discrete active device is combined with an i.c. amplifier. The device—represented by the pear shaped symbol5—may, in principle, be any amplifying element with three electrodes. Terminals \( X, Y, Z \) are defined in Fig. 8(b) for the three types of unit most likely to be used. Control is effected between \( Y \) and \( Z \) and the output current, \( I_x \), appears at terminal \( X \).

It follows from established operational...
amplifier theory that if \( A \gg 1 \) and common-mode effects are neglected,

\[
I_x \approx \lambda (V_{ref} - V_i)/R \quad (10)
\]

The variables at our disposal for fixing \( I_x \) are thus \( V_1, V_{ref}, R \). Suppose \( V_{ref} \) is considered as the "input". Then \( I_x \) increases with \( V_{ref} \). Also, the current supplied by \( V_{ref} \) to the positive input is very low, being only the amplifier input bias current. The latter can be reduced to negligible proportions (<1pA) if an f.e.t. input stage is employed. Fig. 8(c) indicates a method whereby a current \( I_x \) may be made strictly proportional to \( I_1 \). This is shown, for \( V_f = 0 \), by a resistance of the active device and to reduce the sensitivity of \( I_x \) to parameter variations.

The extent to which the last two factors are troublesome is obviously dependent on the magnitude of \( A \).

### Appendix

1. "Current mirror" analysis

If, in Fig. 8(a), \( I_{k1} \) and \( I_{k2} \) are the emitter currents of \( T_1, T_2 \), respectively, current addition at the common base terminal yields,

\[
I_0 = I_{k1} + (I_{k2}(1 + \beta)) \quad A.1
\]

but,

\[
I_{k1} = I_{k2}/m \quad A.2
\]

now,

\[
I = aI_{k2} \quad A.3
\]

hence

\[
I = aI_{k2}[(1/m)+1/(1+\beta)] \quad A.4
\]

or, rearranging

\[
I = m/I_{k2}(m+\beta+1) \quad A.5
\]

and \( (I/I_0) = \beta^* \approx m \), for small "\( m \)"

and \( \beta \gg 1 \) \( A.7 \).

2. "Enhanced current-mirror" analysis

If, in Fig. 6(a),

\[
I_{c1} = \text{collector current of } T_3, \quad I_{e3} = \text{emitter current of } T_3
\]

then from A.6 above, with \( m = 1 \),

\[
I_{c1} = [\beta/(\beta+2)]I_{e3} \quad A.8
\]

summing currents at the base of \( T_3 \),

\[
I_b = I_{c1} + I_{e3}/(1+\beta) \quad A.9
\]

or,

\[
I_b = I_{e3}(\beta/(\beta+2)) + [1/(1+\beta)] \quad A.10
\]

now

\[
I = aI_{e3} \quad A.11
\]

or

\[
I = aI_{e3}/[\beta/(\beta+2) + 1/(1+\beta)] \quad A.12
\]

rearranging

\[
I = I_b/[1 + 2/\beta(\beta+2)] \quad A.13
\]

This gives \( (I/I_b) \) closer to unity than A.6 with \( m = 1 \).

### REFERENCES

Amateur radio in Poland

The Polish amateur radio society Polski Zwiaznek Krotofilaowcow (PZK) is this year celebrating its 40th anniversary. A special jubilee meeting is being held on October 25th. Today there are 6000 members of PZK, about half of them licensed amateurs. Although the Polish amateur is now striving to make and then advise amateurs to join the official "League of friendship with the Army", the Polish amateurs re-established their own society in 1957 following internal changes in Poland in 1956. Current PZK activities include a journal, contests, QSL bureau, maintaining regional amateur radio contacts, running amateur radio courses and supplying emergency communications during floods or forest fires. Over 400 local radio clubs are in affiliation with PZK which, in 1963, became the first Iron Curtain country to re-join the International Amateur Radio Union. There are now over 2500 Class I licenses (h.f./v.h.f.), 450 Class II (v.h.f. only) and 400 club stations. Class I permits range from 20 watts (age 15 to 18), 50 watts (over 18), 250 watts (after 6 years) to 750 watts (on request after 10 years).

Long distances on MHz?

Two recent studies underline dramatically the potential of frequencies as high as 70 MHz to support long-distance ionospheric propagation at low-power. The Canadian amateur, Geoff Kennedy (VE2A10), of Valois, Province of Quebec, has successfully received 70.275 MHz signals from the low-power TF3VHF beacon transmitter on Iceland, and is now striving to make a 50/70 MHz cross-band contact with the U.K. or continental Europe (he transmits on 50.055 MHz c.w.). The Canadian, already well-known for his intensive work on 50 and 70 MHz, believes there may be a connection between auroral, sporadic E and transsequatorial (i.e.) modes of propagation.

This theory receives support from the results of an extended Japanese investigation into i.e. propagation on 32, 48 and 72 MHz over a 4850-km path from Darwin, Australia, to Yamagawa, Japan (K. Tao et al, Journal of the Radio Research Laboratories [Japan] January 1970). This demonstrates that, even in years of low sunspot activity, i.e. propagation frequently extends, particularly in the evening-to-midnight equinoctial periods, to at least 72 MHz. It is noted that i.e. conditions appear to follow "spread F" occurrences and correlate with local sporadic E conditions. The Japanese team suggests that around 32 MHz there are two separate i.e. modes; one during daylight subject to a violent interference-type fading range of about 25 dB; and the night-time mode with a fading range of about 10 dB.

The interest of propagation research workers in i.e. was aroused initially by long-distance amateur contacts across the equator in the 50-MHz band during the period 1947-51; this interesting "chordal hop" mode has since been confirmed by many professional and amateur studies—but there clearly remains much opportunity for further study of i.e. in the 28-, 50- (not available in the U.K.) and 70-MHz amateur bands.

Rise in Morse Test charges

From October 1st, Minpostel is increasing the fee for the Morse Test needed to obtain a U.K. Amateur (Sound) Licence A from ten shillings to £1. The Federal Communications Commission has recently raised the fees charged to U.S. amateurs (who for many years paid no licence fees) though these remain modest by European standards. The charge is now $9 for new, renewed or upgraded operator licenses, but this covers five years. No fees are charged for Novice licences.

Trans-arctic expedition lecture

Radio communications played a vital role in the four-man polar crossing, led by Wally Herbert, in 1968-69. At an R.S.G.B. lecture on Monday, September 28th at 18.30 at the I.E.E., Savoy Place, London W.C.1, Squadron Leader Freddy Church (the expedition's base station operator), Dennis Collins (G2FLG) and Roly Shears (G8KW)—who organized and operated the G7AE "weekend" stations—are to describe the expedition's communications system.

In Brief: The Mullard Jubilee Exhibition at Mullard House, Torrington Street, London W.C.1 (October 5th to 24th, excluding Sundays) is to feature an amateur station built and operated by Mullard radio amateurs and using some of the firm's earliest transmitting valves.... The Port Talbot R.S.G.B. group won the National Field Day shield with a score of 2386 points; Oxford and District Amateur Radio Society was the runner-up with 2174 points. The Bristol Trophy for the leading one-station entry goes to Cannock Chase society with 1633 points. An unusual call—HG 100UA/D—has been frequently heard recently on h.f. bands; this is an exhibition station operating from various venues in Hungary to mark the centenary of the birth of Lenin.... Membership of the International Amateur Radio Club, with headquarters in Geneva, is now 394.... A Scottish v.h.f. convention is being held at the Queen's Hotel, Dundee, on Sunday, October 11th. An afternoon programme of technical lectures will be followed by a dinner. Details from G. C. Somerville, GM3KY 73 Balerno Street, Dundee.... A French biological study balloon, carrying beacon transmitters on 145.22 MHz (tone modulated) and 129.6 MHz (tone one-second pipe) is to be launched in the Nancy area on Sunday, October 11th at 1400 G.M.T. and should reach maximum height about one hour later. Cardiac data on a rat will be telemetered on 27.4 MHz (reception reports to Georges Guinard, 15 Route de Villers, 54. Laxou).
October Meetings

Tickets are required for some meetings: readers are advised, therefore, to communicate with the society concerned.

LONDON
1st. I.E.R.E.—“Some aspects of the design of a universal radar viewing unit” by R. W. Elbourn at 18.00 at 9 Bedford Sq., W.C.1.
1st. S.E.R.T.—“Design and performance of modern loudspeakers” by R. L. West at 19.00 at the Royal Commonwealth Society, Craven St., W.C.2.
7th. I.E.R.E.—“Solid state h.f. communications receiver” by B. M. Soinin at 18.00 at 9 Bedford Sq., W.C.1.
8th. I.E.E.—“Communication by glass fibre” by R. B. Dyott at 17.30 at Savoy Pl., W.C.2.
14th. I.E.R.E.—“The logistics of computer-aided circuit design” by C. S. den Brinker at 18.00 at 9 Bedford Sq., W.C.1.
21st. I.E.E.—“Technology and the Universities” by Professor John Brown the Electronics Division chairman at 17.30 at Savoy Pl., W.C.2.
21st. I.E.R.E.—“Continuing education for electronics engineers” by Dr. K. G. Stephens at 18.00 at 9 Bedford Sq., W.C.1.
22nd. I.E.E.—“A state-space approach to modular circuit synthesis” by Dr. A. W. Keen at 17.30 at Savoy Pl., W.C.2.
22nd. I.E.C.—“An introduction to image analysis” by G. Gardner and Dr Gibbard at 18.00 at 9 Bedford Sq., W.C.1.
29th. I.E.E.—“Developments in soft magnetic materials and their uses” by Prof. J. E. Thompson at 17.30 at Savoy Pl., W.C.2.
29th. I.E.E.—“Space communications—the present and the future” by J. M. Brown at 18.00 at 9 Bedford Sq., W.C.1.

ABERDEEN

BANGOR
20th. I.E.E.—“Electronic measurement in the automobile industry” by M. H. Westbrook at 19.30 at the School of Eng’s Science, University College.

BATH

BOLTON

BRIGHTON
27th. I.E.E.—Colloquium on “Advances in automatic pattern recognition” at 14.30 at the Polytechnic.

BRISTOL
19th. I.E.E.—“Telecommunications—past, present and future” by J. S. Williams at 18.00 at Queen’s Bldg, the University.
27th. I.E.E.E.—“Zinc-air batteries” by G. W. Walkden at 19.30 at Royal Hotel, College Green.

CAMBRIDGE
15th. I.E.E.—“Design techniques for mobile and personal radio telephones” by P. A. Webster at 18.30 at the Enec Labs, Trumpington Street.
20th. I.E.E.—“Current electronic developments in the deep-sea fishing industry” by R. Bennett at 19.30 at the College of Arts & Technology.

CARDIFF
1st. S.E.R.T.—“The all-transistor colour chassis” by T. Ayseough at 19.30 at Llandaff Technical College, Western Avenue.
21st. I.E.E.E.—“Education and training of technicians” by Dr. H. L. Hinzlgraff at 19.30 at the University of Wales Institute of Science & Technology, Cathays Park.
28th. I.E.E.—“Test equipment for colour receiver servicing” at 19.30 at Llandaff Technical College, Western Avenue.

CATTERICK
13th. I.E.E.—“The teaching of digital techniques” by D. Brown at 18.30 at the Camp.

CHATHAM
22nd. I.E.R.E.—“Thick film microelectronics” by A. P. Dyson at 19.00 at the Medway College of Technology.

CHELMSFORD
7th. I.E.E.—“The new Post Office research station at Martlesham” by C. F. Floyd at 18.30 at the King Edward VI Grammar School, Broomfield Rd.

DUNDEE
20th. I.E.E. Grads.—“Computer memory systems” by J. Crabb at 19.30 at the University.

ENFIELD
29th. I.E.E.—“Microelectronics” by E. T. Emmes at 18.30 at the College of Technology.

FARNBOROUGH

FURNIVAL
6th. I.E.E.—“A computer for teaching” by V. F. Thomas at 19.00 at the Technical College.

HULL
29th. I.E.E.—“Review of electronics in cars” by W. F. Hill, at 18.30 at the Y.E.B.

LEICESTER
6th. I.E.R.E./C.E.I.—“How an engineer can take part in the total management of a company” by Dr. F. E. Jones at 19.00 at the University.
14th. I.E.E.E.—“Control systems, computer simulation” by P. J. Lawton at 18.45 at the Hawthorn Bldg, the Polytechnic, The Newark.

 LETCHWORTH
21st. S.E.R.T.—“Art of computation” by C. Fleckney at 19.00 at ICL Engineering Training Centre, Icknield Way West.

LIVERPOOL
14th. I.E.R.E.—“Fast switching techniques as applied to automatic telephone exchange design” by J. L. Lewstey at 19.00 at the University, Dep. of Elec. Eng.
26th. I.E.E.—“The role of the polytechnics” by G. Bulmer at 18.30 at the Polytechnic.

LOUGHBOROUGH
20th. I.E.E.—“Measuring the body’s signals” by J. M. Ivison at 18.30 at Ed. Herbert Bldg, the University.

MALVERN
7th. I.E.R.E.—“Quasars—the most powerful transmitters in the Universe” by Dr. P. J. S. Williams at 19.00 at the Abbey Hotel.

MANCHESTER
12th. I.E.E.—“The polytechnics in perspective” by Sir Eric Richardson at 18.15 at Renold Bldg, U.M.I.S.T.

NEWCASTLE ON TYNE

NEWPORT, I.O.W.
16th. I.E.R.E.—“The future of aircraft landing systems” by W. F. Winter at 19.00 at the Technical College.

POOLE
20th. I.E.E. Grads.—“Integrated circuits in hi-fi systems” by B. A. Reed at 18.30 at the Technical College.

READING
6th. I.E.E.—“Review of electronic telephone switching” by D. J. Harding at 19.30 at the J. J. Thomson Lab, the University.
15th. I.E.E.—“Computer aided instruction” by Dr. D. G. Bate at 19.30 at the J. J. Thomson Laboratory, the University, Whiteknights Park.

ST. AUSTELL
6th. I.E.E.—“Communications satellite” by S. Pittam at 19.30 at the English Clays Lovering Pochin Ltd, Staff Restaurant, John Keay House.

SHEFFIELD
28th. I.E.E./I.E.R.E.—“Large scale integrated circuits” by C. S. den Brinker at 18.30 at the University.

SOUTHAMPTON

SWINDON

TAUNTON
13th. I.E.E.—“Television communications” by A. James at 19.45 at the Castle Hotel.

WEYMOUTH
22nd. I.E.E.—“Holography” by A. E. Ennos at 18.30 at the South Dorset Technical College.

WHITBY
13th. I.E.E.—“Radio astronomy” by I. W. Shefield at 19.00 at Botham’s Cafe, Skinner St.

WOLVERHAMPTON
6th. I.E.E.—“What the C.E.I. means to the professional engineer” by H. F. Schwarz and Sir Arnold Lindley at 19.15 at the Polytechnic.
New Products

M.O.S. Multiplex Switches
High-performance m.o.s. multiplex switches for communications are available in two ranges from Marconi-Elliott Microelectronics, one with leakage currents of 10nA and the other with leakages of the order of 0.1nA. Low-leakage types have been specially selected and are already used in a military message-switching application. Range includes single switches, with either high input or low 'on' resistance (M101, 103 and 106), dual switches, with either high input or low 'on' resistance (M203 or 206), dual pair used as multiplex switch and digital-analogue converter (M406), common-source sextet (M605), and triple pair digital-analogue converter (M606). Devices, all p-enhancement types, are made by the thick-oxide technique, used in high-voltage m.o.s. devices. Process allows increased oxide thickness by vapour deposition technique underneath non-active areas of aluminium conductors, thus avoiding spurious leakage. Marconi-Elliott Microelectronics Ltd, Witham, Essex.

Stabilized Power Supplies
The Roband ECO range of stabilized power supplies provides outputs of up to 50V and 10A. All components are mounted on a single printed board. Stabilization is about 0.005% with ripple and noise typically 150uV pk-pk. A modified re-entrant current characteristic maintains protection of loads and supplies, while preventing lock-out on linear and non-linear loads. They can also be externally programmed and used as constant current supplies. Protection against overvoltage, without spurious shut-down, is made possible by an optional addition. The units range in price from £20 to £49. Roband Electronics Ltd, Charlwood Works, Charlwood, Horley, Surrey.

Logic-state Indicator
Hewlett-Packard model 10528A Logic Clip fits on to t.t.l. or d.t.l. integrated-circuit packages and instantly displays the logic states of all 14 or 16 pins. The clip has 16 light-emitting diodes, each of which follows voltage-level changes on one pin. A lighted diode indicates a high logic state (+5V). The Logic Clip is self-contained. It requires no power connections or adjustments, drawing its power from the circuit being tested, and contains logic circuitry for locating the ground and +5V pins even if clipped on unsymmetrically. The buffered inputs put no more than one t.t.l. load on the circuit being tested. Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks.

Highly Accurate Digital Voltmeter
Digital voltmeter DSV4 from International Electronics has an accuracy of ±0.01% ± 1 digit. Input resistance is 10MΩ on all ranges. There are 123 readings per second. Calibration is automatic between each displayed heading and is effected by reference to a temperature compensated Weston standard cell. Zero offset current and voltage are automatically corrected between each reading. Series-mode rejection at mains supply frequency and its harmonics is greater than 85dB, and common-mode rejection 100dB at mains frequency and d.c. with 1kΩ imbalance in the input leads. The price is £25. International Electronics Ltd, Ewood Bridge, Haslingden, Lancs.

Quarter Squares Multiplier
Quarter squares multiplier type M3-SC from Computing Techniques obtains the product of two functions by implementing the relationship \( XY = \frac{1}{4}(X+Y)^2 - (X-Y)^2 \). Three built-in operational amplifiers perform the summing and inverting operations, while two function generators approximate the required parabolic transfer functions. Four-quadrant operation is provided. Using D1-2 amplifiers, the phase shift is less than 1° at 1kHz; this accuracy can be maintained up to 10kHz, and full power can be obtained up to 30kHz (with reduced accuracy) by using type F1-7 amplifiers. The required inputs are variable A, variable B and reference voltages; the input impedances is approximately 3kΩ. The available outputs, selected by miniature key switch, are \(-AB, A^2-B^2\) as a voltage and \(A^2 + B^2\) as a current; multiplication accuracy is 2% f.s.d. The product output voltage is AB/10 and the output current is ±5mA at ±10V. The multiplier is fitted with a standard...
Opto-electronic Switch for T.T.L.

Light-activated integrated switches have been produced with outputs compatible with both transistor logic and relays. Devices can be used in many applications of light beams including punched card reading and are said to be cheaper than photocells. Included in the TO-18 can is an m.o.s. Schmitt trigger circuit integrated into the same silicon chip. Response can be up to 40kHz and switching threshold is variable over three orders of magnitude by an external RC time constant. Devices are available with either 12-15V or 24-30V operating voltage and logic value of 0 or 1 in the dark state. Price is £2 8s for 1-50 and £1 10s for 5000 up. Arrays of 40 and 60 diodes for character recognition, edge sensing, etc., are also announced by Integrated Photomatrix Ltd, Grove Trading Estate, Dorchester, Dorset. WW 321 for further details

U.H.F. Transistor

The latest addition to the Mullard range of u.h.f. transistors is intended for use as a driver in mobile telecommunications equipment or as an output stage in pocket transmitters. Type BFW98G, it will deliver an output of 500mW at 470MHz when operating with a supply voltage of 13.8V and a drive of 80mW. The transistor is an n-p-n silicon planar device in a new stripline package. Mullard Ltd, Mullard House, Torrington Place, London W.C.1. WW304 for further details

300-W Zener Diode

Type BZWX86 zener diode from Mullard has a continuous power rating of 300W at a mounting base temperature of 65°C; and at an ambient temperature of 30°C it will withstand surges of 2kW. It is intended for use in preventing large electrical transients causing damage to equipment. It has a maximum diameter of 27mm and is 84mm

Dynamic Shift Register

A 512-bit dynamic shift register, the MM5016, from National Semiconductor operates on a standard +5V and -12V power supply and is compatible with bipolar transistors. The device has a 600Hz guaranteed minimum operating frequency at 25°C and an input tap gives 500 or 512 bits. It is available in either TO-5 or dual-in-line packages. No pull-up or pull-down resistors are required on the input and output. Price is 50s for the TO-5 version in lots of 100 or more. U.K. distributors: Athena Semiconductor Marketing Co., Egham, Surrey; Electronic Component Supplies (Windsor) Ltd, Thames Avenue, Windsor, Berks; Farnell Electronic Components Ltd, Canal Road, Leeds LS12 2TU; and ITT Electronic Services, Edinburgh Way, Harlow, Essex. WW 332 for further details

M.O.S. Adaptive Logic for Pattern Recognition

Adaptive logic gate, originally intended for use in pattern recognition experiments at Kent University, is now commercially available from Integrated Photomatrix. The m.o.s. gate (MC901) decodes all possible logic functions of the four binary inputs and sets one of the 16 internal bistable stores. Outputs of these stores are OR-gated to form the output. The adaptive gates can be connected into an array that will 'learn'. If, say, the array is controlling a system, feedback loops can be provided from the system to the array. The output of the array will be a function of the current input and, because of the memory stores, also a function of previous inputs and results as defined by the feedback loops. A particular input pattern does two things. First, it gates the output of one of the stores providing an output if that store contains a '1', second, it gates the input of the same store allowing it to set or reset depending on which of two input lines a 1us pulse is applied. Two additional inputs allow all the stores to be reset. Available in dual in-line packages, price is £7 for 1-99 and £4 10s for 1000 up. Supply voltage is 27V. Integrated Photomatrix Ltd, Grove Trading Estate, Dorchester, Dorset. WW 323 for further details
Monolithic Mica Capacitors
Using monolithic construction the MS611 series of capacitors available from WEL provides high stability over a wide frequency range. The units will operate over a temperature range -55 to +100°C. Insulation resistance is about 100 megohms and tan δ is better than 0.001 at 1 kHz and better than 0.002 at 1 MHz. The upper frequency limit is about 1 GHz. Voltage ratings up to 750V are provided and the standard E12 range of values at 1% tolerance is available from stock. Capacitance range is 10-10,000pF. WEL Components Ltd., 5, Loverock Road, Reading, Berks. WW 327 for further details

