Wireless World, January 1970

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KEYSWITCH RELAYS – WHERE THE ACTION IS
Electronic ignition
Syrter
Microcircuit rationalization

The macrophotograph on this month's cover shows wires being bonded on to integrated circuits at the Mullard Southampton works. On page 6 the future of linear I.C.s is discussed.

OUR NEXT ISSUE

Loudspeaker performance: Paul Klipsch, originator of the Klipsch horn, compares horns and direct radiators
Ceramic pickups and transistor pre-amplifiers: are they incompatible? Matching: what is meant by this term?

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“Explosion in communications”

This was the expression used by Mr. Stonehouse, Minister of Posts and Telecommunications, when he announced in the House of Commons that he was considering setting up an independent enquiry into the long-term future of broadcasting in the U.K. He referred to the need to examine the implications of new technologies, e.g. the possibility of 100 or more communication channels going into every home in Britain via a single wire or microwave link, “which would bring about an explosion in telecommunications”.

One’s immediate reaction to the proposed broadcasting enquiry is “what, another one!” It will be recalled that very few of the recommendations in the Pilkingon report of 1962 were implemented and over the years there have been many proposals made by the various committees of enquiry or commissions which, maybe because they were too sweeping, have been turned down. It would, however, appear from the Minister’s latest statement that if the proposed committee is set up it will be asked to look at the long-term future of internal telecommunications generally and not just broadcasting. If so, this is going to be a gargantuan task calling for technological forecasting. Incidentally, Professor W. H. G. Armytage, of the University of Sheffield, speaking recently to members of the Institution of Mechanical Engineers, said it now seems that “technological forecasting is, like weather forecasting, very respectable”. He pointed out, however, that technological forecasting must not be confused with “the inspired doodling that has characterized science and engineering through its history . . . nor the intuitive forecasts that enabled writers like . . . Hugo Gernsback to predict radar or Arthur C. Clarke to predict the earth satellite”. Professor Armytage defined it as “the application of scientific method—or objective, almost clinical method—to the analysis and forecasting of technological change”.

Bearing this in mind the proposed committee could produce a really far-seeing forecast of telecommunications into the ‘80s and beyond; but the members will need to be supermen or they will find themselves bogged down by tradition and vested interests.

What are the prospects? The idea of a super telecommunications grid covering the whole country has frequently been suggested and with the growing use of telemetry and control systems, as evidenced by a contribution in this issue, it is fast becoming a necessity.

Such a super grid will be an amalgam of radio and cable techniques. Despite our title we are not so bigoted as to be blind to the potentialities of cable for distribution networks. It is, however, worth recalling that in the early days of this journal there was a fierce war waged between cable and wireless (apocryphal stories are told of the sabotage of cable systems in order to show that wireless was inviolable!) but a marriage was arranged. It is, of course, true to say that without radio devices (amplifiers, repeaters, and the like) the present cable networks could not have materialized.

We do not intend to gaze into our crystal ball, engage in inspired doodling or make intuitive forecasts, but the future for the electronics and radio engineers is certainly exciting.
Capacitor-discharge Ignition System

An electronic ignition system, suitable for any car, which offers a large number of advantages over conventional ignition

by R. M. Marston

When this unit is wired up to a car's existing ignition system it greatly improves the shape of the ignition voltage waveforms, and enables a more stable flame-front to be generated in the engine's cylinders. Better combustion is thus obtained, and engine performance is considerably improved.

The unit, which is known as a capacitor-discharge ignition system, confers an impressive list of benefits in terms of engine performance. It gives easy starting, even under sub-zero conditions, and also gives immunity to 100 performance deterioration due to contact-breaker bounce. In addition it gives quicker engine warm-up, improved acceleration, better high-speed performance, and improved fuel economy (2 - 5%). Even more important, it virtually eliminates contact-breaker point burning and wear, gives greatly improved spark-plug life (typically 3 to 5 times longer than in conventional ignition systems), and overcomes the need to adjust contact-breaker and spark-plug gaps with precision.

The ignition unit can be added to any car fitted with a conventional 12-V coil ignition system irrespective of the number of engine cylinders.

Fig. 1 shows the circuit of a conventional, or inductive-discharge ignition system. The contact-breaker (c.b.) points are opened and closed by an engine-driven cam. When the points are closed, current from the battery builds up in the coil primary, to a maximum value of about 4.5A exponentially, with a time constant of L/R seconds, typical time constants are between 2 and 10ms. As the current builds up, it stores an energy 'packet' of (L.P)/2 joules, or watt-seconds, in the coil primary.

When the points open, the primary current collapses rapidly via C,1, and induces a peak potential of about 300V across the coil primary; this voltage is increased to about 30kV at the secondary winding, and this energy is transferred to the spark-plugs by the vehicles distributor. C, and the coil form a resonant circuit when the points are open, and the secondary voltage takes about 125µs to build up to its peak value.