Crystal Filters for Marine Communications
Plessey have introduced a new standard range of crystal filters for use in marine communications equipment employing an i.f. of 1.4MHz. Included in the standard range are upper, and lower sideband filters, and symmetrical filters for a.m. and c.w. applications. In each case, the design meets the selectivity requirements of the Post Office specifications, TSC105 or MPT1201. Operation is specified over the temperature range -10 to +40°C, and each filter is sealed in a metal case measuring 76 x 27.5 x 26mm. The new range is complemented by a 2.182MHz sideband filter which has been specially designed for use on emergency marine equipment, and a broad-band LC filter giving selectivity from 1.6MHz to 4.2MHz while rejecting 1.4MHz. Filter Unit, Plessey Components Group, Titchfield, Hants. WW 334 for further details

10-turn Precision Pot.
Bourns have introduced a new 10 inch diameter, 10-turn, wirewound potentiometer with a glass-filled nylon housing and amplifier and a polycarbonate shaft with a screw-driver slot. Rotational life is guaranteed to 1 million shaft revolutions. The resistance range is 100Ω to 100kΩ, and tolerance ± 5%. Deviation from linearity is ± 0.25% max. Maximum power dissipation is 2.0W at 25°C. The operating temperature range is -55 to + 105°C. Bourns (Trimpot) Ltd, Maryland Works, 9 Brydges Road, Stratford, London E.15. WW 311 for further details

Silicon Infra-red Light Detector
The MSP70 infra-red detector from MCP Electronics Semiconductor Division has, like its predecessors the MSP3 and MSP6, a black tubular housing 1in x 0.25in. It will detect modulated infra-red up to 60kHz. MCP Electronics Ltd, Alperton, Wembley, Middlesex, HA9 4PE. WW 335 for further details

D.C. Multimeter
Multimeter measuring direct current down to picocamperes can now be supplied by Wayne Kerr. Model M300, first seen on the

Cassette Recorder with Dolby System
A new cassette tape-recorder unit, the Kellar DTA 50 available from Kellar Electronics, incorporates the Dolby ‘B’ noise reduction system, and is claimed to give a performance as good as that obtained from gramophone records. The unit comprises a high-quality transport mechanism and a stereo amplifier capable of a continuous power output of 25W per channel. Ordinary cassette recordings can be played on the unit, but the Dolby circuit can be switched in to allow low-noise recordings to be made. The frequency response of the recorder is 40Hz to 12kHz ± 3dB. The wow and flutter is given as 0.15% w.f.d. peak according to C.C.I.R. The use of the noise reduction system results in an increase of 5dB in the signal-to-noise ratio. Price £150. Kellar Electronics Ltd, Maryland Works, 9 Brydges Road, Stratford, London E.15. WW 324 for further details

1.5-MHz Recording Head
Gresham. Recording Heads have produced a high-frequency analogue recording head for operation at 1.5MHz. The 14-channel wideband head-sets are made with a gap of only 25 micro-inches. They are designed for direct analogue recording at 1.5MHz on 1-in tape. The normal tape speed is 120 i.p.s. Gresham Recording Heads Ltd, Feltham Trading Estate, Feltham, Middx. WW 328 for further details

Connectors
Components are supplied by several companies, including WEL. Capacitance range is 10-10,000pF. WEL has tolerance ratings up to 750V are provided and the frequency limit is about 1 GHz. The new range is complemented by a 2.182MHz sideband filter which has been specially designed for use on emergency marine equipment, and a broad-band LC filter giving selectivity from 1.6MHz to 4.2MHz while rejecting 1.4MHz. Filter Unit, Plessey Components Group, Titchfield, Hants. WW 334 for further details

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D.C. Multimeter
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Wayne Kerr stand during the I.E.A. exhibition earlier this year, also measures direct voltage and resistance. Amplifier uses photochopper stabilization with 40-Hz switching to avoid beats with the 50-Hz supply. Instrument also features a small reverse scale for null detection, overload protection, one set-zero control for all ranges, a recorder output of 0-1mA at 11(.2, and a hum rejection filter which rejects hum equivalent to $50 \times f_{s.d.}$

<table>
<thead>
<tr>
<th>Availability</th>
<th>Price £150. Wayne Kerr Co. Ltd., New Malden, Surrey. WW317 for further details</th>
</tr>
</thead>
</table>

**Miniature Power Supply**

The PS5 supply from A.D.M. Electronics measures 70 x 70 x 180mm and provides up to 0.17A over the voltage range 0—15V. The PS5 design has been developed to eliminate damaging transient overshoot at turn-on and turn-off. The supply is fully protected against short circuits and overloads. The transient response is less than 5μs for a full load-current change and the regulation is claimed to be better than 5000 to 1. On full load the ripple and noise do not exceed 500μV, reducing to less than 30μV for load currents below 50mA. A.D.M. Electronics, P.O. Box 3, Merthyr Tydfil, Glamorgan. WW310 for further details

**Range of Transformers**

A series of low-voltage, double-insulated transformers from Adcola has a primary-winding range of 110 to 380V and a secondary range of 6 to 115V. Ratings are 25, 40 or 60W. The casing is secured by clips so dismantling for access to internal parts is quick and does not require the use of a screwdriver. Adcola Products Ltd, Adcola House, Gauden Road, London S.W.4. WW307 for further details

**Distortion Factor Meter**

Push-button controls make this new distortion factor meter easy to use especially for measurements on production radio and TV receivers and audio equipment.

**Monolithic Tuning Indicator**

An integrated circuit tuning indicator is available from Motorola. The addition of a miniature lamp bulb turns the i.c. into an aid to the fine-tuning of f.m. radio and colour television receivers. In use type MC1335 tuning indicator is connected across the f.m. ratio detector. When the receiver is correctly tuned equal voltages appear across each half of the ratio detector centre-tapped coil causing the lamp to light. Unequal voltages turn the lamp off. The device is encased in an eight-lead dual-in-line plastic package and requires a power supply of 20V. The price is 27s each in quantities of 100 or more. Motorola Semiconductors Ltd, York House, Empire Way, Wembley, Middx. WW309 for further details

**V.H.F. Personal Radiotelephone**

A v.h.f. personal radiotelephone consisting of a single lightweight unit suitable for emergency, public and private usage is available from Pye Telecommunications. It is known as the PF2PM, and is equipped for three channel f.m. operation in the 68-88 and 148-174 MHz bands. It meets the Post Office mobile specification and, with an adaptor, can be used in a car or other vehicle. Sockets on the top of the unit make connection with a small external loudspeaker/microphone unit, and an aerial. The unit can be clipped to the waist belt or carried in a specially designed case or harness snug from the shoulder with a flexible wire antenna fitted in the shoulder strap, its loudspeaker-microphone being clipped to the lapel. The whole unit, including battery, weighs only 28 oz. Power is from a single 15V rechargeable nickel-cadmium battery with a capacity of 200mAh, the unit incorporates a circuit to reduce battery drain when no signal is received. Pye Telecommunications Ltd, Newmarket Road, Cambridge. WW 331 for further details
Meter, type TF2337, is complementary to the more elaborate Marconi Instruments TF2331 announced in 1964 and intended for development work. Level is set to give adequate meter deflection at either 400Hz or 1kHz and distortion factor read directly from the other meter. Provision is made for injection of external fundamental frequency in the range 30Hz-7kHz.

**level ranges**

<table>
<thead>
<tr>
<th>Range</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>10mV-30V in 8 ranges</td>
<td>±5% f.s.d.</td>
</tr>
<tr>
<td>10mV range</td>
<td>±10%</td>
</tr>
<tr>
<td>distortion ranges 1-30% in 4 ranges</td>
<td>±5% f.s.d.</td>
</tr>
<tr>
<td>input Z</td>
<td>100kΩ plus 50pF</td>
</tr>
<tr>
<td>fundamental rejection</td>
<td>56dB</td>
</tr>
<tr>
<td>frequencies</td>
<td>400Hz and 1kHz</td>
</tr>
<tr>
<td>plus external facility</td>
<td></td>
</tr>
</tbody>
</table>

Available for 110V use. Price £230. Marconi Instruments Ltd, St. Albans, Herts. WW316 for further details

**Small Tantalum Capacitors**

The Kemet Micron range of small tantalum capacitors, from Union Carbide U.K., are available in either rectangular or cylindrical cases with radial or axial leads. The capacitance range is 0.001 to 220µF, and voltage range 2 to 100V. Standard capacitance tolerances are ±20%, ±10% and ±5% and the operating temperature range is −55 to +125°C. The capacitors consist of very small tantalum anode assemblies with attached leads enclosed in insulated cases filled with epoxy resin. Union Carbide U.K. Ltd, 8 Great Street, London W1A 2LR. WW302 for further details

**Units Symbol Numiculator Tubes**

End-viewing indicator tubes are now made by Hivac which display special symbols—units in particular. Two tubes have the following symbols.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GR8M</td>
<td>pF, nF, µF, mF</td>
</tr>
<tr>
<td>GR81M</td>
<td>nΩ, µΩ, mΩ, Ω, kΩ, MΩ</td>
</tr>
<tr>
<td>%</td>
<td>D%, %</td>
</tr>
</tbody>
</table>

Both operate with minimum strike voltage of 170V and maintaining voltage of 140V. Minimum cathode current needed is 2mA with mean of 5mA and maximum peak current of 20mA. Because of the smaller area of the %, Ω and H symbols, current requirement is half of these figures. Base is B13B and tube height is 26.5mm. Price is about £2 for 100 up. Hivac Ltd, Stonefield Way, South Ruislip, Middx. WW318 for further details

**Wideband Test Oscillator**

Model 4200 oscillator, manufactured by Krohn-hite and available from Omega Laboratories, provides a sine wave in the range 10Hz to 10MHz with 0.5W of power and 0.1% distortion. Frequency tuning is by means of a dial and six push buttons. Amplitude calibration of 0.2dB accuracy is obtained by an eight-position push-button attenuator calibrated in 10dB steps. A continuous output control combined with the attenuator provide 90dB of attenuation. Frequency accuracy is 2%. A fixed 1V output independent of the main output is also available. Price £235. Omega Laboratories Ltd, 59 Union Street, London S.E.1. WW301 for further details

**Video Signal Mixer**

From Aston Micro-Electronics Ltd we have received details of a vision mixer TVM2 for cutting, fading and mixing the pictures from five cameras and one video tape recorder. Two rows of button switches allow any two vision sources to be selected for viewing before transmission. Automatic interlocks prevent accidental mixing of the video tape recorder picture with pictures from the cameras. Although designed for monochrome systems, the 8MHz response of the TVM2 is adequate for colour television. It is claimed that PAL-encoded colour pictures can be mixed without noticeable degradation of picture quality. Aston Micro-Electronics Ltd, Vapery Lane, Farnborough, Woking, Surrey. WW314 for further details

**Tape-transport Mechanism**

Fitch Tape Mechanisms have developed and are now producing an endless-loop tape-transport mechanism using a new system of pinch wheel operation making tape stiction impossible even if the unit is not actuated for long periods with the tape cartridge in the ready position. This mechanism, adaptable to all sizes of cartridge, can be battery or mains powered. It is fully automatic and can be remotely controlled. Fitch Tape Mechanisms, 7a Balham Grove, London S.W.12. WW333 for further details

**Corrections**

"Miniature Tape Recorder" (August p. 413): The complete address for Hayden Laboratories Ltd, who market the Nagra SN recorder, is East House, Chiltern Avenue, Amersham, Bucks.

"Switching Diode" (September p. 463): The diodes illustrated are not the Mullard BAV 44 type described.
ACTIVE DEVICES
A range of zener diodes and varistors manufactured by Schauer Semiconductor Products is described. Literature is available from LST Electronic Components Ltd, 7 Copfold Rd, Brentwood, Essex. The varistors consist of two matched semiconductor junctions and are suitable for meter protection, fractional voltage regulators, etc. WW401

From REL Equipment and Components Ltd, Components Division, Croft House, Bancroft, Hitchin, Herts, a catalogue devoted to semiconductor components, passive and metaloxide capacitors and resistors is available. WW402

We have received the following data sheets from Marconi-Elliot Microelectronics, Witham, Essex. M101, M03. Single metal oxide silicon p-enhancement transistor, 3.5 to 6V thresholds, 30V breakdown and 2mA max off leakage. WW403 M106. Single mos.f. with low "on" resistance (3.5V), p-enhancement, Vpn - 30V and Pfin 300mA max. WW404 M206. Dual mos.f. on a common substrate, similar to M106. WW405 M203, 406, 405. 30V mos.f.s; two is a pair without gate protection; 406 consists of two common-source pairs; and M405 is six common-source mos.f.s in a DIL package. WW406

Integrated Photomatrix Ltd, Grove Trading Estate, Dorchester, have sent us a number of product data sheets:

IPL.11. Light activated switch in TO-18 case consists of silicon planar diode and an n.m.o.s. i.e. for 28V operation. WW407 IPL.1100. Similar to above for -12V operation. WW408 IPL.13. Light-to-frequency converter: planar diode and I.e.s. in TO-18 case, output 10Hz to 100kHz. WW409 IPL.14. Analogue light level sensor in TO-5 case. WW410 HA.14. Paper tape reader head. Planar diodes and I.e.s, no interface circuit required for driving TTL or n.m.o.s. WW411 IPL.20. 50 x 1 light sensitive array. 50 silicon planar photodiodes and a 51-bit shift register on a chip. WW412 IPL.20D. Position-sensitive photocell system. Gives X and Y output voltages proportional to the distance of a light spot from a central position. Accurate to better than 1µm. WW413 WCM.32. Material width monitor. WW414 IPL.20R. 50 x 1 Photodiode array driver. WW415 IPL.15. Light activated switch. WW416 MR.103/4.5/6 A 16-bit shift register; t.t.l. compatible. WW417 MC.501. Adaptive logic gate. WW418 Price list. WW419

We have received a 111-page brochure from British Brown-Boveri Ltd, Glen House, Stag Place, London S.W.1, called "Thyristor Circuits and Diagrams". WW420

American Diodes Incorporated have just started a company in the U.K. called Diodes Ltd at Fairacres Estate, Dedworth Rd, Windsor, Berks. The following literature is available

Short-form catalogue ........................................ WW421 Price list .......................................................... WW422

The 1970 catalogue of Electrovalve, 28 St. Jubes Rd, Englefield Green, Egham, Surrey, lists a variety of semiconductor device together with many other components. Price 2s.

PASSIVE COMPONENTS
We have received the following brochures from Tygadure, Luton, Lanes.

Tygadure radio-frequency coaxial cables WW423 Tygadure equipment wires ........................................ WW424 Tygadure p.t.f.e. equipment wire, cable, aluving, lacing cords and tapes, and glass braided yarn WW425

Engineering Bulletin No.751 from Sprague is called "Beryllia-core silicon-coated Acrasil precision wirewound resistors". Sprague Electric (U.K.) Ltd, Sprague House, 159 High St, Yiewsley, West Drayton, Middlesex.

Swift Hardmans Wholesale Supply (S-O-T) Ltd, P.O. Box 23, Hardmans House, Baille St, Rochdale, Lanes, have produced a catalogue of Belling-Lee components (plugs, sockets, fuse holders and the like) they stock. WW426

Precision miniature wirewound resistors with either radial or axial leads are the subject of a booklet available from Electrothermal Engineering Ltd, 270 Neville Rd, Londen E.7. WW428

B & R Relays Ltd, Temple Fields, Harlow, Essex, have produced a leaflet describing their D-range of relays which have contacts rated at 6A at 240V a.c. or 30V d.c. WW429

The following data sheets on components manufactured by the American Wilbrecht Company are available from J.H. Associates Ltd, 1 Church St, Bishop's Stortford, Herts.

Model 170-S potentiometer with switch WW431 Model 170 R-potentiometer WW432 Model 100 variable resistor (2.54mm diameter) 170-100 WW433 Model 200 miniature slide switch WW434

APPLICATION NOTES
From Fairchild Semiconductor Ltd, Kingmaker House, Station Rd, New Barnet, Herts, a leaflet (No.6) describing the use of the Mu L4102 16-bit associative memory cell and the Mu L0035 64-bit read/write memory cell in a high-speed buffer memory system WW435

Application report B61 from WEL Components Ltd, 5 Loverock Rd, Reading, Berks, examines the construction of the triac and looks at its application in several circuits. The report includes notes on protection and working. Post and packing 2s.

Integrated Photomatrix Ltd, Grove Trading Estate, Dorchester, have produced an application note for the 50 x 1 light sensitive array mentioned in the Active Devices section.

EQUIPMENT
REL Equipment and Components Ltd, Microwave and Electronics Division, Croft House, Bancroft, Hitchin, Herts, have issued a short-form catalogue which lists a comprehensive range of test equipment. WW436

A logic trainer from Limrose Electronics which consists of 16-NAND/NOR gates, or five-switch input register and four indicator lamps is described in a leaflet CK.J02 from Limrose Electronics, Lymm, Cheshire. WW437

EMI Electronics Ltd, Television Equipment Division, Hayes, Middlesex, have produced a 44-page booklet on monochrome closed-circuit television systems for educational purposes. WW438

A Mullard booklet, "Do-it-yourself stereo", price 5s, gives constructional (wood-working) details of some of the possible stereophonic record reproducing assemblies using amplifier and power-supply modules (Mullard "Unils") that can be wired up using only a screwdriver.

CONFERENCES AND EXHIBITIONS
Further details are obtainable from the addresses in parentheses

LONDON
Oct. 14-16 Savoy Place
Earth Station Technology
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)
Oct. 19-24 Olympia
Audio & Music Fair
(C. Rex-Hassan, 42 Manchester St., London W.1.)

BRIGHTON
Oct. 13-15 Hotel Metropole
INTER/NEICON
(P. G. Saville, 21 Victoria Rd., Surbiton, Surrey)

MANCHESTER
Sept. 28-Oct. 2 Belle Vue
Electronics, Instruments and Components Show
(Inst. Electronics, 659 Oldham Road, Baidstone, Rochdale, Lanes)

OVERSEAS
Oct. 5-7 Argonne
Pattern Recognition
(Prof. S. S. Yau, Dept. of Electrical Eng., North
western University, Evanston, Illinois 60201)
Oct. 5-7 Rolla
Communications Conference
(J. R. Brenten, University of Missouri, 123 EE Bldg.,
Rolla, Missouri 65401)
Oct. 6-11 Ljubljana
Modern Electronics Exhibition
(Gospodarsko razstavisce, Ljubljana, Titova No. 50,
Yugoslavia)
Oct. 7-9 Monticello
Circuit & Systems Theory
(G. Metro, University of Illinois, Urbana, Illinois 61801)
Oct. 12-16 Helsinki
British Engineering Week
(League of Commerce of Commerce, 69 Cannon
Street, London E.C.4)
Oct. 13-15 Los Angeles
Telemetering Conference
(International Foundation for Telemetering, 19730
Ventura Blvd., Woodland Hills, California 91364)
Oct. 14-16 Pittsburgh
Systems Science & Cybernetics
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)
Oct. 26-28 Washington
Electronics and Aerospace Systems
(Dr. R. Marsten, NASA Headquarters, Code SC,
Washington D.C. 20546)

Wireless World, October 1970
Morganite 0.75" Cermet Trimming Potentiometers are breaking all our sales records at the moment. And we can’t say we’re surprised. We designed our models 82, 84 and 86 with a power rating of 0.33W at 70°C. We manufactured them to give a tolerance of ±10% under rough, tough industrial conditions. We packed them into that tight little Record Trimmer 0.75" construction. And we trimmed down the price tag to match. Result, they sell like hot cakes. Ask us for samples for evaluation or development projects, and you’ll see for yourself.

What you won’t see, though, is the work that’s put into our record trimmers at our new, expanded cermet production set-up. The examination of components at 50-to-500 times life size. The survival-of-the-fittest electrical testing. And all the crucial assembly stages in between. All you’ll see is the solid, high reliability that you’re entitled to expect from each and every Morganite potentiometer. The reliability that makes us a leader in the field of cermet technology.

Don’t settle for less.

MORGANITE RESISTORS LIMITED
Bede Industrial Estate, Jarrow, County Durham.
Telephone: Jarrow 897771 Telex: 53353

Morgan

WW—006 FOR FURTHER DETAILS
SHRINK YOUR SWITCHING PROBLEMS...

with 4 new improved miniature relays from Associated Automation

Mercury Wetted Contact Relay Type EBRM:
Height only 10mm for low profile PCB mounting; 20mW bi-stable, 40mW single-side-stable; operate time 1ms nominal at max. coil power; life over $26 \times 10^8$ operations at rated load of 100VAC; bounce-free for both Form C or D contact resistance.