Fig. 2 shows typical inductive discharge ignition performance characteristics and ignition requirements at different engine speeds; the early part of the graph, up to about 100 r.p.m., indicates typical sub-zero starting conditions, when battery voltage falls to about 10 V, compared to a normal value of 13.5 V when under dynamo charge. Note that the system operates with very little safety margin under cold-start conditions, and that the available secondary energy becomes inadequate when engine speeds reach 5,900 r.p.m., so that misfiring starts to occur above this speed.

Finally, the relatively long secondary voltage rise times of the inductive system (typically about 125µs) make the ignition system very vulnerable to high energy losses due to fouling of the spark-plug gaps by carbon and oil deposits. These deposits act as a resistance (typically about 2MΩ in cases of bad fouling) across the points. These deposits inevitably absorb some of the applied energy (power-time), and total energy absorption increases in proportion to voltage rise time and fouling resistance.

Capacitor-discharge ignition systems, on the other hand, suffer from hardly any of the snags outlined above. Fig. 3 shows the block diagram of the particular ignition system described here. A self-regulating voltage converter is used to charge storage capacitor C, to 400 V, almost irrespective of actual battery potential. When fully charged, this capacitor stores 0.08 joule.

When the c.b. is closed, zero input is applied to the pulse shaper, and the thyristor is off; a standing current of about 250mA is passed through the c.b. via R, under this condition, to keep the points 'clean'. The converter is operating, and charges C, to 400 V; the capacitor has a charging time constant of about 1.6ms.

Fig. 1. Circuit of a conventional inductive discharge ignition system.

Fig. 2. Typical performance of the circuit of Fig. 1 together with engine requirements. The curves assume that battery voltage is normally 13.5V falling to 10V at cold start.
When the c.b. points first open, the pulse shaper operates and turns the thyristor on in about 2μs. This short circuits the output of the converter, and turns it off. Simultaneously, one side of C1 is connected to ground and discharges rapidly into the primary of the coil; the coil steps the resulting primary voltage up to about 40kV, and the stored energy of C1 is transferred to the spark-plugs. The secondary voltage has a rise time of only a few microseconds. C1 and the coil form a resonant circuit when the thyristor is on, and have a typical resonant frequency of 1600Hz, giving a period of roughly 600μs. At the instant the thyristor fires, the coil’s primary voltage rises (in about 2μs) to 400 V, but 300μs later the voltage falls to zero as the circuit oscillates and the thyristor turns off, preventing further oscillation. Once this happens the voltage converter re-starts and begins to re-charge C1, even though the c.b. points may still be open. The process is repeated when the c.b. opens initially again. Note that the primary coil voltage is isolated from the vehicle’s c.b. terminals, which are thus subjected only to the moderately low voltages and currents.

Fig. 4 (a) shows the actual spark voltage performance of the prototype system at different engine speeds, when fitted to different types of engine, together with worst-case ignition voltage requirements, and Fig. 4 (b) shows the system’s energy generating performance. Note that both the available voltage and energy are well in excess of engine needs under all operating conditions.

The full circuit of the negative ground version of the ignition system is shown in Fig. 5. C1a and C1b form the 1μF energy storage capacitor. Tr1-Tr2, T1, and the D1-D6 bridge form the self-regulating voltage converter. Tr3, and its associated network form the bounce-suppressing pulse shaper, which fires the thyristor via C1.

The voltage converter section operates as follows: Tr1, and Tr2, are an astable multivibrator which uses the halves of the centre-tapped primary of T1, as collector loads and which generates a series of 24 V (approximately) square waves at each collector, at a frequency of roughly 50Hz. The inductive nature of T1 causes the early part of each square wave to shoot above the normal flat top; R1-R1s and zener diodes ZD1 and ZD2, are used to limit this overshoot to 28 V peak. T1 steps the square waves up to 400 V peak at the secondary winding. This voltage is then converted to d.c. via the D1-D6 bridge rectifier, and used to charge C1. It is this overshoot regulation that gives the ignition system its good cold-starting characteristics. R6 gives the circuit a degree of protection in the event of the battery voltage (under dynamo charge) rising above 15 V, and at the same time reduces the C1 voltage at high engine speeds.

It should be noted that, although the converter oscillates at a natural frequency of only 50Hz, it is in fact capable of giving good spark generation at c.b. frequencies in excess of 600Hz, i.e., above 20,000 r.p.m. in a four-cylinder, and above 10,000 r.p.m. in an eight-cylinder engine.

At the moment that the c.b. points first open in each ignition cycle the thyristor is triggered, so Tr1 and Tr2 stop oscillating; 300μs later, the thyristor then turns off, so the multivibrator starts oscillating again. The start of the first half cycle of each converter operation is thus synchronized by the c.b. At c.b. frequencies above about 100Hz, therefore, the converter starts into a half cycle each time the thyristor turns off, but the half cycle is ended prematurely when the thyristor goes on again as the c.b. opens.

The operating frequency of the converter thus synchronizes automatically to half that of the c.b. under this condition. Only a fraction of one natural half cycle is needed to charge C1, to a useful value, so good sparks are generated up to very high engine speeds.

The c.b. bounce-suppressing and pulse shaping section of the unit operates as follows: When the c.b. points are closed, a standing current of about 250mA is passed through

**COMPONENTS LIST**

- **Resistors**
  - In the list below the prefix R and the suffix f have been omitted for clarity.
  - 1—50 ohm
  - 2—66k
  - 3—1k ohm
  - 4—470
  - 5—3.3M
  - 6—1k
  - 7—270
  - 8—270
  - 9—220
  - 10—220
  - 11—100
  - 12—100
  - *5-watt wire-wound
  - 12-watt
  - resister 0.5 Watt

- **Capacitors**
  - C1a and C1b—0.5μF, 600V working, paper or Mylar.
  - C5—0.02 μF, 50V working, Mylar.
  - C6—0.22μF, 50V working, Mylar.

- **Semi-conductors**
  - **Positive earth**
    - Tr1—2N3055
    - Tr2—2N3055
    - Tr3—2N3055
    - D1—1N4001
    - D2—1N4001
    - D3—1N4001
    - D4—1N4001
    - ZD1—ZD2—27V 5% 400W zener diodes.

- **Negative earth**
  - Tr1—2N3055
  - Tr2—2N3055
  - Tr3—2N3055
  - D1—1N4001
  - D2—1N4001
  - D3—1N4001
  - D4—1N4001
  - ZD1—ZD2—27V 5% 400W zener diodes.

- **Transformer T1**
  - Modified L1 or battery charger transformer rated at least 30VA. A 240V primary, 117V secondary. 2A transformer is suitable when modified as per text.
the points via $R_1$; the $R_1-D_1-C_1$ junction is at ground, and the $R_1-D_1-C_1$ junction is grounded via $Tr_3$ base-emitter junction. Assume that $C_2$ and $C_3$ are fully discharged.

At the instant that the c.b. points open, 12 V appear across the points, and $C_1$ charges rapidly via $R_1-D_1$ and the thyristor gate which turns on. Simultaneously, $C_2$ charges rapidly via $R_1$ and $Tr_1$ base so that $Tr_1$ turns on.

At the instant that the points close again, the $R_1-D_1-C_1$ junction once more drops to ground volts; $C_1$ is still fully charged, however, and remains so, since $D_1$ is reverse biased under this condition; $C_2$ is also fully charged, but, since its $R_1-D_1$ side has been pulled down to ground volts, it drives $Tr_1$ base sharply negative, so $Tr_1$ is cut off. $C_1$ thus has no discharge path at this stage, and retains full charge. Consequently, should the points bounce open again at this stage (point bounce only occurs within the first two or three hundred micro-seconds of initial point closure), the thyristor will not be triggered back on again. Now, as soon as the points close, the $C_2$ charge starts to leak away via $R_2$, and eventually, after about 600µs, the charge falls to near-zero and $Tr_1$ is biased on via $R_2$. Once it is turned on, $Tr_1$ provides a discharge path for $C_2$ via its collector and $R_1$; $C_3$ then discharges rapidly, with a time constant of about 35µs. At the end of this period, $C_2$ and $C_3$ are once more fully discharged, and the thyristor is ready to be triggered on again.

Thus, the thyristor is triggered on as soon as the points open, but can not be operated again until the points open again after being fully closed for at least 600µs. The thyristor is thus immune to false triggering by c.b. point bounce.

The positive ground version of the ignition system is shown in Fig. 6. This is similar to that described above, except that a few circuit polarities are changed and the thyristor is triggered on with a negative pulse applied to its cathode via $D_2$.

The only problem involved in the construction of the unit is that of finding transformer $T_1$. This is an iron-cored unit with a turns ratio of 15:1 at a power rating of 30 VA or greater, and with a centre-tapped low-voltage winding. The easiest way to obtain this unit is to re-wind an existing l.t. or battery-charger transformer. The winding procedure is very simple, and the following is an account of that used on the prototype:

The transformer is required, before modification, to have a basic turns ratio of 15:1 or less. Any l.t. or battery-charger transformer that meets this and the 30 VA power requirement can thus be used. The prototype unit started life as a 240 V:17 V, 2 A battery-charger transformer, and thus satisfied the above specifications. Once selected, the low-voltage winding of the unit must be re-wound and centre-tapped to give an exact 15:1 ratio, i.e., a ratio of 240 V:16 V
in this particular case.

To rewind the transformer, remove its securing clamp and dismantle its iron core laminations (making note of their method of assembly), and then remove the coil bobbin. Next, unwind the entire low-voltage winding (which is invariably the outer winding on the bobbin), and carefully note the total number of turns used; now divide the number of turns by the original value of I.T. voltage, to give the transformers basic turns-per-volt value. On the prototype, total turns were 134, and the original voltage was 17, giving a turns-per-volt value of 7.9. Now calculate the I.T. voltage needed to satisfy the 15:1 final turns ratio of the transformer (16 V in this case) and multiply by the turns-per-volt value (7.9) to give the total number of turns to be rewound (128); now re-wind this number of turns on the bobbin to form the primary of the ignition unit transformer, taking care to make a tap at the half way mark. Finally, re-assemble the core laminations and re-fit the transformer clamp; the transformer is then complete and ready for use. The original mains primary is now of course the secondary of the new transformer.