Dry Reed Relay Type ERMC/D/E:
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**Typical operating conditions**

<table>
<thead>
<tr>
<th>Type</th>
<th>Energy input per flash max. (J)</th>
<th>Arc length (in.)</th>
<th>Bore diameter (mm)</th>
<th>Voltage (kV)</th>
<th>Series inductance (μH)</th>
<th>Flash rate</th>
<th>Trigger voltage (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>XL615/4/3</td>
<td>400</td>
<td>3</td>
<td>4.0</td>
<td>2.5</td>
<td>400</td>
<td>1 per 30 sec.</td>
<td>12-16</td>
</tr>
<tr>
<td>XL615/7/3</td>
<td>600</td>
<td>3</td>
<td>7.0</td>
<td>2.5</td>
<td>400</td>
<td>1 per 15 sec.</td>
<td>12-16</td>
</tr>
<tr>
<td>XL615/9/4</td>
<td>1600</td>
<td>4</td>
<td>9.0</td>
<td>2.5</td>
<td>400</td>
<td>1 per 30 sec.</td>
<td>16-20</td>
</tr>
<tr>
<td>XL615/10/5.5</td>
<td>3500</td>
<td>5.5</td>
<td>10.0</td>
<td>2.5</td>
<td>400</td>
<td>1 per 60 sec.</td>
<td>16-20</td>
</tr>
<tr>
<td>XL615/10/6.5</td>
<td>5000</td>
<td>6.5</td>
<td>10.0</td>
<td>2.5</td>
<td>800</td>
<td>1 per 2 min.</td>
<td>20-25</td>
</tr>
<tr>
<td>XL615/10/12</td>
<td>9000</td>
<td>12</td>
<td>10.0</td>
<td>2.5</td>
<td>800</td>
<td>1 per 2 min.</td>
<td>25</td>
</tr>
<tr>
<td>XL615/13/6.5</td>
<td>10000</td>
<td>6.5</td>
<td>13.0</td>
<td>2.5</td>
<td>800</td>
<td>1 per 2 min.</td>
<td>25</td>
</tr>
<tr>
<td>XL615/13/12</td>
<td>18000</td>
<td>12</td>
<td>13.0</td>
<td>2.5</td>
<td>800</td>
<td>1 per 2 min.</td>
<td>25</td>
</tr>
</tbody>
</table>

*At maximum input levels (air-cooled)*

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- PCF86
- PCL86
- PL81
- PC97
- ECC82
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- PCC89
- PCF801
- PCL805/85
- PL504
- PCL83
- EF80
- PC86
- PCC189
- PCL82
- PFL200
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STOCKISTS
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When the AR-3a is placed against a wall, its frequency response is flat to below 40 Hz, and continues even at lower frequencies with very low distortion. To design Big Horn, we turned to page 268 of the standard text, *Acoustics* by Leo Beranek*, to find the equation used to calculate the size of a horn with a cutoff frequency of 40 Hz.

As shown in the scale drawing above, Big Horn is 7 feet high and 9 feet wide; its depth would have to be greater than either of these dimensions. A pair for stereo would take up slightly more space in a living room than two VW buses. Yet, played at the same loudness, the only audible difference between them and a pair of AR-3a systems would be the slightly rougher response of the Big Horns due to reflections inside them. Other than that, the Big Horns should sound excellent; they would simply be not quite as good, and much more costly than AR-3as.

The AR-3a speaker system is made by Acoustic Research and distributed in the U.K. by Bell & Howell.

Complete technical specifications of the AR-3a and other AR high fidelity products are available free on request.

7V r.m.s. Sine or Square from 1Hz to 1MHz

**FREQUENCY:**  1 Hz to 1 MHz in 12 ranges. Accuracy ± 2% ± 0.03 Hz.

**SINE WAVE OUTPUT:**  7V r.m.s. reducible to < 200μV with Rs = 600Ω at all levels.

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**AMPLITUDE STABILITY:**  < ± 1% variation with frequency up to 300kHz.

**SQUARE WAVE OUTPUT:**  7V peak reducible to < 200μV. Rise time < 150ns.

**SYNC. OUTPUT:**  >1V r.m.s. sine wave in phase with the main output.

**SYNC. INPUT:**  ± 1% frequency lock range per volt r.m.s. input.

**SIZE & WEIGHT:**  7" high × 10½" wide × 5½" deep. 10 lbs.

Types TG200 and TG200M generate only sine waves. Types TG200M and TG200DM have a meter calibrated 0/2V, 0/7V and −14/+6dBm. Types TG200 and TG200D have a calibrated control instead of a meter.

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<td>TG200</td>
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<td>TG200M</td>
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<td>TG200DM</td>
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Prices include batteries with 400 hour life. Mains power units are £10 extra.

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This is a high fidelity amplifier (0.3% intermodulation distortion) using the circuit of our 100% reliable—100 Watt Amplifier (no failures to date) with its elaborate protection against short and overload, etc. To this is allied our latest development of F.E.T. Mixer amplifier, again fully protected against overload and completely free from radio breakthrough. The mixer is arranged for 3-30/60Ω balanced line microphones, and a high impedance line or gram input followed by bass and treble controls. 100 volt balanced line output.

THE VORTEXION 50/70 WATT ALL SILICON AMPLIFIER WITH BUILT-IN 4-WAY MIXER USING F.E.T.s.

100 WATT ALL SILICON AMPLIFIER. A high quality amplifier with 8 ohms–15 ohms or 100 volt line output for A.C. Mains. Protection is given for short and open circuit output over driving and over temperature. Input 0.4 V on 100K ohms.

THE 100 WATT MIXER AMPLIFIER with specification as above is here combined with a 4 channel F.E.T. mixer, 3 mic. 1 gram with tone controls and mounted in a standard robust stove enamelled steel case. A stabilised voltage supply feeds the tone controls and pre amps, compensating for a mains voltage drop of over 25% and the output transistor biasing compensates for a wide range of voltage and temperature. Also available in rack panel form.

200 WATT AMPLIFIER. Can deliver its full audio power at any frequency in the range of 30 c/s–20 Kc/s ± 1 dB. Less than 0.2% distortion at 1 Kc/s. Can be used to drive mechanical devices for which power is over 120 watt on continuous sine wave. Input 1 mW 600 ohms. Output 100–120 V or 200–240 V. Additional matching transformers for other impedances are available.

CP50 AMPLIFIER. An all silicon transistor 50 watt amplifier for mains and 12 volt battery operation, charging its own battery and automatically going to battery if mains fail. Protected inputs, and overload and short circuit protected outputs for 8 ohms–15 ohms and 100 volt line. Bass and treble controls fitted. Models available with 1 gram and 2 low mic. inputs, 1 gram and 3 low mic. inputs or 4 low mic. inputs.

20/30 WATT MIXER AMPLIFIER. High fidelity all silicon model with F.E.T. input stages to reduce intermodulation distortion to a fraction of normal transistor input circuits. The response is level 20 to 20,000 cps within 2 dB and over 30 times damping factor. At 20 watts output there is less than 0.2% intermodulation even over the microphone stage at full gain with the treble and bass controls set level. Standard model 1-low mic. balanced and Hi Z gram.

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**VORTEXION LIMITED**, 257-263 The Broadway, Wimbledon, S.W.19
Telephone: 01-542 2814 and 01-542 6242/3/4
Telegrams: "Vortexion, London S.W.19"
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WW—026 FOR FURTHER DETAILS
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Telex 41276 GARDNERS XCH

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Please indicate your requirement by circling the number/s below

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WW—027 FOR FURTHER DETAILS
Digital Logic Systems Simulator for Education and Industry
A Comprehensive Logic Instruction System

* FOR STUDENTS AND ENGINEERS to quickly learn and apply digital logic techniques.
* RUGGED, ROBUST CONSTRUCTION for trouble free operation under hard use.
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First, the secret of our unique success: a special high gain etched foil process that helps us pack each can with more capacitance. Then a design that recognises I.E.C. and B.S. recommendations on logarithmic capacitance ranges, and standardised voltage ratings. And now the basic data. 15 to 150,000μF, at 6.3 to 160V d.c. Ripple currents up to 7.5A. Single-ended cans up to 100V; double-ended axial lead types up to 15,000μF. Cans insulated if you wish.

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Wireless World, October 1970

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In probably 75% of cases the LITESOLD range of lightweight high performance instruments provide the sensible choice. These well-balanced quality tools reflect nearly twenty years development resulting from wide use in industry.

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Telephone: 01-688 8589 & 4559
* Lightweight
* Tropicalized
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* High impedance, high level phones
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* Simple to service.

The new 'Astrolite' headset has been adopted by many of the leading Television, Broadcasting and Programme companies for studio and O.B. use, and no wonder.

It’s fully interchangeable with all known carbon level systems. No more of the ‘snap, crackle and pop’, just the message, clear and reliable, using our new noise-cancelling high quality moving-coil microphone with integral amplifiers.

For noise-free communications, without ‘carbon’ crackles. Write or telephone for a free demonstration, at your premises, without any obligation.

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**Title**

**Address**

WW—033 FOR FURTHER DETAILS
Printed circuit mounts directly to back of Ernest Turner 643 or 642 meter.
Three meter scales available: British Standard—BBC-European.
Nominal 24 Volts DC required.
High stability—all capacitors are Tantalum electrolytic.
Frequency response: 40 Hz—20 kHz ± 0.2 dB
10 Hz—40 Hz ± 2.0 dB
20 kHz—60 kHz ± 2.0 dB
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‘Fall back’ time: 3 secs.
Gold plated 10 way connector.
4 slave meters can be driven from 1 card.
Ferrous or Non-ferrous mounting.
Stereo PPM also available.
Manufactured by: Audio Engineering Ltd.,
33 Endell Street, London, WC2.9BA.
01-836 9373

The Audio Engineering Peak Programme Meter is designed well within the British Standards specification. This precision instrument is used throughout all major Broadcasting and Television Studios in the U.K. and Europe. The PPM 3 is always used where programme level must be accurately measured.
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Equip yourself with a microphone that lets you be heard
the way you should be heard.
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Just as the top stars do.

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This is the lowest-cost Unidyne, but it has all the features that have made Unidyne so popular in show business.
You'll delight at the way it reduces feed back, 'boomy' reverb and pick-up of audience noise. You can use it on stand or in the hand, and there's a built-in On-Off switch, 20ft. cable and a swivel adaptor.
The ideal microphone for high performance on a modest budget.
Complete in carrying case.

Model B588SA Unisphere B
Maxi mike at a mini price!
Gives you maximum features for your money. Superior 'pop' rejection. Trouble-free Cannon type connector (normally found only in higher-price models).
Superb anti-feedback performance. Shock-mounted cartridge for quiet operation.
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WW-036 FOR FURTHER DETAILS
After the fun of the Audio Fair then whatever amplifier equipment you have chosen you will no doubt be interested in the added advantages of incorporating Reverberation or Ambiophonic units. May we advise you on this?

We shall be pleased to supply further details on these two units, and indeed on any Audio equipments, including mixers, microphones and matching units etc.

AUD1/JACW/X/86.

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WW—037 FOR FURTHER DETAILS

PERFORMANCE
POWER!

frequency response at
100 Watts

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WW—038 FOR FURTHER DETAILS
MODEL 2000
PLINTH SYSTEM

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Write for details to: SME LIMITED · STEYNING · SUSSEX · ENGLAND

Motor boards in matching veneers are ready cut and drilled for screwdriver assembly with the appropriate pick-up arm and turntable. An uncut board is also available.

Four-point spring suspension adjustable for height and damping protects the motor board from acoustic feedback and external vibration.
NEW! G6 GEAR BOX
SLOW MOTION DRIVE

- SMALL SIZE 44mm x 54mm x 11mm
- In line input-output shafts.
- Dia/Pointer mount rotates 240 degrees while output rotates 180 degrees.
- Input shaft 8:1 ratio to output.
- Anti-Backlash Gearing.
- Overload slip clutch protects the driven component.

**WAVEMASTER**

"Wavemaster" variable capacitors have brass vanes and a single ceramic end plate. All have 0.248" spindles, extended both ends for ganging by means of our Universal Couplings. All are designed for S.W. working and for one hole fixing. 6mm spindles to order if required. Various capacitances. Largest vane packs 300 pF 0.017 air gap, 50 pF 0.04 air gap.

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Jackson stand-off insulators are designed to perform well in rigorous environments. Their insulation resistance exceeds 20 million megohms even when atmospheric humidity is high. (They meet British Services test specification DEF5334.) They will withstand high steady voltages and intense r.f. fields. Forty different types; ask for catalogue.

- Working voltages up to 10kV.
- Stoved-on silicone treatment; water repellent.
- Ceramic bodies.
- Silver-plated tags.
- No solder. No plastic. No adhesives.

**P.30 2-GANG and P.30 F.M. 3-GANG**

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- Swr ratio 3.5 or 7 or 1:1
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- Ceramic insulators.

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- Gear ratio 25 1:1
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A33
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division of I.M.O. precision controls limited
process timers — level controls — limit switches
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- Repeat accuracy ± 1/2% of full scale
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Low cost, plug-in timer, with automatic reset, and impulse start facilities.
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- Roller arms
- Plungers
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- Very low cost
- All types of actuators
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61 FGP FLOATLESS LEVEL CONTROLLER
Plug-in switch with stainless steel electrodes; senses changes in liquid levels through variations in resistance between electrodes. Controls pump operation to empty and fill tanks or other vessels to pre-determined levels.
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- No electrolytic action
- Solid state circuitry
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- Delivery from stock
£3.14s.0d. (price for switch only) dependent on quantity.

EX-STOCK EX-STOCK EX-STOCK EX-STOCK

WW—042 FOR FURTHER DETAILS
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- **Output 0-260V**
- **Input 230V 50/60 CPS**
- **Shrouded for bench or panel mounting**

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<th>Amp</th>
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<td>£21.0.0</td>
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<td>20</td>
<td>£37.0.0</td>
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Inset shows latest pattern brush gear ensuring smooth continuous adjustment.

**SOLID STATE VARIABLE VOLTAGE CONTROL**

- **Output 25-240V**
- **Input 240V 50 CPS**
- **5 amp & 10 amp model**
- **Completely sealed**

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<th>Amp</th>
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<td>£8.7.6</td>
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<td>10</td>
<td>£13.15.0</td>
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**50 AMP 0-24V DC L.T. SUPPLY UNIT**

- Continuously rated.
- Ideal for photo units.
- Infinitely variable up to 24V DC.
- Size 18 x 12 x 21. High—70lbs. Rear wheels fitted for ease of handling.

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<tr>
<td>10</td>
<td>£13.15.0</td>
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**COMPLETE PHOTO-ELECTRIC SENSOR in one unit**

- Reflective type with built-in light source.
- Will also operate from remote light source.
- Matchbox size.
- Senses any object—colours, thin film.

Operates from 12V AC. Output signal 0.2 amp. 100V.

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<tr>
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**GOLDRING SERIES 800 and 850 STEREO MAGNETIC CARTRIDGES**

Our famous '800 Series' True Transduction cartridges, developed on the 'Free Field' principle, allow the most delicate groove-stored signals to be accurately relayed and re-created with uncompromising precision. And the G.850 Free Field stereo magnetic cartridge, intended primarily for 'budget' hi-fi systems, offers all the advantages of a good quality magnetic cartridge at a very attractive price.

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Goldring Manufacturing Company (Great Britain) Limited, 10 Bayford Street, Hackney, London E8 3SE. Phone: 01-985 1152.
### Capacitance boxes available from 20pf.-140uf. Accuracies up to 0.05%

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<thead>
<tr>
<th>Capacitance Boxes</th>
<th>Capacitance Range</th>
<th>Tolerance</th>
<th>Price</th>
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<td>20pf.-140uf.</td>
<td>up to 0.05%</td>
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### Inductance

Air space 1mH-1H
Accuracy 5%

### Resistance Boxes

from 0.1-10 MΩ
Average accuracy 0.1%

### Resistance Elements suitable for use up to 1MHz.

### Jay-Jay Junior Decade Capacitance Boxes

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<th>Capacitance Boxes</th>
<th>Capacitance Range</th>
<th>Accuracy 1%</th>
<th>Price</th>
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<tr>
<td>JC1</td>
<td>3 Decade 100 pf. to 0.111 mfd.</td>
<td>£12 18s. Od.</td>
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<tr>
<td>JC2</td>
<td>3 Decade 30 pf. to 10.140 pf.</td>
<td>£13 14s. Od.</td>
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### Jay-Jay Inductance Boxes

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<td>L1</td>
<td>3 Decade 1 mH to 1 H</td>
<td>£37 0s. Od.</td>
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<tr>
<td>L2</td>
<td>2 Decade 1 mH to 100 mH</td>
<td>£26 10s. Od.</td>
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<td>L3</td>
<td>2 Decade 10 mH to 1 H</td>
<td>£29 15s. Od.</td>
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### Jay-Jay “Point One” Resistance Boxes

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<th>Resistance Boxes</th>
<th>Resistance Range</th>
<th>Accuracy 0.1%</th>
<th>Price</th>
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<tr>
<td>R1</td>
<td>5 to 100 ohms by 1 ohm steps</td>
<td>£24 10s. Od.</td>
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</tr>
<tr>
<td>R2</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£25 0s. Od.</td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£29 10s. Od.</td>
<td></td>
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<tr>
<td>R4</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£29 10s. Od.</td>
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<tr>
<td>R5</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£10 10s. Od.</td>
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<tr>
<td>R6</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£10 10s. Od.</td>
<td></td>
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<tr>
<td>R7</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£10 10s. Od.</td>
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<td>R8</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
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<td>R9</td>
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<td>R10</td>
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<td>£10 10s. Od.</td>
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<tr>
<td>R11</td>
<td>0 to 1,111,100 ohms by 1 ohm steps</td>
<td>£10 10s. Od.</td>
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<table>
<thead>
<tr>
<th>Case Code</th>
<th>1</th>
<th>5</th>
<th>10</th>
<th>25</th>
<th>50</th>
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<td>755</td>
<td>48/-</td>
<td>46/-</td>
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<td>44/-</td>
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<td>6/-</td>
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<td>50/-</td>
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<td>48/-</td>
<td>47/-</td>
<td>46/-</td>
<td>43/-</td>
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<tr>
<td>1277 white or black panel</td>
<td>55/-</td>
<td>52/-</td>
<td>51/-</td>
<td>49/-</td>
<td>48/-</td>
<td>43/-</td>
<td>6/-</td>
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<td>1277 unpainted</td>
<td>45/-</td>
<td>44/-</td>
<td>43/-</td>
<td>40/-</td>
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<tr>
<td>191010D</td>
<td>199/-</td>
<td>197/-</td>
<td>196/-</td>
<td>194/-</td>
<td>192/-</td>
<td>190/-</td>
<td>18/-</td>
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</tbody>
</table>

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Flexible insulated test probes, colour red or black, at 131/- each for fine steel clips at the tip, opened by button on top. High-speed resetting counter including bezel and socket with speed of over 40 operations per second 165/-. Plug in oscilloscope, 24 volts, with two changeovers 175/.

---

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Sizes in inches

**PLEASE NOTE**

All products except stock items are supplied EX WORKS. Returns or exchange of any item is allowed in normal quantities. Return of goods is at the customer's expense. Minimum order £1. Fully detailed leaflets available.

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For operating and servicing battery equipment from AC Mains. Regulation and impedance comparable with that of fully charged accumulators. Where better regulation is required, unit can be supplied incorporating silicon transistor regulator.

<table>
<thead>
<tr>
<th>Type</th>
<th>Input</th>
<th>Output</th>
<th>Price</th>
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<td>£73.00</td>
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- Accuracy: ± 8% of full scale.

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- Power Ranges: 1W to 10kW.
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<td>133</td>
<td>6.0A</td>
<td>3 x 2 x 2</td>
<td>6.0</td>
</tr>
</tbody>
</table>

The new Rohde & Schwarz Test Assembly consists of a Signal Generator, Frequency Controller and Power Test Adapter, and is intended for use on land mobile Transceivers using the Signal Generator SMDF. The Signal Generator delivers RF signals (CVV, AM/FM) of high frequency stability and high signal-to-noise ratio, both these features being essential for testing sensitive receivers with narrow channel spacings. The Frequency Controller, in addition to improving frequency stability, functions as a counter and discriminator for frequency deviation measurement on externally applied signals. The Power Measuring Adapter includes a 20 watt attenuator, power meter and RF monitoring circuit allowing measurements to be performed using one connecting cable.

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<table>
<thead>
<tr>
<th>Model</th>
<th>FOB US$</th>
<th>Conversion</th>
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<td>FT-250</td>
<td>226</td>
<td>(£94.10)</td>
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<td>FT-150</td>
<td>355</td>
<td>(£150)</td>
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<td>FR-500DX</td>
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<tr>
<td>FL dx 2000B</td>
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VALID FOR ALL ABOVE MODELS

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<tr>
<th>Frequency Ranges</th>
<th>3.5...40MHz</th>
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<th>14.0...14.5MHz</th>
<th>28...30MHz</th>
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<tr>
<td>FT-250 ADDITIONAL DATA TO ABOVE</td>
<td>Transmitter Power: SSB/CW = 200W PEP Input, Am = 80W Input, Sensitivity 0.3μV for 10db/SN Stability 100kHz, VOX Crystal Filter 3.18kHz, Antenna &amp; Filter Matching 60...1200. Weight 8kg. Length 335 x Height 140 x Depth 260mm. Delivered with power supply extra price FOB US$ 60 (£25.4).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT-150 ADDITIONAL DATA TO ABOVE</td>
<td>Transmitting Power: 150W PEP Input, Sensitivity Better Than 1μV for 10db/SN Stability 500kHz, VOX Crystal Filter 3.18kHz, Antenna &amp; Filter Matching 60...1000. Weight 18kg. Length 400 x Height 150 x Depth 350mm.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT-500 ADDITIONAL DATA TO ABOVE</td>
<td>Transmitter Power: SSB/CW = 500W PEP Input, Am = 200W Input, Sensitivity 0.5μV for 6db/SN Stability 100kHz, Crystal Filter 3.18kHz. Weight 18kg. Length 370 x Height 160 x Depth 290mm.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>FL-500 ADDITIONAL DATA TO ABOVE</td>
<td>Sensitivity 0.5μV for 10db/SN Additional Frequencies to Above 2.3, 9.9, 10.5, 26.9...27.5MHz FM with Optional Extra Demodulator. Weight 18kg. Length 370 x Height 160 x Depth 290mm.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>FT-250 ADDITIONAL DATA TO ABOVE</td>
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<tr>
<td>FT-500 ADDITIONAL DATA TO ABOVE</td>
<td></td>
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<tr>
<td>FL dx 2000B</td>
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</tbody>
</table>

2M FM HAND & AUTO/TRUCK TRANSCEIVERS

- 2 CHANNEL VHF/FM 132...174 MHz Crystal Controlled Tolerance ±0.002% 2W Power, 45cm Built-in Antenna (External Connection for 500 Antenna), Channel Separation Max. 500kHz, Sensitivity 0.5μV/20db/0.3μV/12db. Built-in Accessories: 1 EXTRA QUARTZ CRYSTAL, LEATHER CASE, EARPHONE CHARGING BATTERY, WIDTH 80 x HEIGHT 220 x DEPTH 50mm. Weight 1kg. 145.0MHz. 145.15MHz. Model TA-101FG FOB US$ 240 (£101)

11M AM HAND TRANSCEIVERS

- 2 CHANNEL AM 26.965...27.265 & 28.500 MHz Quartz Crystal Controlled, Tolerance ±0.005% 1.6W Input Power, Highly Sensitive Receiver. Noise Limiter, 137cm Built-in Rod Antenna inclusive of Accessories Dimensions. Width 90 x Height 210 x Depth 40mm. Weight 1.2kg. Model TS-510 FOB US$ 50 (£21)


THE ABOVE UNIT PRICES ARE ALL TO BE UNDERSTOOD AS F.O.B. Cadenazzo-Lugano, Switzerland FOR DELIVERY WITHIN 24 HOURS FROM OUR CUSTOMS BONDED WAREHOUSE FROM FINANCIALLY FINALISED ORDER.

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16 lbs of high quality performance for only £65

The S51B is the answer for a low cost, easy to use single-beam oscilloscope.

Here are some of the reasons why:
- Small size—light weight
  8" x 7" x 15". 16 lb.
- 5" flat-faced P.D.A. tube.
- Bandwidth DC-3MHz.
- Auto sync and trigger level control.
- Proven performance of over 20,000 S51’s in use throughout the world.
- Send for full specification now!!!
This month's cover picture, showing the latest Burndept Electronics radiotelephone in use at an airport, draws attention to the continuing expansion in mobile radio communications, the technical problems of which are discussed in the report on page 494.

IN OUR NEXT ISSUE

Loudspeaker driver units. The fundamental parameters of moving-coil speakers will be examined and some new thinking introduced by Ted Jordan.

The first of a series of three articles on the design and construction of a high-quality tape recorder.

Details of an extra-versatile tone control.

Contents

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Telephone: (212) 699-3250.
How we made thyristors a commercial proposition for consumer products

Three years ago a Mullard design team was given the problem of developing thyristors for motor speed control in washing machines and drills. Thyristors offered important advantages over conventional power control methods, but at that time, production was confined to relatively expensive industrial devices. The high unit cost was essentially due to specialist production techniques.

Two Requirements The Mullard team set about designing inexpensive thyristors, together with triggering devices, for use on domestic mains supplies. Two current handling capabilities were identified as being necessary to meet the range of applications—6.5A for washing machines and other heavy current loads, and 2A for drills and lighter loads.

Within six months two consumer type thyristors, BT101 and BT102, had been developed for 6.5A applications, and they were soon in mass production. Now these devices, in the TO-64 stud-mounted metal encapsulation, are well established.

Low-cost Plastic After further design work, a new plastic device, the BT100A, was introduced to meet the lower current requirements. Plastic power device technology is highly specialised, and only intensive effort over many years has resulted in the highly automated manufacturing techniques which ensure extremely good reliability.

Computer Testing To cope with the necessary high rate of production, computer techniques were introduced to record test results and to allow automatic grading. The testing cycle was significantly shortened by the use of high-current pulses for directly heating the thyristor crystal. This is one of the best automated methods of testing breakdown voltages at the highest junction temperatures.

The result? A range of thyristors capable of meeting all the consumer-appliance manufacturers' current needs, and of improving both the efficiency of power-control and the usefulness of the units controlled. They offer consumer product manufacturers smooth, continuous and efficient power control.

Worth it? Right from the beginning we've had everything under our control, so that we can be sure the product will give consistent service. This also enables us to relate quality with the best possible price. Something which applies across the very wide Mullard component range. Our components find applications as unexpected as Astronomy and Zoology, giving us experience in many technologies. Experience our customers now take for granted.

Mullard components for consumer electronics

Mullard Limited
Consumer Electronics Division
Mullard House Torrington Place
London WC1E 7HD

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Psst.
Like to know a military secret?
It'll cost less than you expect

At Electrosil we're so used to making electronic components to above-average specification that we sometimes forget to shout it out loud enough. So memorise this and act upon it:

'MECPOT® type MP32X wirewound trimming potentiometers from Electrosil are manufactured to military standards but sold at industrial prices.

So you get more for the same money, then there's the assurance you get from knowing 'MECPOT® won't be the cause of costly computer downtime. Because at Electrosil we stake our all on reliability. The 'MECPOT® is just one of Electrosil's high reliability range of trimming potentiometers for military and industrial applications.

'MECPOT® Type No. MP32X
- Copper cored element giving 1W at 70°C
- Precious metal wiper and separate gold plated wiper-return track for low electrical noise
- PTFE leadscrew bearing ensuring stability under mechanical shock
- Welded internal connections unaffected by your soldering process
- Diallyl phthalate case with excellent solvent resistance and dimensional stability
- Entirely British design and manufacture

ELECTROSIL LIMITED, P.O. Box 37, Pallion, Sunderland, Co. Durham.
Telephone Sunderland 71481, Telex 53273.

have the experience
WW—106 FOR FURTHER DETAILS
This bigger than average contact area, spring formed for extra low smooth insertion forces, is one of the major factors that gives the Cinch 0.1" Modular Edge Connector its reputation for optimum reliability. In addition, available platings include 5 microns of gold on the mating surfaces with 2 microns of gold overall.

Any number of ways, from 5 to 65, can be supplied in the basic 0.1" module. High precision mouldings are in glass filled diallyl phthalate, and contact termination options are mini-wire wrap, solder slot, vee-form, or flow solder.

Cinch 0.1 pitch 'Greenline' Modular Edge Connector
No. of ways: 5 to 65 max.
Current Rating: 5 amps (d.c. or a.c. RMS) per contact at 25°C
Working Voltage: 700 V. d.c. or a.c. peak
Insertion Force: 8 oz. max. per way on nominal board
Contacts: Phosphor bronze.

Polarising keys can be supplied to ensure instant correct positioning. End fixes are also available, in metal with open or closed end, and in plastic with closed end.

Rapid reliable deliveries in bulk quantities are assured. We'll gladly submit quotations for your requirements or send fully detailed data sheets.
CN 15 Watts. Ideal for miniature and micro miniature soldering. 18 interchangeable spare bits available from .040" (1mm) up to 3/16". For 240, 220, 110, 50 or 24 volts.

G 18 watts. Fitted 3/32" bit for miniature work on production lines. Interchangeable spare bits 3/32", 1/8", 1/4" available. For 240, 220 or 110 volts. 36/-. 


Complete precision soldering kit This kit — in a rigid plastic "tool-box" — contains: 
- Model CN 15 watts miniature iron, fitted with a bit. Interchangeable spare bits .04", .06", .08". 
- Reel of resin-core solder. 
- Felt cleaning pad. 
- Stand for soldering iron. 

From Electrical and Radio Shops or send cash to Antex. 55/- 

Model CN 240/2 15 watts - 240 volts Fitted with nickel plated bit (3/32") and in handy transparent pack. From Electrical and Radio Shops or send cash to Antex. 34/-


Please send me the Antex colour catalogue.

Please send me the following irons

Quantity Model Bit Size Volts Price

I enclose cheque/P.O./cash value

NAME

ADDRESS

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Concentrated Performance

Fifty years' experience of the design and manufacture of wound components at the disposal of the Electronics Industry.

Inter-stage and head matching transformers. Where the very lowest hum levels must be achieved, bi-limboid construction and/or heavy Mumetal cans may be specified.

Gas-tight versions available with ceramic seals.

Power transformers in simple and bi-limboid (hum cancelling) form.

Line transformers, balanced and unbalanced.

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There is an M in Decca

It stands for Motorola and you'll see it in the Decca single standard TV chassis. It's the mark of the Motorola quality and reliability that got radio on the road and helped to put men on the moon.

Motorola is one of the largest semiconductor manufacturers in the world. Its U.K. plant is at East Kilbride. Also in Europe there is a factory in France and another to be established in Germany, whilst the Company's European headquarters are in Geneva.

It's because Motorola understands quality and reliability that their equipment has provided the essential communication links (radio and TV) between the moon surface and earth.

That too is why there is an M in Decca—it stands for reliability.

Motorola Semiconductors Limited
York House, Empire Way, Wembley, Middx.
Tel: 01-903 0944. Telex: 21740 Motsem Wembley.

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Semiconductors.
STC is proud to announce that its entire range of Star equipment has received the award of the British Council of Industrial Design. Elegant and functional in design the Star Mobile Radiotelephone and Starphone Pocket Radiotelephone are milestones in the design of Radiotelephone products.

The rapid acceptance of Star Mobile Radiotelephones in the UK and in over 30 countries throughout the world is a forceful reminder of the importance of design in worldwide marketing success.

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STC

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The professional one

Here it is, Solartron's outstanding 1240.
The multimeter that's not just a toy but a real step forward in instrument technology.
Now everyone can go digital!
You get Amps, Volts, Ohms - a.c. and d.c. - down to 100 microvolts and dual slope integration for noise rejection.
Technology apart, the 1240 has automatic polarity indication and a straightforward control layout including a single range selector and fingertip function switches. It's the easy-to-handle go-anywhere portable multimeter.
Go digital with the new 1240. From Solartron, European leaders in digital instrumentation.
Post the magazine's reply-paid card and we'll send you our data sheet of full details.
Chances are you'll find precisely the industrial tube you want in the BRIMAR standard range without the expense of a special.
Electrosil's new Pick-a-Back connector, with the snap action, is the most advanced concept yet in D.I.P. testing. You can say goodbye to tedious test probes. Electrosil Pick-a-Backs are designed for D.I.L. packages mounted onto a P.C. board. Made specifically for testing and fault location, the connector will snap on to a D.I.L. package, obviating the need for test probes.

There is quick release action. You have no more costly "write-offs" due to accidental shorting between adjacent pins. Pick-a-back's integrally moulded contact comb prevents shorting and also serves as an attachment guide.

It can be used singly or in multiples to test complete I.C. boards before flow soldering.

- Gold plated beryllium copper contacts with wiping action for reliable contact.
- Four versions available to mate with all standard 14 pin and 16 pin D.I.P.s.

(Patent and Registered Designs applied for).

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SIGNAL LAMPS

GENERAL PURPOSE MINIATURE AND NEON TYPES

This fine selection of Miniature Signal Fittings includes models accepting L.E.S., S.B.C., and T.I. bulbs, together with types supplied complete with in-bulb neon lamps, the majority of which are fitted with the appropriate resistor for use on 110 or 250V supply. The plastic lenses on filament lamp models are available in five brilliant transparent or translucent colours, whilst the neon types are available with Red, Amber or Clear lens and the normal 'pink' glow neon or with a clear lens and a green glow neon. The various lens and body styles give a wide choice to the designer engineer. Most models are panel mounting, fixing by rear nuts, spring washer or inbuilt spring clips, but D.965-966 is a NEW model developed for direct connection to a printed circuit assembly.

SMALL AND MEDIUM TYPES

Small and medium models accept filament lamps with M.E.S., M.B.C., C.E.S., S.E.S., and S.B.C., caps and are suitable for a wide variety of use in all types of equipment. In most cases, there is a choice of plastic or glass lens, each type being available in five transparent or five translucent colours, Red, Amber, Blue, Green and Clear or White. Many models can also be supplied with a choice of a black moulded or chrome plated metal bezel, and/or a choice of lampholder. Fixing is normally by a rear nut to a single panel hole, with cable connection to screw terminals or solder tags. Bulb replacement is normally from both the front and rear.

HEAVY DUTY TYPES

Heavy duty models accept E.S. or B.C. capped lamps and are of extremely robust construction for use on machine tools and heavy plant. Lenses are normally glass but are still available in the usual five transparent and translucent colours. The bodies are produced from heavy gauge metal or heavy duty plastics and fixing is normally by bolts rather than our usual rear-body nut. In addition to our standard heavy duty models, we can also supply special services grades of signal fitting, all with J.S. numbering and approval and B.E.F. 5,500 etc. finishes. A full list of all Bulgin Signal Lamps is available on request—see below for the appropriate brochure number.

FOR DETAILS OF OUR COMPLETE RANGE OF SIGNAL LAMPS REQUEST BROCHURE 1502/C

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WW—115 FOR FURTHER DETAILS

OVER 4,000 VARIETIES
New for Project 60

the world’s first high fidelity phase lock loop FM tuner

It has always been our policy at Sinclair Radionics to employ new and highly advanced circuitry in our products so that we can offer better performance at competitive prices. Our new F.M. tuner is the first in the World to use the phase lock loop principle. We have also incorporated such advanced features as varicap diodes for the tuning, printed circuit coils for the tuner and I.F. strip, A.G.C., A.F.C., an excellent squelch circuit to silence the tuner between stations, an Integrated Circuit stereo decoder and the option of remote control and push button switching.

The phase lock loop principle was first applied to receivers for reception from satellites because of the important improvements in signal to noise ratio that could be obtained by this technique. In addition there were the benefits of greatly improved selectivity and sensitivity. The Project 60 tuner, as the specifications show, is unsurpassed by any tuner now available yet we are able, because of the new circuitry, to sell the product at a fraction of the price.

From the high fidelity point of view this new circuit has the very important advantage of very much lower distortion than any other tuner known to us.

A voltage controlled oscillator (V.C.O.) in a phase lock loop tuner is kept in phase with the incoming signal by a phase comparator or detector which compares the two and feeds a control voltage to the oscillator. This control voltage is the audio output in the case of an F.M. signal. Since it is possible to design a V.C.O. which has an extremely linear voltage to frequency transfer characteristic excellent audio fidelity can be readily achieved. Furthermore, the oscillator can track a signal whilst completely rejecting a nearby stronger signal which would cause interference in a conventional receiver.

In use the tuner is especially attractive because the squelch circuit gives complete silence between stations and because fine tuning is accomplished automatically by the tuner. Accurate tuning is therefore ensured.

The use of an integrated circuit for the stereo decoder part of the circuit helps to give improved performance as it enables us to use a far more sophisticated circuit than would otherwise be possible. In particular stereo separation is excellent. Switching from mono to stereo is automatic and is indicated by a bulb.

The Project 60 tuner is supplied completely built and tested and ready to be mounted into any cabinet you choose. It may be used with any high fidelity amplifier including of course the Project 60 amplifier systems. The remarkable selectivity and sensitivity will make it possible to receive stereo transmissions in many more areas and foreign broadcasts will also be received far more readily. It is well remembered that the Project 60 tuner will operate well on only a few inches of wire in most areas should this be necessary.

Project 60 F.M. tuner specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of transistors</td>
<td>16 plus 20 in I.C.</td>
</tr>
<tr>
<td>Tuning range</td>
<td>87.5 to 108 MHz.</td>
</tr>
<tr>
<td>Capture ratio</td>
<td>1.5dB</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>2μV for 30dB quieting</td>
</tr>
<tr>
<td>Squelch level</td>
<td>7μV for full limiting</td>
</tr>
<tr>
<td>A.F.C. range</td>
<td>20μV</td>
</tr>
<tr>
<td>Signal to noise ratio</td>
<td>± 200 KHz</td>
</tr>
<tr>
<td>Total harmonic distortion</td>
<td>&gt;65dB</td>
</tr>
<tr>
<td>Stereo decoder operating level</td>
<td>0.15% for 30% modulatio</td>
</tr>
<tr>
<td>Pilot tone suppression</td>
<td>2μV</td>
</tr>
<tr>
<td>Cross talk</td>
<td>30dB</td>
</tr>
<tr>
<td>I.F. frequency</td>
<td>40dB</td>
</tr>
<tr>
<td>Output voltage</td>
<td>10.7 MHz</td>
</tr>
<tr>
<td>Aerial Impedance</td>
<td>2 x 150mV R.M.S.</td>
</tr>
<tr>
<td>Indicators</td>
<td>75 Ohms</td>
</tr>
</tbody>
</table>

Mains on; Stereo on; tuning indicator

Block Diagram

Price: £25 built and tested. Post free.

Sinclair Radionics Ltd.

at the International Audio and Music Fair, Olympia, Stand 44

WW—116 FOR FURTHER DETAILS
Project 60

Laboratory standard modular high fidelity

Sinclair Project 60 comprises a range of modules which connect together simply to form a compact stereo amplifier with really excellent performance. So good, in fact, that only 2 or 3 amplifiers in the world can compare in overall performance and now the constructor has choice of assemblies with either 20 or 40 watts output per channel, with or without filter facilities.

The modules are: 1. The Z.30 and Z.50 high gain power amplifiers. 2. The Stereo 60 preamplifier and control unit. 3. The Active Filter Unit. 4. 4 supply units—PZ.5; PZ.6; PZ.7 and PZ.8.

In a normal domestic application, there will be no significant difference between PZ.5 or PZ.6 unless loudspeakers of very low efficiency are being used, in which case the PZ.6 will be required. For assemblies using two Z.50’s there is the PZ.8 supply unit to ensure maximum performance from these amplifiers. No skill or experience are needed to build your system and the Project 60 manual gives all the instructions you can possibly want, clearly and concisely. Perhaps the greatest beauty of the system is that it is not only flexible now but will remain so in the future as new additions are made to the range. A stereo F.M. tuner is next to come.

<table>
<thead>
<tr>
<th>System</th>
<th>The Units to use</th>
<th>In conjunction with</th>
<th>Your Project 60 Units will cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Car Radio</td>
<td>Z.30</td>
<td>Existing car radio, Sinclair Micromatic £9/6</td>
</tr>
<tr>
<td>B</td>
<td>Simple battery powered record player</td>
<td>Z.30</td>
<td>Crystal pick-up, 12 V or more battery supply and volume control £9/6</td>
</tr>
<tr>
<td>C</td>
<td>Mains powered record player</td>
<td>Z.30 and PZ.5</td>
<td>Crystal or ceramic P.U., Vol. control etc. £9.0</td>
</tr>
<tr>
<td>D</td>
<td>20+20 watts RMS stereo amplifier for most needs</td>
<td>Two Z.30s, Stereo 60 and PZ.5</td>
<td>Crystal, ceramic or magnetic P.U., most dynamic speakers, FM tuner, etc. £23.18.0</td>
</tr>
<tr>
<td>E</td>
<td>20+20 watts RMS stereo amplifier for use with low efficiency (high performance) speakers</td>
<td>Two Z.30s, Stereo 60 and PZ.5</td>
<td>As for E £28.18.0</td>
</tr>
<tr>
<td>F</td>
<td>40+40 watts RMS deluxe stereo amplifier</td>
<td>Two Z.60s, Stereo 60 PZ.8 and mains transformer</td>
<td>Microphone, up to 4 P.A. speakers, 12 Volt battery with converter, or 45 V d.c., controls £32.17.6</td>
</tr>
<tr>
<td>G</td>
<td>Outdoor public address system</td>
<td>Z.50</td>
<td>Microphone, up to 4 P.A. speakers, 12 Volt battery with converter, or 45 V d.c., controls £6.8.9</td>
</tr>
<tr>
<td>H</td>
<td>Indoor P.A.</td>
<td>One Z.50, PZ.8 and mains transformer</td>
<td>Microphone, guitar, heavy duty speakers etc., controls £17.8.6</td>
</tr>
<tr>
<td>J</td>
<td>High pass and low pass filters</td>
<td>AFU</td>
<td>D, E or F as above £5.19.8</td>
</tr>
<tr>
<td>K</td>
<td>Stereo F.M. tuner</td>
<td>To be released shortly</td>
<td></td>
</tr>
</tbody>
</table>

How to assemble and use Project 60 modules to best advantage in the above and other applications will be found in the fully descriptive Project 60 manual included with Project 60 systems. This 48 page manual is available separately, price 2/6d including postage.

WW—117 FOR FURTHER DETAILS
**Z.30 & Z.50 POWER AMPLIFIERS**

The Z.30 together with the Z.50 are both of advanced design using silicon epitaxial planar transistors to achieve unsurpassed standards of performance. Total harmonic distortion is an incredibly low 0.02% at full output and all lower outputs. Whether you use the Z.30 or Z.50 power amplifiers in your Project 60 system will depend on personal preference, but they are the same physical size and may be used with other units in the Project 60 range equally well. For operating from mains, for the Z.30 use PZ.5 for most domestic requirements, or PZ.6 if you have very low efficiency loudspeakers. For Z.50, use the PZ.8 described below.

![Z.30 & Z.50 Power Amplifiers](image)

**SPECIFICATIONS** (Z.50 units are interchangeable with Z.30s in all applications.)

**Power Outputs**

- Z.50: 40 watts R.M.S. into 3 ohms from 40 volts: 30 watts R.M.S. into 8 ohms, using 50 volts.