Construction of the rest of the unit should present no problems, and it can be wired-up direct from the circuit diagram. The prototype positive ground version of the unit (see photographs) is mounted in an 8 × 6 × 2½-in metal box; the two power transistors (Tr1 and Tr2) and the thyristor are mounted, via insulating washers, to the box surface (which acts as a heat sink); most of the remaining components are mounted on a piece of Veroboard Panel; external connections to the unit are made via a 4-way terminal block.

When construction is complete, give the unit a simple functional check by connecting terminal O to chassis and terminal D to the 'hot' side of the car's battery; a "humming" noise should now come from the unit, indicating that the converter section is operating, and total current consumption should be roughly 800mA; approximately 400 V should be available between the anode and cathode of the thyristor when tested with a 20,000 o/volt meter. If this test is satisfactory, the unit can now be fitted to the car.

The complete unit can be either mounted in the glove compartment (as in the case of the prototype), or can be fixed to the rear fire-wall of the engine compartment (but not close to the exhaust system). The unit can be either wired directly to the existing coil and c.b. assembly, or, preferably, can be wired to these components via a 5-way plug and sockets (Fig. 7), in which case the driver can change from conventional to capacitor discharge ignition by simply fitting an alternative plug into the socket.

Once wiring is complete, turn on the ignition, operate the starter, and check that the system functions well under actual driving conditions; there is no need to re-adjust c.b. or spark-plug gaps, etc.

Results vary from one car to another, but improvements are particularly evident in cars that have covered a considerable mileage since their last tune-up.

Finally, once the unit has been found to perform satisfactorily over a reasonable mileage, it is recommended that the entire circuit be covered with an electrically insulating coat of water-proof paint or varnish, to exclude the harmful effects of moisture. The unit can then be expected to operate correctly for the life of the vehicle.
The Future of Linear I.C.s

A few simple integrated circuits, with guaranteed long-term availability, could meet nearly all the needs of the industrial manufacturer

by R. Hirst*

Linear integrated circuit packages have been available for a relatively short period in Britain. By virtue of the techniques employed and the expense incurred in developing and manufacturing monolithic circuitry reasonably large production quantities are required to make the selling price compatible with circuits manufactured from discrete components. This fact in itself restricts the market to which the initial product may be tendered as the industrial design engineer, with a relatively small piece-part requirement, is unable to incorporate devices that are essentially made for the domestic sphere. While the majority of linear integrated circuits will meet industrial requirements, it is the fear of an abrupt cessation in supply at the end of two or three years, due to the biennial change in the requirements of the mass radio and television market, that causes the main concern to the long-term industrial user.

Linear integrated circuit manufacturers seem unable to grasp this situation and continue to pour into the market complex, incompatible and non-interchangeable units mounted in a multitude of mechanical assemblies as can be seen from Table 1.

Based upon a simple survey it would seem reasonable to maintain production of one or two devices that at the present time have more than paid for their tooling costs by virtue of large-scale distribution. It would be necessary to inform the industrial equipment manufacturer which devices would be available for a relatively long time. The consumption, based upon this type of selling, could be surprisingly large and the risk to semiconductor manufacturers spread over a much greater number of customers.

To show how simple linear integrated circuitry could be, the following excursory appraisal of the requirements of a substantial portion of the industrial consumer has been presented. There would appear to be four main areas in which integrated circuitry could be used to great advantage, these are switching, I.F. amplification, H.F. amplification, frequency conversion.

Switching: This appears to have been adequately covered by the majority of semiconductor manufacturers and it is possible to obtain devices from different manufacturers that are directly interchangeable. The presentation has stabilized in the shape of fourteen-lead dual-in-line packages, usually epoxy encapsulated. The cost of the pack approaches or improves upon the cost that may be achieved by discrete techniques and the only aspect that now remains is to have more standardization and interchangeability.

I.F. amplification: As the majority of integrated circuits are d.c.-coupled, it would seem reasonable to lump together the I.F. and H.F. requirements thus reducing the consideration of linear amplification to a single unit. This device is described under the heading of H.F. amplification.

H.F. amplification: There is an integrated circuit available on the market with a flat frequency response up to 45MHz which is entirely d.c.-coupled. This device is being used in large quantities in the manufacture of domestic radio and television. It is a Mullard unit type F104B and is mounted in a 12-pin TO—5 can. The internal circuit of this device is shown at the left-hand-side of Fig. 1 and it can be seen to be very simple in design but nevertheless adequate in performance. A variety of response curves may be obtained by changing the value of C1 as shown in the graph of Fig. 2. The circuit in the shaded portion of Fig. 1 is a directly coupled emitter-follower which can be used to reduce the output impedance so that the unit may be terminated in a coaxial lead to feed a further unit which could be some distance from the amplifier.