**Frequency response** 30 to 300,000 Hz ± 1dB

**Distortion** 0.02% into 8 ohms

**Signal to noise ratio** better than 70 dB unweighted

**Input sensitivity** 250mV into 100 Kohms.

**Size** 31 x 21 x 8 ins.

Curve shows power versus distortion for Z.30 and Z.50.

---

**STEREO 60 Pre amp/Control Unit**

Designed for the Project 60 range but suitable for use with any high quality power amplifier. Again silicon epitaxial planar transistors are used throughout, achieving a really high signal-to-noise ratio and excellent tracking between channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs.

**SPECIFICATIONS**

- **Input sensitivities**
  - Radio - up to 3mV
  - Mag. p.u. - 3mV: correct to R.I.A.A. curve ± 1dB. 20 to 25,000Hz. Ceramic p.u. - up to 3mV: Aux. - up to 3mV
  - Output - 250mV. Signal to-noise ratio - better than 70 dB.
  - Channel matching - within 1 dB.
  - Tone controls - TREBLE -15 to +15dB at 10kHz: BASS -15 to +15dB at 100Hz.
  - Front panel - brushed aluminium with black knobs and controls.

**Size** 81 x 11 x 4 ins.

Built, tested and guaranteed £9.19.6

Curve to show bass and treble cut and boost.

---

**ACTIVE FILTER UNIT**

For use between Stereo 60 unit and two Z.30s or Z.50s, the Active Filter Unit matches the Stereo 60 in styling and is as easily mounted. It is unique in that the cut-off frequencies are continuously variable, and as attenuation in the rejected band is rapid (12dB/octave), there is less loss of the wanted signal than has previously been possible. Amplitude and phase distortion are negligible. The Sinclair A.F.U. is suitable also for use with any other amplifier system. Two stages of filtering are incorporated - rumble (high pass) and scratch (low pass). Supply voltage -15 to +35V. Current -3mA. H.F cut-off (-3dB) variable from 28kHz to 5kHz. L.F cut-off (-3dB) variable from 25Hz to 100Hz. Filter slope, both sections 12dB per octave. Distortion at 1kHz (35V supply) 0.02% at rated output.

Built, tested and guaranteed £5.19.6

---

**POWER SUPPLY UNITS**

The units below are designed specially for use with the Project 60 system of your choice. Illustration shows PZ.5 power supply unit to left and PZ.8 (for use with Z.50s) to the right. Use PZ.5 for normal Z.30 assemblies and PZ.6 where a stabilised supply is essential.

- **PZ-5** 30 volts unstabilised £4.19.6
- **PZ-8** 45 volts stabilised £5.19.6
- **PZ-6** 35 volts stabilised £7.19.6
- **PZ-8 mains transformer** £5.19.6

---

**GUARANTEE** If within 3 months of purchasing Project 60 modules directly from us, you are dissatisfied with them, we will refund your money at once. Each module is guaranteed to work perfectly and should any defect arise in normal use we will service it at once and without any cost to you whatsoever provided that it is returned to us within 2 years of the purchase date. There will be a small charge for service thereafter. No charge for postage by surface mail. Air mail charged at cost.

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**To: SINCLAIR RADIONICS LTD., 22 NEWMARKET RD., CAMBRIDGE**

Please send NAME ADDRESS

for which I enclose cash/cheque money order

WW—118 FOR FURTHER DETAILS
**Sinclair IC-10**

The world’s most advanced high fidelity amplifier

**Specifications**
- **Output**: 10 Watts peak, 5 Watts R.M.S. continuous
- **Frequency response**: 5 Hz to 100 KHz ±1dB
- **Total harmonic distortion**: Less than 1% at full output.
- **Load impedance**: 3 to 15 ohms.
- **Power gain**: 110dB (100,000,000,000 times) total.
- **Supply voltage**: 8 to 18 volts.
- **Size**: 1 x 0.4 x 0.2 inches.
- **Sensitivity**: 5mV.
- **Input impedance**: Adjustable externally up to 2.5 M ohms.

**Circuit Description**
The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. Class A/B output is used with closely controlled quiescent current which is independent of temperature. Generous negative feedback is used round both sections and the amplifier is completely free from crossover distortion at all supply voltages, making battery operation eminently satisfactory.

**Applications**
Each IC-10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity. These include stabilised power supplies, oscillators, etc. The pre-amp section can be used as an R.F., or I.F. amplifier without any additional transistors.

---

To: SINCLAIR RADIONICS LTD., 22 NEWMARKET RD., CAMBRIDGE

Please send

NAME
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SINCLAIR IC-10 with IC-10 manual
Post free. 59/6

Sinclair
At the International Audio and Music Fair, Olympia, Stand 44
**Q.16 High fidelity loudspeaker**

Developed out of the revolutionary and much praised design of the original Sinclair Q.14 comes this more advanced version to meet the requirements of even greater numbers of high fidelity enthusiasts. The Q.16 employs the same well proven acoustic principles in which a special driver assembly is meticulously matched to the physical characteristics of the uniquely designed housing. In reviewing this exclusive Sinclair design, technical journals have been loud in their praise for it and it comfortably stands comparison with very much more expensive loudspeakers. The shape of the Q.16 enables it to be positioned and matched to its environment to much better effect than is the case with conventionally styled enclosures, and with its improved styling, the Q.16 presents an entirely new and attractive appearance. A solid teak surround is used with a special all-over cellular black foam front chosen as much for its appearance as for its ability to pass all audio frequencies unimpaired. The Q.16 is compact and slim and is the ideal shelf-mounted speaker, and brings genuine high fidelity within reach of every music lover.

**Specifications**

**Construction:**
A sealed seamless sound or pressure chamber is used with internal baffle, all of materials carefully chosen to ensure freedom from spurious tone coloration.

**Loading:**
Up to 14 watts R.M.S.

**Input impedance:**
8 ohms

**Frequency response:**
From 60 to 16,000Hz, as confirmed.

**Driver unit:**
Specially designed high compliance unit having massive ceramic magnet of 11,000 gauss, aluminium speech coil and special cone suspension. Excellent transient response is achieved.

**Size and styling:**
9½" square on face x 4½" deep with neat pedestal base. Black all-over cellular foam front with natural solid teak surround.

**Price:**
£8 19 6.

---

**Micromatic** Britain’s smallest radio

Considerably smaller than an ordinary box of matches, this is a multi-stage A.M. receiver meticulously designed to provide remarkable standards of selectivity, power and quality. Powerful A.G.C. is incorporated to counteract fading from distant stations; bandspread at higher frequencies makes reception of Radio 1 easy at all times. Vernier type tuning plus the directional properties of the self-contained special ferrite rod aerial makes station separation very much easier than with many larger sets. The plug-in high fidelity type magnetic earpiece which matches exactly with the output of the Micromatic provides wonderful standards of reproduction both for speech and for music. Everything including the batteries is contained within the attractively designed case. Whether you build your Micromatic or buy it ready built and tested, you will find it as easy to take with you as your wristwatch, and dependable under the severest listening conditions.

**Specifications**

**Size:**
1½" x 1½" x ⅞" (46 x 33 x 13mm).

**Weight including batteries:**
1 oz. (28.35gm) approx.

**Tuning:**
Medium wave band with bandspread at higher frequency end.

**Earpiece:**
High-fidelity magnetic type.

**Battery requirements:**
Two Mallory Mercury Cells, type R.M. 675, for long working life.

**Case:**
Black plastic with anodised aluminium front panel, spun aluminium dial.

**Controls:**
Tuning dial, and on/off switching by means of earpiece plug.

**Price:**
Available in kit form complete with earpiece, case, instructions and supply of solder in fitted pack. 49½.

Ready built, tested and guaranteed. 59½.

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Sinclair Radionics Ltd, 22 Newmarket Road, Cambridge  Telephone 0223 52731

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For Educational, Professional and Home Constructors

<table>
<thead>
<tr>
<th>Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>AP105 50/volt multimeter (illus.)</td>
<td>£6.10.0 p/p 3/6.</td>
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<td>Leather case 3/6.</td>
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<td>300M 20/volt.</td>
<td>£6.17.6 p/p 3/6.</td>
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<td>Case 1/6.</td>
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<td>Case 30/6.</td>
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<td>TML 35 2xvolt.</td>
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<tr>
<td>Leather case 12/6.</td>
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<tr>
<td>TE15ui Valve voltmeter (illus.)</td>
<td>£11.10.0 p/p 7/6.</td>
</tr>
<tr>
<td>Price £11.10.0 p/p 7/6.</td>
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<tr>
<td>VM51 Transistorised AP/K multivoltmeter</td>
<td>£63.90.</td>
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<tr>
<td>Price £63.90.</td>
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<tr>
<td>TE30D RF generator (illus.)</td>
<td>Price £15.6 p/p 7/6.</td>
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<tr>
<td>Price £15.6 p/p 7/6.</td>
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<tr>
<td>TE21D Matching audio generator</td>
<td>£17 p/p 7/6.</td>
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<tr>
<td>Price £17 p/p 7/6.</td>
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<tr>
<td>TE15 Grid dip meter</td>
<td>Price £18.0 p/p 3/6.</td>
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<td>Price £18.0 p/p 3/6.</td>
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<tr>
<td>TO31 Scop (illus.)</td>
<td>£37.10.0</td>
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<td>Price £37.10.0</td>
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<tr>
<td>ORC12A, WEIN BRIDGE RC AUDIO OSCILLATOR</td>
<td>Price £30.</td>
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<td>Price £30.</td>
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STC TIME DELAY MODULE


ELECTRONIC ORGANS

<table>
<thead>
<tr>
<th>Description</th>
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<tr>
<td>MODERN ALL BRITISH TRANSISTORISED DESIGNS AVAILABLE AS KITS OR READY BUILT</td>
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<tr>
<td>VENEREATED CABINETS FOR ALL MODELS</td>
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<tr>
<td>9 NOTE, 41 NOTE SINGLE MANUAL DESIGNS ALSO TWO MANUALS: 41 NOTE</td>
<td></td>
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<tr>
<td>KITS AVAILABLE IN SECTIONS AS REQUIRED</td>
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<tr>
<td>HP AND CREDIT SALE FACILITIES</td>
<td></td>
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</tbody>
</table>

When in London call in and try for yourself. Let us quote for all your organ component requirements.
NEW HYSERESIS MOTORS BY WALTER JONES. Type 14050/12, 24v, 50 c/s 1550 RPM cont. rated. 20 amp. Current seizure. 2 r.p.m. 1/10 inch single. Price £14.50 each. Carr. Paid.

THORN DIGITAL INDICATOR. A modular unit easily read through glass screen even under bright lighting. 12 characters, 0 to 9, decimal point and minus sign. The units of the characters 13/16 high on acrylic, ledge-like for 1 watt mains operation. Shelf panel 4" x 11", depth overall 1", matt black finish. Supplied with 12 lamps. Choice of the following ratings: 6V, 0.1A, 0.06W. £6.00 each, spare lamps 24/- a pair. Carr. Paid.

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MINIATURE "LATCH-MAK" RELAY. Type L25D, 300-250v, A.C. Non-reversing. One make on break. Price £3.00 each, 12-volt. 30v. Once current is applied, relay holds in position until input polarity is reversed. Manufactured in special quantities by Sperry Gyroscope Co. Ltd. 3ins long, 5/16" dia. (excluding pins). Please state vertical or horizontal position on order. £2.50 each. Carr. Paid.

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NEW "CATER ELECTRIC" 12 r.p.m. MOTOR. Non-reversible. 1" spindle. 24v, A.C. Open frame with cast aluminium cooled housing. Sturdy constructed. Approx. 25 lbs. 1.0 amp. Overall size (approx.) 3" x 3" x 4" plus spigot. 45/-, P. & P. 3/-.

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BUSINESS HOURS: 264 PENTONVILLE ROAD, LONDON, N.1 9.30-6 (1 p.m. Sat.s.) (ONE MIN. FROM KINGS X STATION) Tel. 01-837 7401

NEW CARTRIDGE ELECTRIC. 12 r.p.m. MOTOR. Non-reversible. 1" spindle. 24v, A.C. Open frame with cast aluminium cooled housing. Sturdy constructed. Approx. 25 lbs. 1.0 amp. Overall size (approx.) 3" x 3" x 4" plus spigot. 45/-, P. & P. 3/-.

MINIATURE "LATCH-MAK" RELAY. Type L25D, 300-250v, A.C. Non-reversing. One make on break. Price £3.00 each, 12-volt. 30v. Once current is applied, relay holds in position until input polarity is reversed. Manufactured in special quantities by Sperry Gyroscope Co. Ltd. 3ins long, 5/16" dia. (excluding pins). Please state vertical or horizontal position on order. £2.50 each. Carr. Paid.

NEW DIAMOND "H" 240v. A.C. ELECTRICAL PANEL LAMPS. Type 14080/12, 24v, 50 c/s 1550 RPM cont. rated. 20 amp. Current seizure. 2 r.p.m. 1/10 inch single. Price £14.50 each. Carr. Paid.

NEW "CATER ELECTRIC" 12 r.p.m. MOTOR. Non-reversible. 1" spindle. 24v, A.C. Open frame with cast aluminium cooled housing. Sturdy constructed. Approx. 25 lbs. 1.0 amp. Overall size (approx.) 3" x 3" x 4" plus spigot. 45/-, P. & P. 3/-.

THORN DIGITAL INDICATOR. A modular unit easily read through glass screen even under bright lighting. 12 characters, 0 to 9, decimal point and minus sign. The units of the characters 13/16 high on acrylic, ledge-like for 1 watt mains operation. Shelf panel 4" x 11", depth overall 1", matt black finish. Supplied with 12 lamps. Choice of the following ratings: 6V, 0.1A, 0.06W. £6.00 each, spare lamps 24/- a pair. Carr. Paid. Quantity discounts on application.


MILBASE—3 in. Synchro Magdip. Type E191-615/101/50v. 50 Hz. Recent manufacturer in original makers packing. £16 pair.


SERVO POTENTIOMETERS

New precision linear linear potentiometers. £5.50 per unit. £75.0. Carr. Paid. Continuous track. £3.50 each. Carr. Paid.

PENNY & GILES. Size 15.0. Type Q2621-271. Continuous track. £2.50 each. Carr. Paid.

SERVO POTENTIOMETERS

Beckman, Type A250. 10 turn. £15.0. Ring Len. ±0.01% 500V. £5.0. Carr. Paid.


NEW DIAMOND "H" 240v. A.C. ELECTRICAL PANEL LAMPS. Type 14080/12, 24v, 50 c/s 1550 RPM cont. rated. 20 amp. Current seizure. 2 r.p.m. 1/10 inch single. Price £14.50 each. Carr. Paid.

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SEIMS HIGH SPEED RELAY. Type 89L, 1,700121 to 1,700121 coil. New 15/- each. Carr. Paid.


BACO Rotary rheostat. Type L25. 100 g. 28 watts. 1.5 in. dia. in spigot. 12/- each. P. & P. 2/-.

TIME ELAPSED REGISTER. This robust and accurate instrument functions 24v, D.C. Has a clock with a time of 1 hour (60 min. 1 min.) metering. Total of 36,000 hrs. Non-reant sealed unit, chrome bezel, through mounting. 7 x 3 3/4 in. overall. 65/-, Carr. Paid.

ATLAS MIDGET PANEL LAMPS un-charged for sale requiring a brilliant but tiny light source. Available with flat, round or angled leads. White glass bulb, 12 volt 1/10 amp. 50 c/s. Small size 1/2" dia., 1 1/8" long, price each 10/-; large size 1/2" dia., 1 1/8" long, price each 15/-; in white porcelain, price each 20/-; indicator lamp holders and caps for midget panels. Also stocked available red, green, blue, 25x each (complete) minimum order 4 units.

Sylvania circuit breakers gas filled providing a fast thermal response between 60° and 100°. With withstand impulse up to 2,000 lbs. sq.in. rated 10 amp. at 240v. continuous. Fault currents of 28 amps. at 250v. 12v. 0.5 amp. coated to head, type IHMGD125 (size 15). Ratio 100. £5.0. Carr. Paid. Original maker packing. £10.0. Carr. Paid. Quantity discounts on application.

New 75-0.75 Microamperemeter by Sifam. 750. ohm movement, their reading. Sja divisions x 1 plastic front, projecting, lift-off base. 75/-, each. Carr. Paid.

ALSO LIMITED NUMBER OF THE FOLLOWING:

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ELENIC INDICATOR LAMPS AND CAPS FOR MIDGET PANELS. Also stocked available red, green, blue, 25x each (complete) minimum order 4 units.

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RESISTORS:

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<th>Type</th>
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<td>Carbon</td>
<td>1/2W</td>
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PAPER CONDENSERS:

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<td>TV, 500V</td>
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ELECTROLYTIC CONDENSERS:

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<tr>
<td>31 Mains radio/T/V</td>
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<td>Transistor types</td>
<td>20</td>
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<td>Mixed high/low voltage</td>
<td>15</td>
<td>10/-</td>
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<tr>
<td>20µF D.C. Electrolyt</td>
<td>50</td>
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<tr>
<td>MULLARD POLYESTER CONDENSERS</td>
<td>80</td>
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<tr>
<td>SILVER MICA</td>
<td>100</td>
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<tr>
<td>WIRE-WOUND PRE-SET SLIDERS</td>
<td>15</td>
<td>10/-</td>
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<tr>
<td>VOLUME CONTROLS: Double, Mixed</td>
<td>5</td>
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NUTS AND BOLTS:

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<tr>
<td>B A.</td>
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<td>100</td>
</tr>
<tr>
<td>Metal speaker grilles: 7in. X 3½ in.</td>
<td>2</td>
<td>10/-</td>
</tr>
<tr>
<td>V.H.F./F.M. TUNERS: Need EEC85</td>
<td>10</td>
<td>10/-</td>
</tr>
<tr>
<td>VEROBOARD: Cutter 5⅜ 2¼ in. x 1½ in. Bds.</td>
<td>10</td>
<td>10/-</td>
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G. F. MILFORD, Drayton Bassett, Tamworth, Staffs. Postage (minimum) per order 2/-.
**Mains TRANSFORMERS**

Note all these are first grade Transformers and all have full mains and waveform protection.

1. **230v. 60Hz. Transformer**
   - Upper mounting: size 3 x 14 in., approximately 1 watt, 0.46 A.C. size 2 x 2 x 2 in. 1.5 amp. Earth screen between primary and secondaries. This transformer will operate within its rated power diagram available, price £2. Suitable output transformer is type 5694, price £2.90.

   **Mains Transformer Type No. 45732**
   - Chassis mounting: size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   **Mains Transformer Type No. 56694**
   - Chassis mounting: size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.

   **OUTPUT TRANSFORMERS**
   - Chassis mounting: size 3 x 14 in., approximately 1 watt. A, size 2 x 2 in., 10 amp. E. and similar valves. Price 2/6 each.

   **Mains Transformer Type No. 5694**
   - Chassis mounting: size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.

   **Mains Transformer Type No. 56695**
   - Chassis mounting: size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.

   **TRANSFORMER**
   - Size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.

   **Mains Transformer Type No. 56894**
   - Chassis mounting: size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.

   **TRANSFORMER**
   - Size 3 x 14 in., 2 secondaries one 50 volt at 40 mA and other 6 volt at 60 mA. Earth screen supplied and protection diagram available, price £2.90. Suitable output transformer is type 5694, price £2.90.

   Price 2/6 each.
HIGH STABILITY DC LABORATORY POWER SUPPLY UNIT

Type NOBATRON by Sorensen of U.S.A.

MODELS:

GRC—40—8A i/p 110-120V 50 Hz o/p 0-40V at 8 amps. £126.

DCR—40a—10A i/p 200-240V 50 Hz o/p 0-40V at 10 amps. £160.

DCR—150–5A i/p 200-240V 50 Hz o/p 0-150V at 5 amps. £190.

These are modern slim line rack mounting units incorporating many desirable features such as overload protection etc. Carriage extra.

MUTUAL INDUCTANCE BOX

TYPE R.7005

Specification Range: 0.11-100 mH in 0.002 mH divisions. Accuracy: ± (0.3 ± 0.012%) M/

where M = value of mutual inductance in mH set on the box. Frequency range: 0.25-2 KHz for all decades except 1 = 0.15 KHz. Maximum current: 0.5A for decades 1A for var icommeter (both primary and secondary windings). Case: Polished teak. List price £65. Our price £17.10.0.

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Delay of 3.3 to 129.2 micro second 4 ohm. Length: 2 ft. x 1 in. £23.10.0.

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Alum Resistor Type NRC 501/120, 120 ohm coil. £3. P. & P. 15.0. Windless Mini Relay type ICR 100/15.0. £3. P. & P. 15.0.

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PROGRAMME SWITCH

By General Electric. Model 01 101 consists of a Bode as at key 1 10 isom 100 in 1960 £108.0. P. & P. 15.0.

TRANSITOR AMPLIFIER

Type 7A-150 to 0.5 W. Full spec. £4. P. & P. 15.

CODER SHAFT POSITION


MULTIPLEXER


ANALOGUE—DIGITAL CONVERTER

Unicorder type UCD 101. £95.10.0. £195. P. & P. 50.

ACCELEROMETERS

Model LA 3 K Potentiometer ± or 100-1000 operating Voltage 10V. 1,000 resistance. £4.50. £15.0. Megger 0.5 A type LA 9 6- or — 1000 24V. 0.5. £38. £125. P. & P. 50.

CALIBRATION PHASE METER

By Perkin Elmer. Range 200-1,000 ohm. 0/10/100. £230.0. P. & P. 50.