This circuit has been used in a number of assemblies operating from 100Hz to 30MHz and it was found that by substantially increasing the value of C1, that the gain at 100kHz could be

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* Flatpack

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* Flatpack

Fig. 1. The Mullard F104AB is shown on the left which can fulfill nearly all the industrial manufacturers needs for I.F. and H.F. amplification. The shaded area contains an emitter-follower circuit which can be added so that the circuit can be made to drive long coaxial lines.
increased from 20dB to 30dB if some increase in harmonic distortion could be tolerated. From the curves in Fig. 2 it is obvious that, if the amplifier is used in a relatively narrow band, the value of \( C_1 \) may be altered to accurately provide a given level of gain. For instance with \( C_1 \) in the order of 25pF the gain at 50MHz would be approximately 26dB. However, if the value of \( C_1 \) was reduced to 12pF the gain would have decreased to something in the order of 19dB. As \( C_1 \) is an external component it is an easy task to use a ceramic trimmer adjustable from 5pF to 25pF to take up the gain spreads of the integrated circuit.

Obviously this package does not deliver a great deal of power but it may be terminated in one or more stages to give the required output level. It may also be preceded by an emitter-follower in order to increase the input impedance should the need arise. At frequencies below 10MHz the small value of \( C_1 \) is unlikely to promote sufficient change in gain to enable the variable capacitor to take up the spreads from circuit to circuit and it is probable that if a considerable gain change is required at the lower frequencies it will be necessary to alter the value of the series input resistor. However, as previously indicated, if \( C_1 \) is replaced by a fixed large value of capacitor the gain can be adjusted over a considerable range, but it then becomes necessary to change a capacitor physically, rather than make a simple adjustment. This amplifier has now been produced by Newmarket Transistors Ltd, under the title MC 809 and is a thick film device mounted in a dual-in-line package.

Frequency conversion: Fig. 3 shows a simple ring modulator circuit using four diodes and two transformers. This unit may be manufactured from discrete components but the degree of balance required for industrial applications, over a wide temperature range, cannot be easily achieved unless the diodes are carefully matched and mounted in a common heat-simulating device. With the aid of standard monolithic techniques this type of modulator may be readily presented on one chip thus ensuring that the elements have a similar temperature coefficient and are mounted in close proximity.

At the present time transistor monolithic ring modulators are available on the market as standard units but unfortunately the frequency range is very limited and cannot be considered for high-frequency work.

The circuit of Fig. 3 is not the only method of obtaining balanced frequency conversion but it is a simple device that can have a very wide and flat frequency response providing that the transformers are designed correctly. A unit of this nature has a considerable field of application throughout the military and industrial manufacturing industry.

Conclusion: Little has been done to establish the needs of industrial manufacturers as far as integrated circuits are concerned. If just one or two of the more simple integrated circuits, at present available to the domestic consumer, were to be classified as devices with long-term availability, the military and industrial manufacturer would undoubtedly respond by including such units in future designs.

During some recent observations into designs promoted by just one industrial manufacturing company it was noted that during the past three years, sixteen totally different amplifiers had been designed to achieve a small signal gain of between 20 and 30dB at 100kHz. Each one of these amplifiers could easily have been replaced by the circuit indicated in Fig. 2 without any detriment to the performance. Some startling but accurate conclusions were reached when cost estimates were prepared for the development and manufacturing cost of the discrete assembly on one hand, and the integrated assembly, on the other.

In the instance of the sixteen amplifiers designed around discrete components, it was ascertained that a total of 2 man-years were involved in the engineering, drawing and planning. The total annual consumption of the final amplifiers was small in the order of 500 units, costing approximately £5 each. The total cost over a manufacturing period of five years was as follows: development—£8,000, 2,500 units—£12,500; giving a total expenditure of £20,500.

Replacing these sixteen different designs with a common integrated circuit the development period could be reduced to one half man-year costing about £2,000 leaving a total of £18,500 to be spread over 2,500 integrated units giving a unit price of £7.8s for a simple three-stage device. There is no reason why a semiconductor manufacturer could not make a substantial profit at such an elevated unit price. The advantage to be gained by the industrial manufacturer at such a price would not be directly financial but a reflection in the substantial period of time that a skilled engineer would now have to devote to the more elaborate task of system design.

The modern circuit engineer is now likely to find that his services are more and more in demand in the laboratory of the semiconductor manufacturer where, chemistry, physics and electronics come close together. There is a vast shortage of skilled engineers in every country and it has to come that the majority of skills available will be employed in the design of systems using integrated circuitry as the basic building blocks. This does not detract from the skill of the circuit engineer but to the contrary indicates that a much higher degree of skill must be used in planning the minimum number of configurations to be used over a very wide and varied market.

*Communication Division, S.T.C. Ltd.

**Corrections**

J. Dinsdale, author of "A Design in Retrospect" in the November issue, writes: "There is an unfortunate ambiguity in Fig. 5 which does not make it clear whether the mk I or mk II design is being discussed. It is important that the earphone-loading network (shown in the dotted box) is connected in place of the loudspeaker in whichever design is being used. On no account should there be a direct d.e. path from the collector of \( T_n \) to ground, as Fig. 5 could imply." Also for May read April in ref. 9.