MAGNETIC AMPLIFIER


MOTORS

LOW TORQUE HYSTERESIS MOTOR M231

Ideal for laboratory chart drive. Extremely quiet, useful in cases where murmur motor would be a. Sine wave distortion less than 1% at 1W. Dimensions 120mm. £25. P. & P. 50.

SYNCHRONOUS MOTORS


DATA TRANSMISSION—SYNCHROS

A selection from our wide range

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<th>Current</th>
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8 DIGIT UNIVERSAL COUNTER TIMER MODEL 1037-5


HYSTERESIS REVERSIBLE MOTOR

Incorporating two coils. Each coil when energized will produce opposite rotation of output shaft. 1900 50 Hz, 110/120 V, 50 Hz. Price £7.00. P. & P. 50.

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193 CRYSTAL CONTROLLED OSCILLATOR STC. 16-LUX 50A

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(204) NOISE GENERATOR CT 410 WAYNE HERR

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(210) NEW AUTOMATIC CYCLING OSCILLATOR ACOL 12

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(D.C. TACHOGENERATOR

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8 LOW FREQUENCY DECADE OSCILLATOR D-840-B

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(149) WOBULATOR OM 2877/02 PHILLIPS

Range 5 Hz -10 MHz. £125. P. & P. 50.

(188) SIGNAL GENERATOR CT 480 SANDERS. Range 7 KHz-100 MHz. £175. P. & P. 50.

(179) WAVEFORM SHAPER MK 200 GRASS.

Input 120 V, 50/60 Hz. £125. P. & P. 50.

(141) FM FREQUENCY MULTIPLEXER-PYE. Range 100-1 MHz. £175. P. & P. 50.

(146) SIGNAL GENERATOR CT 480 SANDERS. Range 5 Hz-100 MHz. £175. P. & P. 50.

8 KHz. £45. P. & P. 50.

(179) WOBULATOR OM 2877/02 PHILLIPS

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The clock will automatically turn off any appliance—radio, TV, light, etc. at any pre-set time up to 60 min. and in conjunction with the AUTO setting will switch on the appliance again next morning.

The clock measures 4.5W x 1 (H x 3D) lowwall from front of drum to back of switch. SPEC: 210/240V AC, 50/60 Hz, operating voltage 250V, 3A. Complete with instructions. NUMERALS OF APPLICATIONS: COMPLETE WITH KNOBS

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- DCV: 0-15-150-300-1200 at 2K ohms/V
- ACV: 0-6-30-300-1200 at 2K ohms/V
- DC CURRENT: 0-30mA, 0-1A, 0-10A
- Resistance: 0-150K ohms
- Ohms: 100-1000 ohms

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20,000 O.P.V. Multimeter. Features 24 measurement ranges with mirror scale. Large 3 x 2 in. meter. Full scale accuracy. DCV and current: ± 2% ADVC ± 3%. Resistance: ± 3%. Special 0.6V DC range for transistor circuit measurements.

SPECIFICATION:
- DCV: 0-0.6-3-15-30-60-120-300-1200 at 10K ohms
- ACV: 0-6-30-300-1200 at 10K ohms
- DC CURRENT: 0-30mA, 0-1A, 0-10A
- Resistance: 0-150K ohms
- Ohms: 100-1000 ohms

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**INTEGRATED CIRCUITS**

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**VIDEO OSCILLOSCOPE TF 950A A &**

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**AVO VALVE CHARACTERISTIC METER complete with**

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**AVO SIGNAL GENERATOR CT 37F, 10 MHz, sine and pulse modulation**

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**SOLARTRON EQUIPMENT**

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**TRANSMITTERS E7 4336**

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**IMPEDBANCE BRIDGE TYPE TF 316 (No. 0). Measures L & C at 20kHz, 1kHz, 10kHz, Ranges:- L: 10-100, C: 0-100pF.**

**MARCONI TEST EQUIPMENT**

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**FIELD TELEPHONE TYPE "PF".**

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**P. C. RADIO LTD.**

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**ALL VOLTAGE IN STOCK includes Gallahad Ray Tubes and ELECTRICAL VALVES, U.K. made only, over 11/- in stock free. C.O.D. 0/- in stock.**

**PLEASE NOTE**

Unless offered as "as seen" ALL EQUIPMENT ordered from us is completely overhauled mechanically and electrically in our own laboratories.
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Individually spec. with each unit. £10 ea.

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**KLYSTRON POWER SUPPLY** (Elliot PKU1). £120

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"E.MI." 10 x 14 in. 50 watts 8 ohm (144/500A). Four
speakers mounted on a single main axis. Separate "X-over
unit balances both bass and f, s. 20 Hz to 20,000 Hz.
Rise time 0.005 sec. A truly magnificent system.

"FANE" 12 in. 20 watt 15 ohm. (122/10A). With integral
transducer and Spring mounting. Price £25. P.P. 10/-. 

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housing. 240V. Brand new. £6.

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4 contact covers. 24v. 500 ohm 7/8v.

**PRECISION CABLES** (Special manufacture). Beautifully made
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Type 2. 2.20 ft. 3. £6. P.P. 3/-.

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Banner pack of 5 boards. Components too varied to enumerate. At least 100 transistors and diodes. £2.

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**H.T. TRANSFORMERS. Prim. 200/240v. Sec. 300-0-300v.
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**L.T. TRANSFORMER.** Prim. 240v. Sec. 33-33v, 5
amps. 48v. P.P. 10/-. £5. P.T. 15/-.

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**L.T. TRANSFORMER.** Prim. 240v. Sec. 115v. 1/- 2/0.

**L.T. TRANSFORMER.** Prim. 240v. Sec. 115v. 1/- 2/0.

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**REFERENCES**

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Banner pack of 5 boards. Components too varied to enumerate. At least 100 transistors and diodes. £2.

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**RELAYS (Carr.) 1000A**. All types. Brand new.
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Weight 4 oz. Type 1. 950 ohm, 3/f. 1/-. Type 2 1600 ohm, 3/f, 1/-.

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Rhode & Schwarz BN1105(2) standard Attenuator 0.1µ to 500 ohm
0.1µ—600Mhz
0.1µ—400MHz. Price £70.
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Happy Stabilised P.S.U. Model MSB 24/2.

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35G envelope, with flying lead connections. Easily removed. BRAND NEW. Price £10.0.0.

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**MUIRHEAD DECADE OSCILLATOR** Type GSK1 Model 99B 500 kHz. This Precision Instrument has an accuracy of ±5 parts in 106. Standard range of 1 cps to 111.000 KHz. Continuously variable frequency range ±20% from 10 KHz to ±1% of full range. Price £350. Our Price £250. 

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EX COMPUTER PRINTED CIRCUIT PANELS 3" x 4" packed with semiconductors and two quality resistors, capacitors, diodes, etc. Our price, 10 boards 10/-, P. & P. 1/-.

100/100
diagram issued. Transistor Diodes included.

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Code Power Tolerance Range Values

C 1/2W 5% 1.0E-320/46(3)
C 1/2W 10% 1.0E-320/46(3)
C 1/2W 10% 1.0E-320/46(3)
C 1/2W 10% 1.0E-320/46(3)
C 1/2W 10% 1.0E-320/46(3)
M 1/2W 10% 1.0E-320/46(3)
W 1/2W 10% 1.0E-320/46(3)
W 3W 1.0E-320/46(3)
W 3W 1.0E-320/46(3)
W 3W 1.0E-320/46(3)
W 3W 1.0E-320/46(3)

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Please note: only decades of 10, 22 and 47 are available (see below note)


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Input sensitivities: CER, P.U. 100mV into 3 meg ohms.
Total distortion: @ 1 kHz @ 9 watts 0.5%.

**Specification:**
- Output per channel: 10 watts r.m.s.
- Frequency bandwidth: 20 Hz to 20 kHz ± 1 dB @ 1 watt
- Total distortion: @ 1 Hz @ 9 watts 0.5%
- Input sensitivities: CER, P.U. 100mV into 3 meg ohms.
- Tuner 100mV into 100K ohms.
- Tape 100mV into 100K ohms.

**Input to noise ratio:** 70 dB on all inputs (with vol. max).
**Output sockets:** on each channel.
**Signal to noise ratio:** 70 dB on all inputs (with vol. max).
**Overload Factor:** Better than 26 dB.

High fidelity transistor stereo amplifier employing field effect transistors. With this feature & accompanying guaranteed specifications below, the Viscount F.E.T. vastly surpasses amplifiers costing far more.

**DESIGN FEATURES**
- 7-transistor fully-discrete M.W.-L.W. system.
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- Sensitive, reliable, compact.
- High Permanence: 50 WATT AMPLIFIER.
- Size: 12” x 6” x 2” in teak-finished case. Bowl: £41.00 plus 12.10 P & P. Complete stereo system £41.00 plus 12.10 P & P.
- Circuit 2/6 FREE WITH PARTS.

**50 WATT AMPLIFIER**
- AC MAINS 200-250V £28.10s.

**ALL TRANSISTOR**
- Extremely reliable general purpose valve amplifier.
- For speech or broadcasting circuits operating at lower power levels.

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- T.90 watts Pre-aligned I.F. module and tuner together with comprehensive instructions guarantees success first time.
- 12 volts negative or positive earth. Size 7" x 2" x 4½" deep.

**Complete Stereo System £41**
A WIDE SELECTION OF SERVOMOTORS NOW AVAILABLE INCLUDES THE FOLLOWING TYPES:

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LATEST RELEASE OF RCA COMMUNICATION RECEIVERS AR88


Same model as above in secondhand condition (guaranteed working order), from £45 to £60, each.

*SET OF VALVES: new, £3 10/- a set, post 7/-; SPEAKERS: new, £1 each, post 10/-; HEADPHONES: new, £1 5/- a pair, 600 ohms impedance. Post 5/-.

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MARCONI SIGNAL GENERATOR TYPE TF-144G: Freq. 85 Kc/s-25Mc/s in 8 ranges. Incremental: ± 1% at 1Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 100 millivolts, 10 ohms 100v-1 volt—52.5 ohms. Internal Modulation: 400v/sine wave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250v, 40-100C/s. Consumption approx. 40 watts. Measurements 19x4 12x10 in. Secondhand condition. £25 each, 30/-.

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50-60c/s, 500 watts. 7" x 5" x 5". Mounted in steel ventilated case. £3 each, steel case 5" x 6f" x 7". Bitumin impregnated. £5 each, Carr. 12/6.

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**CONTROl PANEL: 230 v. A.C., 24 v. D.C. @ 2 amps, £2/10/- each, carr. 12/6.

**OMITTE VARIABLE RESISTORS**: 5 ohms, 51 amps; or 2.6 ohms at 4 amps. Price 1/- each.

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- 1 amp D.C. 50/8
- 1 amp A.C. 50/8
- 5 amp A.C. 50/8
- 20 amp A.C. 50/8
- 100 amp A.C. 50/8
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- Square fronts

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- 6V, D.C. 50/8
- 6-0-2V D.C. 0/50/8
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*Moving iron — all others moving coil.* Please add postage.

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 Assumes small range output 100 Hz to 300 MHz. £20. P. & P. 5/-.

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**WIRELESS World**, October 1970

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**MARCONI TF34M BEAT FREQUENCY OSCILLATORS**

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QUALITY + 

Allen Bradley resistors are selected by most of the World's manufacturers of really top class instrumentation and this includes the APOLLO Moon shot equipment and similar projects where component failure is unthinkable.

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Orders can usually be shipped ex-Milwaukee within ten days. If you can't wait that long, extensive stocks are held closer by in London and Manchester. Write or phone for an up to date stock list.

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Our Price Only £7 5/0

Solve your communication problems with this new 4-Station Transistor Intercom system (1 master and 3 subs), in de luxe plastic cabinets for desk or wall mounting. Call, talk, or listen from Master to Subs and Subs to Master. Operates on one 9v battery. On/Off switch. Volume control. Ideally suitable to modernise Office, Factory, Workshop, Warehouse, Hospital, Shop, etc., for instant inter-departmental communications. Complete with 3 connecting wires, each 66ft. and other accessories. Nothing else to buy. P. & P. 7/6 in U.K.

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A top quality DE-LUXE transistorised intercom consists of MASTER and SUB for desk/wall mounting. Call, talk, or listen from either unit. On/Off switch, volume control. Ideally suitable as "BABY SITTER" or Door Phone. A boon for cripples and invalids. Useful in the home, surgery or business for instant 2-way conversations, effective range 200ft. Unsurpassed in QUALITY AND PERFORMANCE. Complete with 66ft. connecting lead. Battery 2/6 extra. P. & P. 4/6. Price Refund if not satisfied in 7 days.

Why not increase efficiency of Office, Shop and Warehouse with this incredible DE-LUXE Portable Transistor TELEPHONE AMPLIFIER which enables you to take down long telephone messages or converse without holding the handset. A useful office aid. A must for every telephone user. Useful for hard of hearing persons. On/off switch. Volume Control. Operates on one 9v battery which lasts for months. Ready to operate. P. & P. 3/6 in U.K. Add 5/6 for Battery. Full price refunded if returned in 7 days.

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DIGITAL COMPUTER

This is a well proved solid state digital computer, with well over 200 systems sold in the UK and abroad. Reliability has been proved by long periods of operation. It has many advantages, such as low running costs, compact design, automatic programming, extensive libraries of programmes available and a wide variety of input and output devices and auxiliary equipment can be coupled making this system suitable for use in all classes of work.

Typical Configuration:
Central Processor with 4096 Core Store. Type 3 Paper Tape Station. One Tape Reader 500 characters per sec. (Elliott TS/93). One Tape Punch 100 characters per sec. (Teleprinter BRPE E11). Keyboard console and associated desk. Creed Teleprinter. Automatic Floating Point Unit.

PART USED COMPUTERS AVAILABLE SHORTLY
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A well-proven electro-mechanical card punch, with duplicating, spacing, and skipping facilities. Two types of keyboard are available for this model Alpha/Numeric and Alphabetic. The alphabetic largely resembles a typewriter keyboard, enables alpha punching by the operation of one key.
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FEATURES: Motor cut-out switch for clearing card jams. Stop Lever for stopping card at the 80th column. Also available H129 card verifiers.

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Flexowriter programmable automatic writing machine for automatic letter writing. Data preparation work, invoice format paper work, edge punching cards, cutting continuous cards, preparing unit cards, preparing stub cards, reading/punching punched tape. Price from £175.

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3" MAGNETIC TAPE
CERTIFIED 550 B.P.I.
800 B.P.I. ON 2,400-FT. REELS. GUARANTEED REPLACEMENT IF FAULTED. £6.10.0

<table>
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<tr>
<th>1 in. Highest grade 2,400 ft.</th>
<th>£3. 0.0</th>
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<tbody>
<tr>
<td>1 in. 10 in. dia. spool and cassette</td>
<td>£1.10.0</td>
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<tr>
<td>1 in. 8 in. dia. spool and cassette</td>
<td>£1.10.0</td>
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<tr>
<td>1 in. metal 10 in. dia. spool and cassette</td>
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<tr>
<td>1 in. N.A.B. centres 10 in. spool only</td>
<td>£1. 0.0</td>
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ENGLISH ELECTRIC LEO
Lector Automatic Document Reader
A photo electric document reader sensing contrast between marks and background, transposing on to 7 or 8 channel paper tape. Suitable for transcribing order forms, meter reading sheets, stock control forms and market research returns, etc.

TAPE READERS
Photo Electric Readers for all colour paper tape up to 1 in.
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A low cost, simple pocket machine with reject outstitching facilities. Permits data entry into the computer direct from source documents. Handles up to 1,200 documents per minute and is suitable for use with a wide variety of character recognition systems and optical mark reading employing computer printing and/or manual data entry.

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80 COLUMN
The Punch is a table-mounted model punch. For the Serial Punching of alpha-numeric Data, Alpha or Multi Hole Punching is made by depressing two or more keys simultaneously. Also available refurbished ICT 103 80 col. verifiers. With full warranty.

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(NeW) Ceramic construction, wind ing technology in Vitreous Enamel. Heavy duty brush assembly designed for continuous duty. Available from STOCK IN THE FOLLOWING TWO VALUES: 60 Watt (1) 100v. 2 Am, (2) 40v. 1.5 Am, (3) 20v. 3 Am, (4) 10v. 6 Am, (5) 5v. 12 Am, (6) 2.5v. 24 Am, (7) 1.25v. 48 Am, (8) 1.2v. 72 Am. Each £10.5/6 plus 2/- Postage. **DIRECT DELIVERY**

**MINIATURE UNISELECTOR**

3 banks of 11 positions, plus reversing. 240 volt. 40 ohm coil. 24-36 v. D.C. operation. Carefully selected precision manufactured, extensively retested. 2/-, plus 2/- P & P.

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**MINIATURE RELAYS AT COMPETITIVE PRICES, COMPLETE**

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- 9000 70 - 100 6/6

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2 x 1.3 volt 250 MAH Nickel Cad. Cells. Complete with trigger coil, £6/6 plus 2/- P & P. Black Silver Skirted knob calibrated in Nos. 1-9, 1-15 in. dia. bush bracket, push knob and lenses. £2/6 plus 2/- P & P.

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240/250-volt, D.C. operation. Switching unit-junction Timer and S.C.R. (30v. 1.5 amp.) encapsulated in metal case. Timing interval adjustable from a fraction of a second to several hours by means of external resistor or pot. By adding a 24v. Relay many other complex timing functions are possible. Price: £4/6 incl. circuit board, £2/6 plus 2/- P & P. 230/240V A.C. 10 AMP MOTOR (Non Reversible)

Extremely powerful. Continuously rated. Offered at the low price of 95/- each. 100% satisfaction or money back.

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Ideal present for Electromechanical minded boy. Easy to build, solid state. Two full octaves (less sharp and fast). Packed hardwood case, using two pentile 1v. batteries. Complete set of playing speaker, etc., together with full instructions and 10 tunes. Have all the pleasures of building an organ and finish with a musical, functional, gift for any boy or girl. Price £3/6. P & P 4/-

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(Type 1) 11 v. torque, 10 lb. in. Reversible (7000 h.p.) Mini. 38mm. (Type 2) 28 v. torque 20 lb. in. in 1000 rpm. 55 cycle 28 v. amp. The above two precision made U.S.A. motors are offered in the £100 to £150 voltage of 115 v. A.C. Supplied complete with transformer for 230/250V A.C. operation. Price, either type £13.00 plus 6/- P. & P or less transformer £2/9. P & P.

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**VONNER ELECTRIC TIME SWITCH**

200/250 volts. Ex-G.P.O. Tested, surface condition. Two On, two Off, every 24 hrs. It is manually preset by means of a dial. Price 1/9/6 incl. 1/6/6 dial. Also supplied with Solar Dial Off and on at dawn.

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Functionally certified, suitable for bench or field work, complete with 3000 volt 50 cycle 1000 volties, S.T.A. Type S.T.A. particularly suitable for Telecommunications work. £9/6. Each. 500 gauges £17/6. All gauges £15/6. 250 gauges £10/6. All gauges £5/6. Please ask for quotation. We do not sell catalogues or literature only. For Osborne, please ask for quotation. We do not sell catalogues or literature only.
Sea-going Radio Officers can now make sure of a shore job and good pay.

If you’d like a job ashore, at a United Kingdom Coast Station, the Post Office will start you off on £965—£1,215, depending on age, with annual rises up to £1,650 (salaries are under review) and good prospects of promotion to higher posts.

You will need to be 21 or over, with a 1st Class Certificate of Competence in Radiotelegraphy issued by the Postmaster General, or the Ministry of Posts and Telecommunications, or an equivalent certificate issued by a Commonwealth administration or the Irish Republic.

Find out more by writing to:-

GET AHEAD WITH SIEMENS

Siemens, one of Europe’s major growth companies, is expanding fast in Britain. Spearheading this expansion is our electronics business, and so we are always in need of able and ambitious engineers, sales and service men. Even if your specific assignment isn’t listed here, therefore, you are invited to send a brief curriculum vitae. We may have precisely the opportunity for career development you are looking for.

SERVICE ENGINEER
We urgently need a Service Engineer to work on high-quality telecommunications test equipment. This is an important assignment; the successful applicant will have had extensive experience of servicing and calibrating this type of equipment. HNC is desirable, but appropriate experience is more important. The job is based in Croydon, and an attractive salary will be negotiated.

INTERNAL TECHNICAL SALES ENGINEER
(Electronic Components)
A man with a sound technical background in electronic components (min. O.N.C.) is required in our Croydon office. The job entails solving customers' technical problems (frequently by telephone) and liaising between our engineers and works. The successful applicant will be capable of working well under pressure. An attractive salary will be negotiated, appropriate to age and qualifications.

Write to the Personnel Officer at this address:
Siemens (U.K.) Limited, Great West House, Great West Road, Brentford, Middx.
Tel: 01-568 9133
There will be a number of vacancies in the Composite Signals Organisation for experienced Radio Operators in 1971 and subsequent years. Specialist training courses lasting approximately 8 months are held at intervals. Applications are now invited for the course starting in September 1971.

Salary Scales
During training with free accommodation provided at the Training School:

<table>
<thead>
<tr>
<th>Age</th>
<th>Salary (per annum)</th>
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<tr>
<td>21</td>
<td>£848</td>
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<tr>
<td>22</td>
<td>£906</td>
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<tr>
<td>23</td>
<td>£943</td>
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<tr>
<td>24</td>
<td>£981</td>
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<tr>
<td>26 and over</td>
<td>£1,023</td>
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</table>

On successful completion of course:

<table>
<thead>
<tr>
<th>Age</th>
<th>Salary (per annum)</th>
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<tr>
<td>21</td>
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<td>22</td>
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<tr>
<td>23</td>
<td>£1,150</td>
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<tr>
<td>24</td>
<td>£1,214</td>
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<tr>
<td>25 (highest age point)</td>
<td>£1,288</td>
</tr>
</tbody>
</table>

then by 6 annual increments to a maximum of £1,749 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must be United Kingdom residents, normally under 35 years of age at start of training course, and must have at least 2 years’ operating experience or PMG qualifications. Preference given to those who also have GCE ‘O’ level or similar qualifications.

Interviews will be arranged throughout 1971.

Application forms and further particulars from:
Recruitment Officer, Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Glos., GL52 5AJ.
Tel: Cheltenham 21491 Ext. 2270

DIEHL CALCULATING SYSTEMS
require additional ELECTRONIC AND ELECTRO-MECHANICAL ENGINEERS

To maintain a range of electronic/electro-mechanical printing calculating systems in London and the Home Counties. The range includes the Diehl Combitron Desk Computer, Punch tape input/output equipment, and interfacing equipment. Full training will be given to successful applicants who should have either technical background to ONC/HNC level, City and Guilds or Radio/Radar experience in the forces.

Realistic salaries which will be related directly to experience and capabilities. Transport will be provided. Please send full details of experience to:

Service Manager,
Calculating Systems Ltd.,
Pyramid House,
956 High Road, Finchley, N.12.

Design Engineers
TV and Radio
for a well established company having a substantial share of the local markets for radio, radiogram, record player and hi-fi equipment, and now moving into the manufacture of domestic television receivers. These are three new posts to deal with specialist design needs, as follows:

Design Engineer
Car/Portable Radio
to initiate and develop designs and circuits for the mass production of FM/AM radio receivers. Reporting to the Technical Manager he will be responsible for optimising designs by the application of transistor circuitry; he will be supported by drawing office staff and facilities. Candidates should be qualified at HNC level in electrical engineering or electronics and have at least 5 years’ experience in circuit and component design of radio receivers. Reference ZH.1789.

Design Engineer
TV Receivers
to initiate and develop designs and circuits for domestic television receivers for both black and white and colour. Reporting to the Technical Manager he will be responsible for the complete electronic designs of sets to meet local systems. He will be supported by drawing office staff and facilities. Candidates should be qualified at HNC level in electrical engineering or electronics and have at least 5 years’ experience in designing television or associated electronic equipment. Reference ZH.1760.

Industrial Designer
Entertainment Equipment
To co-operate with technical designers in the final designs of radio, TV and similar equipment to suit market trends and local production methods. In this post technical qualifications are less important than the proved ability to modify and dress technical designs to meet sales requirements without degrading their technical performance. Candidates must have at least 5 years’ experience as industrial designers in the light electrical appliances or electronics industries. Reference ZH.1761.

For all three posts the starting salary is negotiable up to £3,000. Free life insurance, contributory provident fund and medical aid scheme. Appointed candidates will be expected to emigrate to South Africa with the assisted passage scheme. Telephone or write to P. H. L. Thomas quoting the appropriate reference.
APPOINTMENTS

If you’re a telecommunications man and match up to the qualifications below cut yourself into a slice of Britain’s future

Become a Radio Technician in the fast-growing world of Air Traffic Control

Please send me an application form and details of how I can join the fascinating world of Air Traffic Control Telecommunications.

Name
Address

Not applicable to residents outside the United Kingdom

To: A J Edwards, C Eng, MIEE, The Adelphi, Room 705, John Adam Street, London WC2 marking your envelope 'Recruitment'

Sending this coupon could be your first step to a job that’s growing in importance every year.

The National Air Traffic Control Service needs Radio Technicians to install and maintain the vital electronic aids that help control Britain’s ever-increasing air traffic.

This is the kind of work that requires not only highly specialised technical skills but also a well developed sense of responsibility, and candidates must be prepared to undergo a rigorous selection process. Those who succeed are assured a steadily developing career of unusual interest and challenge.

Starting salary varies from £1044 (at 19) to £1373 (at 25 or over): scale maximum £1590 (higher rates at Heathrow). There is a good annual leave allowance and a non-contributory pension for established staff.

You must be 19 or over, with at least one year’s practical experience in telecommunications, (‘ONC’ or ‘C and G’ qualifications preferred).

NATCS
National Air Traffic Control Service

Work as a RADIO TECHNICIAN attached to Scotland Yard

You’d be based at one of the Metropolitan Police Wireless Stations. Your job would be to maintain the portable VHF 2-way radios, tape recorders, radio transmitters and other electronic equipment, which the Metropolitan Police must use to do their work efficiently.

We require a technical qualification such as the City & Guilds Intermediate (telecommunications) or equivalent.

Salary scale: £1,161 (age 21), rising by increases to £1,590 plus a London Weighting Allowance. Promotion to Telecommunication Technical Officer will bring you more.

For full details of this worthwhile and unusual job, write to: Metropolitan Police, Room 733 (RT), New Scotland Yard, Broadway, London, S.W.1.

NCR requires additional ELECTRONIC, ELECTRO MECHANICAL ENGINEERS and TECHNICIANS to maintain medium to large scale digital computing systems in London and provincial towns.

Training courses will be arranged for successful applicants, 21 years of age and over, who have a good technical background to ONC/HNC level, City and Guilds or radio/radar experience in the Forces.

Starting salary will be in the range of £900/£1,350 per annum, plus bonus. Shift allowances are payable, after training, where applicable. Opportunities also exist for Trainees, not less than 19 years of age, with a good standard of education, an aptitude towards and an interest in, mechanics, electronics and computers.

Excellent holiday, pension and sick pay arrangements. Please write for Application Form to Assistant Personnel Officer NCR, 1,000 North Circular Road, London, NW2 quoting publication and month of issue.

Plan your future with NCR
RADIO TECHNICAL OFFICERS

Earnings in excess of £2,000 p.a.

The P.L.A. operate a wide telecommunications network from Tower Pier to the outer Thames Estuary, and vacancies exist at the King George V Dock for Radio Technical Officers to maintain the equipment at maximum efficiency.

To ensure adequate coverage, a shift system is operated.

Salary scale: £1,400-£1,520 p.a.


Plus allowance for week-end and public holiday working: £275 p.a.

Payment at enhanced rates for overtime working when required.

Earnings in excess of £2,000 p.a. are possible.

Minimum qualifications:-O.N.C. Electrical Engineering or City & Guilds Intermediate Certificate in Telecommunications Engineering plus Radio II or equivalent Service qualifications.

Applicants should have at least 5 years' experience in semiconductors and in at least two of the following fields:

- V.H.F. and U.H.F. Radio
- Radar and Microwave Links
- Telemetry and Digital
- Teleprinters and Message Switching.

Application forms may be obtained from:

The Chief Engineer (Personnel),
Port of London Authority,
P.O. Box 242, Trinity Square,
London, E.C. 3P 3 BX

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X-RAY SERVICE ENGINEER
(to be stationed in Nairobi, Kenya)

Candidates for this position must be prepared to travel extensively and have a thorough and practical experience with the installation and maintenance of:

X-RAY EQUIPMENT, ELECTRO MEDICAL and HOSPITAL EQUIPMENT

A working knowledge of Electronic Calculators will be an added advantage.

The successful applicant will be on contract for a tour of three years. In the first instance with three months paid overseas leave. Salary will be dependent on experience and qualifications in the scale of K.£1,800—K.£2,100 with an annual bonus payment. Terms include annual local leave, free housing, medical scheme, company's pension fund and car, children and education allowances.

Written applications, giving full details of education, qualifications, age and experience should be forwarded to:

TOM MANAGEMENT LTD
P.O. Box 12186
NAIROBI, Kenya

Interviews for this position will be arranged in the United Kingdom or The Netherlands.

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PORT OF LONDON AUTHORITY

One of the subsidiaries of a large international trading organisation operating in East Africa, requires the services of an:

NEWS IS OUR BUSINESS AT REUTERS—we gather it from all over the world, sift it, edit it, and then get it to our thousands of subscribers just as fast as we can—twenty-four hours a day, every day of the year. We couldn't begin to cope without sophisticated data handling systems and computers. We are dependent on our communications and need more data processing or data transmission engineers to service our equipment comprising the following:

- PDP8 electronic message switching systems.
- STOCKMASTER and electronic brokerage systems, including remote display terminals.
- Reuters international data transmission systems
- Peripheral and ancillary equipment.

Qualifications. Preferably HNC, or equivalent, in relevant subjects. Consideration will also be given to Retiring Service personnel with Service qualifications, or engineers without formal qualifications but trained by a leading computer or communications company.

Experience. Two years or more in the maintenance of digital equipment—Processing, Retrieval or Data Transmission. Preference will be given to applicants who have experience in all three areas of operation.

Salary and Conditions. Starting salary will depend on experience and ability, and holidays and general conditions of employment are among the best in industry. Some vacancies will require shift working on a two shift system which operates from 8-4 and 2-10 alternate weeks. These positions are at our Head Office in London and for those applicants who measure up to our requirements we can promise an interesting and busy life where rewards will match performance.

Write or telephone for an application form, to:

Brian Heywood,
REUTERS Limited,
85 Fleet Street, London, EC4
Telephone: 01-353 6060
**Communications Technicians**

**Home and Overseas**

The Diplomatic Wireless Service requires men capable of working without supervision for the installation, modification, maintenance and operation of (a) radio transmitters and receivers, remotely tuned aerial systems, telexprinters and voice frequency telegraph equipment over a worldwide network, or (b) very high power transmitters, receiving equipment, tape-recorders, generating plant, etc., at several high power broadcasting stations, or (c) a wide variety of telephone subscribers' apparatus, machine telegraph and other specialised equipment, or (d) microwave receivers, associated test equipment, recorders and audio amplifiers, or (e) machine telegraph and electronic ancillaries.

Initial appointment will normally be at Hanslope Park (Bucks), or Crowborough (Sussex) or in London, but successful candidates must be prepared to serve anywhere in the United Kingdom or overseas.

**QUALIFICATIONS:** O.N.C. in Engineering, including a pass in Electrical Engineering, or equivalent standard of technical education; and at least 5 years' appropriate training and experience.

**SALARY (National):** £1,224 (at 21) to £1,352 (at 23) to £1,643 (at 28 or over on entry), rising to £1,839, with prospects of increases to £2,730 on promotion. (London rates are £75 or £125 more). Non-contributory pension.

For full details and an application form (to be returned by 8 October, 1970), write to Mr. M. W. Timmins, Senior Personnel Officer, Wireless World, October 1970

**Installation Design Draughtsmen**

This senior appointment (with appropriate salary) involves responsibility for preparing radio station installation plans and supporting lists of installation materials.

Resulting from expansion of Pye Telecom Radio Systems business, the position demands considerable experience. Probably in your early 30's and having served a workshop apprenticeship, you should have as a minimum O.N.C. or equivalent in mechanical engineering. You'll need in addition a sound background in the mechanical design of light electronic or electrical equipment, preferably in the telecommunications industry; ability to read architectural drawings as applicable to installation design; familiarity with industrial procedures; and awareness of the market position for the supply of proprietary equipment used in large radio installations.

Please write, including details of your previous career to: Mr. M. W. Timmins, Senior Personnel Officer, Pye Telecommunications Ltd, Newmarket Road, Cambridge, CB5 8PD Telephone: Cambridge 61222

**UNIVERSITY OF LANCASTER**

**ELECTRONICS TECHNICIAN**

The Department of Engineering invites applications from suitably qualified persons for a post as Laboratory Electronics Technician who must be experienced in solid state electronics and instrumentation; duties will include assisting in the design and making of new equipment for teaching or research and the maintenance of laboratory equipment.

Applicants must possess a University degree in Electrical or Electronic Engineering, or equivalent in mechanical engineering. You'll need in addition a sound background in the mechanical design of light electronic or electrical equipment, preferably in the telecommunications industry; ability to read architectural drawings as applicable to installation design; familiarity with industrial procedures; and awareness of the market position for the supply of proprietary equipment used in large radio installations.

Please write, including details of your previous career to: Mr. M. W. Timmins, Senior Personnel Officer, Pye Telecommunications Ltd, Newmarket Road, Cambridge, CB5 8PD Telephone: Cambridge 61222

**MEDICAL ENGINEERING IN HOSPITALS**

**MEDICAL ELECTRONICS TECHNICIAN**

required in the Northampton Group of Hospitals to service, repair and calibrate a wide range of electronic equipment used in hospitals for medical, surgical and engineering purposes.

Candidates should have good practical experience in radio/telecommunications, pulse generation, automatic control systems or electro-medical equipment. Possession of HNC or NVQ in electronics or a comparable qualification would be an advantage.

Opportunities for further study and training available. Salary scale: £1,356—£1,764 p.a.

If you are interested in receiving further details of this opportunity, please write to Mr. J. M. W. Timmins, Senior Personnel Officer, Pye Telecommunications Ltd, Newmarket Road, Cambridge, CB5 8PD.

**West Sussex County Council**

**INDUSTRIAL TRAINING CENTRE, CRAWLEY**

**TRAINING INSTRUCTOR**

Qualified applicant required to instruct Electrical Craft and Technician Engineer apprentices during first two years of apprenticeship. Good qualifications and experience in electronics are essential.

Salary scale: £1,362—£1,902—£2,052 per annum

Further particulars and application form from: Head of Centre, Industrial Training Centre, College Road, Crawley. Completed form to that address within 14 days of the appearance of this advertisement.
Design/Development Engineers
—come and make our products obsolete.

Today's new developments at Pye Telecom will be old hat within 5 years. That's the attitude which has put this company on top of the radio-telephone manufacturing league.

Now Pye Telecom are hotting the pace up further still. With massive expansion. And, hopefully, your help. You will be in the midst of exciting innovations—new products, new techniques, new components. Everything your work demands will be there—including computers for use as design aids and on-line Europe-wide research facilities.

In return for your talents... rewards, promotion opportunities and conditions of service which match the very best in industry today. There's a choice of 2 pleasant locations—Cambridge or Southend—and relocation expenses will naturally be company paid.

So how about it? You'll need an electronics degree or equivalent, circuitry experience, and preferably 2/3 years of VHF/UHF radio-telephone design experience. It will help, alternatively to have experience in other fields such as radar broadcasting or television.

Please phone for an application form or write giving full details of your experience and salary requirements to:
Mike Timmins, Senior Personnel Officer,

Pye Telecommunications Ltd
Newmarket Road, Cambridge, CB5 8PD.
Tel: Cambridge 61222

Electronic Video Recording

EVR is being jointly developed by a consortium of CIBA, the international chemical group, ICI and CBS of America; Ilford is a member of the CIBA group, and we now require the following additional staff for this project at Basildon in Essex.

SENIOR AUDIO ENGINEER
and AUDIO ENGINEER

for the operation and maintenance of high quality magnetic and optical sound equipment.

A good theoretical knowledge and practical experience of audio recording and reproduction is essential. Candidates should also have experience of interlock system, multiple track recording, frequency modulation, audio dubbing facilities, compression, expansion and frequency equalisation equipment, measurement of distortion, wow and flutter and all other parameters in an audio system. An appropriate qualification would be an advantage.

Applications for the above position must be prepared to work on shifts in due course. Commencing salaries will be in the range £1800 to £2500, according to qualifications and experience. We operate a contributory pension scheme, free life assurance and sickness schemes. Assistance will be given with relocation expenses where appropriate.

Applications, quoting reference ZH.39, giving details of qualifications and career to date, should be addressed to:
The Personnel Manager, Ilford Limited, Christopher Martin Road, BASILDON, Essex.

ILFORD
Electronic Video Recording

EVR is being jointly developed by a consortium of CIBA, the international chemical group, ICI and CBS of America; Ilford is a member of the CIBA group. The EVR Unit at Basildon in Essex requires a:

SHIFT CONTROL ENGINEER

to be responsible for the supervision of the overall operation of the video tape and sound transfer facilities on a shift basis.

The successful applicant will preferably have experience of video tape recording and editing, telecine operation, tele-recording and film characteristics, optical and magnetic sound transfer, vision and sound mixing apparatus and the control of staff in a senior television engineering capacity.

Applicants must be prepared to work on shifts in due course.

Commencing salary will be negotiable in line with experience.

Assistant will be given with relocation expenses where appropriate and rented accommodation can be arranged under the Basildon New Town scheme.

ILFORD

SENIOR TEST ENGINEERS

The leading U.K. Manufacturers of high grade T.V. monitors and ancillary T.V. studio equipment require Senior Test Engineers for their rapidly expanding test department. Situated in the Berkshire town of MAIDENHEAD the company offers pleasant working conditions, good salaries, and a friendly environment.

Duties will cover the testing and troubleshooting of our complete range of equipment. Previous experience on television equipment is not essential but candidates must have a thorough knowledge of electronics and testing procedures.

Reply to:

PROWEST ELECTRONICS LTD.,
Boyn Valley Road, Maidenhead, Berks.
Telephone: Maidenhead 29612

TELECOMMUNICATIONS ENGINEERS WEST AFRICA

Qualified Telecommunications Engineers are required for servicing and maintenance of radiotelephone equipment and associated items in tropical West Africa.

Qualifications: HNC or higher.

Contract: One year plus leave extensible.

Salary: According to age, experience and qualifications. Commencing at not less than equivalent £2000 sterling, free accommodation and passages. Preference for bachelors with tropical experience but not essential.

Interested? Apply for application form to:

C.O.D.E.C.O.
2b Sussex Road - New Malden - Surrey

THE UNIVERSITY OF LEEDS

Applications are invited for posts in the following Department: PHYSICS

(i) EXPERIMENTAL OFFICER/SENIOR EXPERIMENTAL OFFICER

The successful applicant will be responsible for the design of a wide range of electronic apparatus covering DC and pulse amplifiers and digital recording systems. Minimum qualification: Degree in Physics or Electrical Engineering, together with appropriate experience. A well-equipped laboratory is available. Reference number 22/6/C1.

(ii) RESEARCH FELLOW/RESEARCH ASSISTANT

Applicants should have a Ph.D. or appropriate research experience and should be interested in applying their knowledge and experience to the analysis and interpretation of data from the Haverah Park Extensive Air Shower Array. This Array has now been running for ten years and is yielding results on primary cosmic-ray particles with energies in excess of 10^{17}eV. The post will be tenable for two years. Reference number 22/7/C1.

SALARY SCALES:

Experimental Officer/Senior Experimental Officer: £995 - £2,235.
Research Fellow/Research Assistant: £900 - £1,600.

Applications (2 copies) stating age, qualifications and experience and naming three referees, should be sent to the Registrar, The University of Leeds, Leeds LS2 9JT. Please quote appropriate reference number.
Installation Engineers, Technicians & Testers
Ref. 25720
To test and commission Multiplex, Co-axial Line and Microwave Radio Systems.
Ideal candidates will be less than 45 years of age with practical experience on some of the above equipment. These challenging posts call for drive, initiative and common sense. It is necessary for applicants to be prepared to work anywhere in the U.K.

Applications should be addressed to
The Personnel Officer,
STC Chester Hall Lane,
Basildon, Essex.

Test Technicians
Ref. 27221
The diversity of products manufactured at the Basildon Plant demands experienced testing staff for work on complex transmission systems. Candidates should hold an ONC in electrical engineering and be able to offer considerable practical experience in the field of testing and fault clearing all types of land-unit, pcm and microwave equipment.

Applications should be addressed to
The Personnel Officer,
STC Chester Hall Lane,
Basildon, Essex.

RADIO SPECIALIST
POLICE DEPARTMENT ZAMBIA

- Salary £2,310 to £2,590 according to experience
- Low Taxation
- Contract of 36 months
- 25% Tax Free Gratuity
- Educational Allowances
- Subsidised Housing

Duties will involve the maintenance and installation of police radio equipment throughout Zambia, travelling by road and air. The equipment includes modern low and medium power H.F. equipment, S.S.B. equipment and V.H.F. equipment including multiplex links. Knowledge of maintenance of teleprinters, diesel and petrol generators preferred.

Candidates, who will serve in the rank of Inspector of Police (non-uniformed), must have completed a five year apprenticeship or hold a service trade certificate or equivalent qualification and have at least six years post qualification experience.

Apply to CROWN AGENTS, ‘M’ Division, 4 Millbank, London, S.W.1 for application form and further particulars stating name, age, brief details of qualifications and experience and quoting reference M2Z/61274/M/F.
Communications Technician
Libya
For installation and maintenance work on all types of equipment including UHF/VHF, teleprinter, and telephone exchange. This is a bachelor posting with 17 days home leave after each 45 days and very generous terms and conditions.
Candidates should possess a minimum of City and Guilds Telecommunications Certificate PL 49 or equivalent, and have experience of telephone and teleprinter equipment. Please write briefly quoting reference ZH166, to: P. J. Montanjees, Recruiting Officer, The British Petroleum Company Limited, Britannic House, Moor Lane, London, EC2Y 9BU.

ELECTRONIC SERVICE ENGINEER
Required to assist in the Servicing, Maintenance and Development of electronic and electro-magnetic equipment in the Printing industry.
Although formal technical qualifications are not vital, applicants must have a wide experience in press register and drive controls, complex relay logic, computer peripheral equipment, etc. The position also necessitates light mechanical work.
It is intended that the engineer will be engaged on shift duties.
Salary by negotiation. Apply in writing to:-
PERSONNEL OFFICER
HAZELLS OFFSET LIMITED,
Leigh Road, SLOUGH, Bucks.
Member of The British Printing Corporation Limited

Metropolitan Police Office
TELECOMMUNICATIONS TECHNICIANS
Five posts in the Lines Section of the Telecommunications Branch at New Scotland Yard involving co-ordination and planning in connection with the provision, development and maintenance of line communications and associated equipment.
Candidates (men or women) should normally be aged at least 23. They must have ONC in Engineering, including a pass in Electrical Engineering, or have attained an equivalent standard of technical education, and at least 5 years’ appropriate training and experience.