The values of two resistors in the Wien Bridge Oscillator on page 575, December issue, were incorrect in the diagram. For 68k and 33k, read 6.8k and 3.3k. See also page 11 for addendum to last month's "Letters".
News of the Month

American radio and TV production

It would appear from the latest figures issued by the U.S. Electronic Industries Association that there is a grave decline in the indigenous radio industry. Not that the sales of domestic receivers have declined but that there has been a growing influx of imported sets while the number of home-produced models has decreased.

The total sales of domestic a.m. and f.m. receivers produced in the U.S. during the first nine months of 1969 was 3.58M compared with 4.15M during the same period in 1968. Imports, however, rose by about 5M to 24.6M of which some 4M eventually bore U.S. company labels. The picture in car radio is very different. Of a total of 8.87M units (a slight increase on the 1968 figure for the same period) just over 1.2M were imported.

Of a total of 9.85M television receivers sold during January-September 1969 (of which over 4.6M were colour) 1.23M imported sets bore U.S. labels and a further 1.58M carried foreign labels. Incidentally, about 13% of the colour receivers sold in the U.S.A. during the first nine months of 1969 were imported.

Figures for the disposal of receivers in the U.K. (supplied by the British Radio Equipment Manufacturers' Assoc.) do not show imported equipment. Disposals of domestic radio receivers declined from 762,000 for the first nine months of 1968 to 547,000 for the same period in 1969. Car radio sets dropped from 309,000 to 262,000. Monochrome television receiver deliveries declined from 1,220,000 in 1968 to 1,172,000 in 1969 and colour sets from 89,000 to 77,000.

German satellite earth station

Germany's earth station at Raisting, near Munich, now has a second paraboloid aerial. This, like its counterpart at the U.K. Goonhilly station, will enable communication to be maintained via satellites in both the eastern and western hemispheres.

The main physical difference between Raisting's aerials I and II is that the designers have dispensed with the use of the radome cover in the latest installation. Although this gave protection from the weather it also created a problem—a film of water or ice on the radome caused background noise. Aerial II is fitted with 5000 infra-red radiators to prevent icing. The dish is 28.5m in diameter and the gain 60dB which corresponds to a power gain of one million as compared with an isotropic radiator operating at 4GHz. Maser pre-amplifiers with a 25-MHz bandwidth were originally used in the receiving section of the earth station, but parametric amplifiers with a 500-MHz bandwidth and a gain of 10,000 have now been installed by Siemens who undertook the refurbishing of the station.

Information service for engineers

INSPEC the Institution of Electrical Engineer's information service in physics, electrotechnology and control, is to launch a selective dissemination of information (SDI) service in electronics in January. It will be available on an individual or group subscription basis in the United Kingdom only. Periodical articles on all aspects of electronics, published in English or English translation, will form the basis of the service. The institution plans to start a comprehensive SDI service covering all languages and the complete subject range of INSPEC in 1971. This service is part of the overall plan for the development of a comprehensive information service, which is being supported by the Office for Scientific & Technical Information of the Department of Education & Science. For the past year the SDI service in electronics has been limited to some 600 research workers as part of a government-supported information research project. Further information and details may be obtained from the manager, INSPEC SDI Investigation, I.E.E. 26 Park Place, Stevenage, Herts.

Cranfield Institute of Technology

Cranfield College of Aeronautics, which was founded at Cranfield, Bedford, in 1947, has been granted a Royal Charter to become the Cranfield Institute of Technology with power to award its own higher degrees. As its original title implies it has been concerned principally with aeronautics but in future its object will be "to advance, disseminate and apply learning and knowledge in the disciplines of the sciences, engineering, technology and management". The Institute will also pay particular attention to "the educational needs of industry, commerce and the public services".

Laser space communication

The first laser communications system to be used in a satellite is to be developed by Aerojet-General Corp., of Azusa, Calif., under contract to NASA. The equipment is to be used aboard the Applications Technology Satellite—F (ATS) which is scheduled for launching from Cape Kennedy into a synchronous orbit in 1972. The contractors will develop both the spacecraft equipment and the associated ground equipment. When ATS—G is launched in 1974 the laser
communications experiment may be extended to include spacecraft-to-spacecraft links.

Conferences on tape

"Cassette Colloquia" is the name of a programme begun by the Institute of Electrical and Electronics Engineers to keep its members technically up to date. Cassette recordings of special seminars, workshops, sessions etc, conducted by the I.E.E.E. will be available to members and non-members. The recording technique for the cassettes involves speech compression without pitch change. This, in conjunction with editing, allows 2½ hours of material to be converted to 75 minutes in the cassette of a recent meeting. A cassette containing this length of recording costs $10.