SALARY: £1,477 (at age 23)—£1,768 (at 28 or over on entry); rising to £1,964. Promotion prospects. Non-contributory pension.

For full details and an application form (to be returned by 8 October 1970), write to Civil Service Commission, Alencon Link, Wembley, Middlesex.

CIRCUIT DESIGNERS
Required for Television and Communication Development, dealing with broad spectrum of circuit techniques embracing solid-state technology from discrete components to L.F.I.
The positions are with the engineering design subsidiary of a leading television organisation, preferred qualifications are B.Sc., H.N.D. or H.N.C. and the membership of an appropriate professional body. Company insurance and pension scheme, three weeks leave, salary which is competitive with comparable industry levels, will be paid.

Reply to the:
Managing Director,
DYNAMIC TECHNOLOGY LIMITED,
Station House, Harrow Road, Wembley, Middlesex.

UNIVERSITY OF ST. ANDREWS
Department of Psychology
Applications are invited for the post of CHIEF TECHNICIAN
in the Department of Psychology tenable for three years in the first instance. The person appointed should hold a Higher National Certificate or its equivalent and possess special skills in the design and construction of electronic control apparatus. Salary scale £1676 to £1909; starting salary according to qualifications and experience. Pension scheme. Applications, with the names of two referees, should be lodged not later than 15 October, 1970, with the Secretary of the University
College Gate, St. Andrews
from whom further particulars may be obtained.

SITUATIONS VACANT

A FULL-TIME technical experienced salesman required for retail sales, with good knowledge of television and radio equipment.


APPLICATIONS are invited for the post of electronics technician in the Department of Psychology. Candidates should have or be completing Final City and Guilds in Electronic Servicing, or an equivalent qualification. Candidates with ET4 or O.N.C. and with special experience in electronics will be considered. Familiarity with electrophysiological equipment or interest in or experience with neural commutors would be an advantage. The salary will be on the scale: £1,035–£1,303 per annum.

Applications with full details to:- Secretary, The University of Manchester, Whitworth Park, Manchester, M13 9PL.

ARE YOU INTERESTED IN HI FI?
If so, and you have some experience of selling in the Retail Radio Trade, an excellent opportunity awaits you at Telesonic Ltd., 87 Tottenham Court Road, London, W.1. Tel. 01-397 7467/8.

A SENIOR Transformer/Rectifier design Engineer is required for varied and interesting projects associated with equipment up to 300 kVA/50 K.W. We are an expanding Company of Manufacturing Electrical Engineers located in South Herts. Box W.W. 97 Wireless World.

CANADA. Thousand Islands Tourist Region, TV engineer for expanding modern service department. Starting salary $5,200–$5,500. Write, Atkinson Sheridan Co., 139 King St. W., Brockville, Ontario, or phone 01-387 7467.

ELECTRONIC ASSEMBLY and wiring accepted by manufacturing workshop, phone Workshop Manager, Pan Wholesale Ltd., 33-37 Wardour Street, W.1. Telephone 01-387 742.

ELECTRONIC TECHNICIAN required in Department of Medicine. Work involves development and maintenance of respiratory instrumentation in Clinical and Physiotherapy sections of group. Good knowledge of electronic and digital techniques desirable. Salary range £1,235–£1,535 per annum. Applications to Secretary, Royal Postgraduate Medical School, Darnel Road, London, W.12, quoting ref. 2/444.

JUNIOR ELECTRONIC TECHNICIAN required for construction and repair of electronic instruments and maintenance of a Linear Accelerator, O.C.R., D.O. level in Physics and Maths required. "A" levels or O.N.C. an advantage. Day release for further study is possible. Salary according to age and experience. Apply with full details to the Director, Medical Research Council Cyclotron Unit, Hammersmith Hospital, London, W.12.
Electronic Video Recording

EVR is being jointly developed by a consortium of CIBA, the international chemical group, ICI and CBS of America; Ilford is a member of the CIBA group and our plant at Basildon, Essex, requires a:

TECHNICAL ASSISTANT
for the operation and maintenance of Television and Audio Equipment

A good knowledge of radio and television theory together with some practical experience in television engineering or allied fields is essential. HNC or equivalent would be an advantage.

Commencing salary will be from £1300 according to qualifications and experience. We operate a contributory pension scheme, free life assurance and sickness schemes.

Applications, quoting reference ZH.40, giving details of qualifications and career to date, should be addressed to:

The Personnel Manager, Ilford Limited, Christopher Martin Road, BASILDON, Essex.

DEVELOPMENT ENGINEER

Urgently required—a dynamic young Development Engineer to join a design team working on H.F. Single Side Band Transceivers. Must be thoroughly familiar with the application of integrated circuits, field effect transistors and other state-of-the-art techniques. Attractive salary, Staff Pension Scheme, Canteen facilities, etc.

Please apply giving a summary of your experience in this field of activity to The Personnel Manager, Labgear Ltd., Cromwell Road, Cambridge. Tel. No. Cambridge 47301.

Applications are invited from qualified candidates for the following post in the Electronics Department at Poole General Hospital:

ELECTRONICS TECHNICIAN III

Qualifications: O.N.C., H.N.C., City & Guilds or equivalent.

Salary: £1,180 x 8 Increments to £1,500 per annum.

The Department will be primarily concerned with the installation, testing and maintenance of an extensive range of diagnostic/therapeutic and allied electronic equipment, and ultimately with research and development of bio-medical equipment in consultation with medical staff.

The position offers adequate scope for initiative and career progression, including the possibility of assistance with further training.

Applications, giving full details, including qualifications, experience and the names and addresses of two referees, to the Hospital Secretary, Poole General Hospital, Poole, Dorset.

Supervisory Systems Technicians

A progressive, well-paid career could be yours, in our expanding Systems Design Department. We have vacancies at junior and intermediate levels, with opportunities for promotion to Engineer grades, for technicians who have experience of industrial instrumentation or digital electronics and the ability to work on detail logic design.

Applicants should have, or be studying for, a City & Guilds, ONC or HNC qualification in electronic engineering.

Write or telephone D. J. W. Barker, Training & Recruitment Officer, for a full job specification and application form.

Serck Controls systems division
Queensway, Leamington Spa, Warwickshire
Tel: Leamington Spa 27030.

A member of the Serck Group
TECHNICIANS AND ENGINEERS FOR ST. ALBANS AND LUTON
QUALIFIED OR NOT!

VACANCIES exist for work on testing and calibrating valve and solid-state electronic measuring equipment embracing all frequencies up to u.h.f. in Production, Service and Calibration departments.

APPLICATIONS are invited from people of all ages with experience of all aspects of electronic engineering, or formal training in electronics and from ex-Armed Services technicians.

HIGHLY COMPETITIVE SALARIES, negotiable, based on previous employment, training, qualifications, approximate salary required, quoting WW 6

MARCONI INSTRUMENTS LIMITED, Longacres, St. Albans, Herts.
Tel: St. Albans 59292
Luton Airport, Luton, Beds.
1 Luton 31441.
A GEC-Marconi Electronics Company

Telecommunications Engineer
Up to £2,438

The Meteorological Office is looking for an engineer to work at its headquarters in Bracknell, Berks, on the planning, provisioning and installation of landline and radio telecommunications systems. These systems transmit data and analogue/digital facsimile, some of the input being received via satellites and the output being fed into computers. The work is varied, interesting and involves the use of most modern techniques.

Applicants must have satisfied the training and examination requirements of an appropriate Institution (or be Corporate Members) or hold a degree in engineering or physics. Some relevant experience expected.

STARTING SALARY: up to £2,438 according to qualifications and experience. Non-contributory pension.

Write to Civil Service Commission, Alancon Link, Baslingstoke, Hants, for application form, quoting S/7546/76. Closing date 8 October, 1970.

M A I N T E N A N C E ENGINEER required for major recording studio in London. Preferably experienced in setting up and maintaining professional equipment, but applicants background will be considered. Please apply in writing to Mr. P. Godwin, Pye Studios, A.V.T. House, Gt. Cumberland Place, London, W.1. Tel: 739599

M E D I C A L PHYSICIST TECHNICIAN required in the Artifical Kidney Unit at St. James's University Hospital. Main responsibilities will be to maintain and calibrate electrical/electronic equipment, X-ray machine, dialysis apparatus and dialyzer; and attend to patients and clients in their domiciles. Experience in maintenance, X-ray and dialysis, salary and conditions of service in accordance with the scales laid down by the Council of Medical Practitioners for local authorities. Applications stating age, experience and qualifications together with the names of two referees to be submitted to the Group Secretary, St. James's Hospital, Leeds LS9 7TP.

P L O Y M O N T POLYTECHNIC, DEPARTMENT OF CIVIL, MECHANICAL AND PRODUCTION ENGINEERING. Required, Technician Grade III to maintain, service and assay electronic apparatus and equipment. Salary £1,248-£1,556 p.a. and £1,650-£1,727 p.a. according to experience and qualifications. London allowance £135 p.a. and possible £30 or £50 p.a. qualification allowance. Five-day, 35-hour week. Leave - 4 weeks annual. Pension scheme. Letters only to Registrar (C/T/722), Queen Mary College, Mile End Road, London, E.1, quoting above reference, to whom they should be returned by 5th October, 1970.

R I D E R P H O N E LTD. require fully experienced TELECOMMUNICATIONS ENGINEERS and ELECTRONICS INSPECTORS. Good communications salary, with appropriate vacancies from ex-service personnel or personnel about to leave the Services. Please write giving full details to: The Personnel Manager, Rundcom Ltd., Brookmail Road, Wembley, Middx.

S E N I O R TECHNICIAN/TECHNICIAN required for the construction, development and testing of an interesting variety of electronic apparatus in modern chemistry teaching and research laboratories. Salary in ranges £1,245-£1,554 p.a. and £1,650-£1,727 p.a. according to age and experience. London allowance £135 p.a. and possible £30 or £50 p.a. qualification allowance. Five-day, 35-hour week. Leave - 4 weeks annual. Pension scheme. Letters only to Registrar (C/T/722), Queen Mary College, Mile End Road, London, E.1, quoting above reference, to whom they should be returned by 5th October, 1970.

T E C H N I C I A L OFFICERS in ELECTRONICS required for the design and development of solid state circuitry involved in the provision and use of a cyclotron for medical research. Applicants should have a Postgraduate or HNC, and experience in the use of integrated circuits, switching circuits, or data handling techniques. Age under 35. Salary in range £1,245-£1,554 p.a. and £1,727-£2,037 L.W. Apply to Director, Medical Research Council Cyclotron Unit, Hammersmith Hospital, London, W.12.

T H E UNIVERSITY OF MANCHESTER INSTITUTE OF SCIENCE AND TECHNOLOGY, TECHNICIAN OR SENIOR TECHNICIAN (ELECTRONICS). Ref. OPT/207/40 required in the Department of Orthopaedic Optics. The successful candidate will be required to maintain, and occasionally design and build, electronic and other research equipment. Current research with the Department includes studies and applied optics and neuromuscular control techniques on visual perception. Salary Grade 4 Technicians, £600-£737 per annum. Senior Technicians, £1,245-£1,554 per annum. (Additions of £30 and £50 in each grade for educational qualifications). Overtime and nights will be required, and salary will be dependent upon qualifications and experience. Requirements for application forms, quoting above Reference, should be made to the Registrar, U.M.I.S.T., Manchester 1.


W I R E L E S S TECHNOLOGY. There are vacancies at the VOLUME Office, Bedroom House, 384-386 Finchley Road, London, N.3, for Technician and Operating Staff. Particulars and application forms, stating whether able to maintain, and installation and maintenance of VHF and UHF wireless and electrical apparatus. Overtime work. Salary £1,245-£1,554 p.a. 5-day, 40-hour week with overtime payable and 5 weeks annual leave. Excellent prospects. Good Pension Prospects. QUALIFICATIONS—City and Guilds intermediate and higher qualifications, or some experience in Telecommunications. For further details write to: Director-General, Research and Development, Home Offices, 69 Rochester Row, London, S.W.1. (01-892-4076).

X-RAY TUBE ENGINEER OR TECHNICIAN for X-ray tube plant in important country in SOUTH AMERICA. Candidate must have minimum of 7 years' experience in production of x-ray and rotating anode x-ray tubes. No language requirement. Salary will be minimum £4,000 annually plus use of car and other benefits. Outstanding opportunity for British citizen. Write giving full details to "X-Ray Tubes," Box No. 762, Wireless World.

A R T I C L E S FOR SALE
A VQ Mk. 1 Valve Characteristic recorder, mini-cabinet. £85 ex-o.p. Weeked, 35 and 1200 Series. 1 Valders Road, Burgess Hill, Sussex.

W H A T S D E L A Y INDICATOR, complete with installation and maintenance of VHF and UHF wireless apparatus. Overtime work. £1,245 per annum. £50 p.a. 5-day, 40-hour week with overtime payable and 3 weeks annual leave. £1,554 per annum. Good Pension Prospects. Q U A L I F I C A T I O N S — City and Guilds Intermediate and Higher qualifications, or some experience in Telecommunications. For further details write to: Director-General, Research and Development, Home Offices, 69 Rochester Row, London, S.W.1. (01-892-4076).

P R E S S - T A S K - A - TASK ISOTROPE, complete with installation and maintenance of VHF and UHF wireless apparatus. Overtime work. £1,245 per annum. £50 p.a. 5-day, 40-hour week with overtime payable and 3 weeks annual leave. £1,554 per annum. Good Pension Prospects. Q U A L I F I C A T I O N S—City and Guilds Intermediate and Higher qualifications, or some experience in Telecommunications. For further details write to: Director-General, Research and Development, Home Offices, 69 Rochester Row, London, S.W.1. (01-892-4076).
**Electronic Video Recording**

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**VTR ENGINEERS**

They must possess operational and maintenance experience of 2" quadruplex video tape recorders and have a thorough knowledge of colour television principles.

Applicants must be prepared to work on shifts in due course. Commencing salaries will be negotiable according to qualifications and experience. Assistance will be given with relocation expenses where appropriate. Rented accommodation can be arranged under the Basildon New Town scheme. We operate a contributory pension scheme, free life assurance and sickness schemes.

Applications, quoting reference ZH.41, giving details of qualifications and career to date, should be addressed to: The Personnel Manager, Ilford Limited, Christopher Martin Road, BASILDON, Essex.

**AGRICULTURAL RESEARCH COUNCIL**

Food Research Institute

Electronics technician required. The work is concerned with the construction and testing of electronic equipment together with some maintenance of existing instrumentation.

Applicants should have served an apprenticeship and possess a good theoretical and practical electronic background together with some workshop experience. An O.N.C. in electronics will be an advantage.

Salary on Technical Works Grade III, starting salary according to age, from £1,092 to £1,442 at age 28, rising by annual increments to a maximum of £1,643.

Optional contributory superannuation scheme. Application forms from Secretary, Food Research Institute, Colney Lane, Norwich, NOR 70F, quoting 70/18.

**JUNIOR TECHNICIAN**

required at our Hampstead Laboratories, Holly Hill, N.W.3. Suitable for applicant in early 20's with some experience of workshop practice and interest in electronic instrumentation. Minimum qualifications 4 G.C.E. 'O' Levels to include English, Maths and a science subject.

Salary according to age on scale £706 to £1,144 p.a.

Please apply quoting our reference WW64/1 to:

Miss A. Furber,
NATIONAL INSTITUTE for MEDICAL RESEARCH,
Telephone: 959 3666

**COUNTY BOROUGH OF BRIGHTON EDUCATION COMMITTEE**

Tenders are invited for the Supply of Close Circuit Television Equipment for the Brighton Polytechnic (Technology).

Forms of Tender are available from the Director of Education, 54 Old Steine, Brighton, BN1 1EQ.

**Test Technicians**

Our test department is expanding. It is responsible for the testing of magnetic storage devices, high-speed printers, punched-card and paper-tape equipment.

For people with experience in electronics, opportunities exist immediately. Further vacancies will arise over the next few months. Training will be given to those who do not have previous computer experience.

Applicants must have worked on the testing, maintenance or repair of electronic equipment, and preference will be given to those qualified to ONC (Elect.) or C & G Final.

Locations: Kidsgrove and Winsford. Both are situated in rural surroundings bordering on the Cheshire Plain. Housing is available at attractive prices, and assistance with mortgage can be arranged.

Write giving details of age, qualifications, and experience, to: Brian Buckley, Personnel Manager, International Computers Limited, Kidsgrove, Stoke-on-Trent, quoting reference WW498M.

**International Computers**
Radio and Electronic Engineers

The National Air Traffic Control Service requires radio and electronic engineers to work on sophisticated electronic systems. 

They are involved in the installation and maintenance of radio and electronic equipment, including automatic data transfer systems, closed circuit television installations, and other automatic data systems used for aviation purposes.

The job entails working on sophisticated systems, which may require a high level of skill and expertise.

Prospects of promotion within 3 years are outstanding.

For more details and an application form, contact the Civil Service Commission.

We offer

A TAPE RECORDER ENGINEER

the opportunity of working in an up-to-date service department on Uher recording equipment. The applicant should be familiar with the latest transistorised circuitry as well as being able to carry out mechanical work on such equipment.

We offer a good salary, non-contributory pension scheme, subsidised canteen facilities and some free local transport.

If you are interested, please write giving brief details about your qualifications and experience to:

The Personnel Officer, BOSCH LIMITED, Rhodes Way, Watford, Herts.
MARSH £25. 109 Waverhall Road, Watford.

NEW CATALOGUE No. 11, containing credit vouchers for 4 valves 16/-, new available. Manufacturers' new and surplus electric and mechanical components, price 4/6, post free. Arthur Smith Radio Control Ltd., 26 Gardner Street, Brighton, Sussex.

THF, COLOUR and TV SERVICE SPARES. Leading British makers' surplus Colour Frame and Line time base units incl. EMU transformer, £25, carriage 18/., integrated VHF/UHF 6 position push button tuner, 4 transistors, knobs, circuit data. Easily adapted for use as 6 position UHF tuner, £4/15/6, P/P 4/6. MURPHY 600/750 series complete UHF conversion kit incl. tuner, drive assembly, 521 IF amplifier, 7 valves, £3/15/6, P/P 2/15/6. AT7639 Peto Scott, drive ass'y, transistorised coils, £20, P/P 15/6. Plessey 4 position push button tuner, £17/15/6 for less tuner £15/6. SOBELL/GEC 625/625 switchable IF amplifier and output circuits, 25/6, P/P 15/6. Ultra £15 1F AMP chassis and circuit, 30/6, P/P 20/6. Philips 625 IF AMP panel and circuit 30/6, P/P 25/6. UHF tuners, transistorised, slow motion drive unit, output panel, £5/15/6, P/P 2/15/6. New manufacturer tested VHF tuner. AT393 Peto Scott, complete tuner, £20, P/P 15/6.

PADINOR LTD., 68 Dale Street, MANCHESTER for 6V systems, cost as above. Also available with 30:1 ratio. CWO 32/6, P/P 5/6.

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Solution: use Lexor cascadable modules

Lexor uniline build-a-delay system

Engineers with a delay problem will swiftly recognise the value and flexibility of Lexor uniline cascadable modules. The wide range of incremental values makes delay building simple, quick and economical. An exact delay required for a circuit can be established instantly in-situ.

With the uniline system the required delay value can be achieved by adding or subtracting modules in steps as small as 5nS. These miniature encapsulated units are designed to mount directly on to printed circuit boards on a 0.1" matrix and their small uniform size allows them to be positioned in any configuration which can be accommodated by an existing circuit layout.

They are available from Stock.

Having resolved the problem of delay value, take further advantage of the Lexor service by ordering—

Sets of uniline modules made up in composite blocks or a custom-built single unit to an equivalent value in any form required.

Leaflet L2 gives full technical specification and application notes.
COMPATIBLE PRINTED CIRCUIT SOLDERING MATERIALS

PC.2 MULTICORE TARNISH REMOVER
removes tarnishes and inorganic residues as the second half of a pre-cleaning process before soldering. It leaves the copper unaffected.

PC.90 MULTICORE PEELOFF SOLDER RESIST
is a temporary solder resist which can be peeled off with tweezers after soldering, leaving the original clean surface. It can be used for masking gold plated edge connections and holes to which heat sensitive or other components must be added later.

PC.41 MULTICORE ANTI-OXIDANT SOLDER COVER
which forms a liquid cover on the solder bath either side of the solder wave, largely preventing the formation of dross.

PC.80 MULTICORE SOLVENT CLEANER
removes organic contaminants such as grease, perspiration and residues of organic solutions from prior processes, as a pre-cleaning process before soldering. It is also very efficient in removing rosin-based flux residues after soldering.

PC.10A MULTICORE ACTIVATED SURFACE PRESERVATIVE
is a pre-soldering coating for preserving the clean surfaces established by the PC.80 Multicore Solvent Cleaner and PC.2 Multicore Tarnish Remover. PC.10A does not need to be removed before soldering and in fact contributes to the efficiency of the soldering process. PC.10A should be used whenever there is a delay between cleaning and soldering.

PC.52 MULTICORE PROTECTIVE COATING
is a lacquer which should be applied after soldering for protecting printed circuits from deterioration or failure in service. It can easily be soldered through or repaired if modifications or repairs are necessary at a later date.

SOLDERABILITY TEST MACHINE
MARK 3

SOLDERING HANDBOOK
The most comprehensive book on soldering for industrial use, containing 120 pages with 100 illustrations and invaluable reference charts. Features practical and theoretical methods of soldering in electronics and allied industries, and is divided into three headings.

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