V.H.F. complaints

The British Broadcasting Corporation has completed an analysis of reports of unsatisfactory v.h.f. reception (during 1968/69) which shows that more than 50% of the complaints were due to the use of inadequate aerials or to faulty or maladjusted receivers. A great deal of dissatisfaction could be avoided, it is said, if dealers would advise when an external aerial is necessary and would also make sure that customers know how to tune their receivers.

Full colour spectrum from infra-red

New phosphors, employing rare earth elements in crystals, have been found by workers at Bell Telephone Laboratories to convert infra-red radiation into any colour of the rainbow. The source of infra-red energy is a gallium arsenide diode. The initial use of the combination of GaAs diodes and infra-red-to-visible phosphors was reported by General Electric. The phosphors can be painted on the diodes—green or red light is produced by certain crystals containing erbium or holmium, and blue light using thulium. With one of the phosphors, colours gradually change from green through yellow, off-white, and orange, and finally to red, as power is increased. The red light produced is as bright as that emitted directly by other solid-state lamps.

WWV standard frequency transmissions

The National Bureau of Standards (U.S. Department of Commerce) in Boulder, Colo., is responsible for the operation of four radio stations (WWV, WWVB and WWVL at Fort Collins, Colo., and WWVH, Hawaii) that transmit accurate time and frequency information. The formats of two of these stations, WWV and WWVH, are being reviewed for possible changes and modification. A questionnaire has been sent to many known users of the broadcast services and any other users (government, military, industrial, scientific or private individuals) who wish to receive the questionnaire are asked to write to WWV, 1969, National Bureau of Standards, Boulder, Colo. 80302.

For the record, station WWV has been transmitting standard radio frequencies on a regularly announced schedule since March 1923 and WWVH began supplementing the broadcast services of WWV from a site on Maui, Hawaii, in 1948. Both stations broadcast the same services on high-frequency carrier waves. Stations WWVB and WWVL at Fort Collins transmit on L.F. and V.L.F. The services of all four stations are described in publication 286, NBS Frequency and Time Broadcast Services, available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for 25 cents.

TV camera for low-light levels

A television camera, type GTNV-1 capable of producing pictures from scenes illuminated at light levels equivalent to starlight, has been introduced by STC. Minimum scene-illumination requirement for the camera, is about 2 x 10^-4 ft. candles so that it can respond to scenes that are invisible to the human eye. A vidicon tube is used in conjunction with a three-stage image intensifier having a very high overall gain. Typical brightness magnification is 35,000 times. No special contrived illumination such as infra-red beams, or reliance on self-emitted infra-red is necessary. For use underwater, where there is very little light, a clearer picture is obtained by using the natural light available rather than an artificial source, the light from which tends to be scattered back to the camera and so degrading the picture.

The STC low-light television camera with cover removed

W.W. Diary

The larger-page size 1970 Wireless World Diary (5 x 3 inches) has enabled a more readable type to be used for the information section which includes those features found to be most acceptable to users. They include formulae, circuits, aerial data, colour television and stereo broadcasting characteristics, transistors, data, frequency allocations, addresses of organizations and many other facts and figures.

The Diary, which has a week-at-an-opening, costs 10s. (leather) or 7s. (resin).

American incentive licensing allocations

Although the U.S. Federal Communications Commission recently suspended the application of proposals for increasing the sub-allocations of h.f. bands available only to amateurs holding Extra Class licences, there remain substantial portions of the bands available only to those holding Extra Class and Advanced Class licences, as part of the policy of encouraging American amateurs to study for the more advanced licence examinations, in a scheme introduced in November 1969. The first 25 kHz of the 3.5, 7, 14 and 21-MHz bands are available only to Extra Class telegraphy, the frequencies 3.8 to 3.9, 7.2 to 7.25, 14.2 to 14.275 and 21.25 to 21.35MHz are now all subject to reservations for either Extra Class only or for Extra Class and Advanced Class telephony. Our correspondent Pat Hawker says British amateurs have expressed opposition to an A.R.R.L. proposal that American telephony operation should be authorized in the band 14.1 to 14.2MHz.

Mysterious generation of u.h.f. exploited

An unexplained phenomenon, discovered at RCA Laboratories in 1967, has been harnessed by RCA to produce the most powerful pulses of radio energy in the u.h.f. range yet achieved by a solid-state device. The effect occurs in avalanche diodes, when they are placed in a circuit tuned to oscillate at frequencies lower than those at which the diodes are supposed to be able to oscillate. For reasons that are still not fully understood, when electrical pulses are now applied to the diodes, they abruptly enter an “anomalous mode” of operation and begin to produce microwave oscillations with powers and efficiencies substantially higher than normal. It is reported that by combining five such devices in a single tiny package and operating them in the anomalous mode, microwave pulses with peak powers above 1,200W have been produced with efficiencies above 25%.
Letters to the Editor

The Editor does not necessarily endorse opinions expressed by his correspondents.

Transistor Distortion Characteristics

Mr. Linsley Hood’s results (given in his November article) are rather unexpected, in one respect. A perfect transistor would exhibit a voltage gain independent of $h_{fe}$, and, in his particular test circuits, independent of the load resistance as well. Yet the reported figures, even allowing for the imperfections of the transistors, are at variance with this expectation. They are also at variance with my own measurements.

In a practical circuit, the voltage gain is very nearly $g_m R_L$, for a planar transistor with low “extrinsic base resistance". Now $g_m$ is a function of the collector current, not the current amplification factor. It is about 40 $I_C$. Thus a transistor operating at $I_C = 1$ mA has a $g_m$ of about 40 mA/V.

Mr. Hood’s tests, $I_C R_L$, was kept constant, so one would have expected the voltage gain to be constant, to a first approximation, irrespective of the variation in $h_{fe}, I_C$, and $R_L$. In circuit A, for example, $I_C R_L$ was fixed at 5, so the expected voltage gain is 200, not 40–140 as reported.

My own quick tests on a silicon planar transistor (BFY51) produced the expected results: the voltage gain with 5 V dropped across the load was 185–210 for loads of 1–8 kΩ; i.e., and 8 to 1 variation in collector current. There is clearly something wrong somewhere.

In the case of alloy transistors, the extrinsic base resistance is comparatively high, and changes the performance appreciably. At the higher collector currents and lower values of $h_{fe}$, this resistance (perhaps a few hundred ohms) is comparable with the “true" input resistance $25 h_{fe}/I_E$. Its effect is to reduce the apparent $g_m$ and also to make the transistor operate, not as a purely voltage-driven stage, but in a mode between voltage drive and current drive.

This latter effect improves the linearity. It follows that the linearity of any voltage amplifier stage can be improved by inserting base resistance. The price you pay is in reduced gain and increased noise. (Much the same effects are obtained by the use of an unbypassed emitter resistor.)

If large output voltage swings are taken, distortion due to Early Effect may become important. (This was reported by Dr. Bailey in connection with one of his power amplifiers, where the driver stage had to deliver large swings.) It may well be that a low-$h_{fe}$ transistor shows less of this distortion than a high-$h_{fe}$ one, though correct selection of types is perhaps better than selecting for low $h_{fe}$.

G. W. Short,
South Croydon,
Surrey.

The author replies

I was pleased to read Mr. Short’s letter, and I note with interest, his argument that a transistor should, ideally, always give an identical stage gain, as a voltage amplifier. However, this is not the situation one finds in practice, nor is it the conclusion one draws from gain calculations made using the classical formula, using the conventional $h$ parameters, for a common emitter configuration.

$$M = \frac{h_{re}}{h_{fe}}\frac{(1+h_{re}Z_L)}{Z_L}$$

assuming $Z_{pec} = 0$.

Taking the transistor type which he quotes, and obtaining the typical values for the $h$ parameters, $h_{re}$, $h_{oe}$, $h_{ce}$ and $h_{fe}$ from the Mullard data sheets, the calculated stage gains for a BFY51, under ideal conditions of zero source and emitter impedance, vary from 210 to 319 over the range of collector loads 1 to 10 kΩ.

However, there is a less complex formula quoted by Manasse, using the concept of the “$h$ determinant" $\Delta_h$, ($\Delta_h$)

$$M = \frac{h_{fe} R_L}{h_{re} \Delta_h - h_{re}}$$

Since over the range of loads in question with a BFY51, $\Delta_h$ is very small, this approximates to:

$$M \approx \frac{h_{fe} R_L}{h_{re}}$$

So, if the input impedance of the transistor increases linearly with the product $h_{fe} R_L$ (and $h_{re}$ may remain nearly constant), the theoretical condition could be met. Normal device shortcomings, such as doping inhomogeneity, carrier trapping and the base-emitter spreading resistance presumably give rise to the failure of the theoretical model.

However, with regard to the gain figures I quoted for the devices I examined, it had not been my intention that these values for gain should be taken as the voltage gain of such devices under ideal voltage amplifier conditions. Alas, low-distortion signal generators do not have zero output impedance. My intention was, rather, to establish a form of "figure of merit" for such devices, and to determine the comparative performance, say, of germanium versus silicon and n–p–n versus p–n–p. In this context the fact that the signal generator had not a zero impedance output was not of importance.

In fact, the apparatus used was a Solartron VF252 precision millivoltmeter, a Radiometer BKFS10 distortion meter and a Marconi TFI 101 low-distortion oscillator, with 1kHz output filter. (The modulus of the output impedance of the Marconi oscillator is 660 ohms, which accounts for the actual stage gain being lower than the calculated zero input impedance value.) It was remiss of me not to mention in the article the source impedance used, but, surely, if one really wanted to know what the typical stage gain of a particular device would be under zero input and zero emitter resistance conditions, one would calculate it from the formulae, rather than try to measure it with a possibly very untypical component.

With regard to the point raised by Mr. Engstrom in his letter in the December issue, may I say that the points he raises are agreed. The treatment of transistor voltage amplifier non-linearities on the basis of variation in the input admittance is, indeed, the classical approach. However, I quote Mr. P. J. Baxandall’s observation that in transistor circuit design it is much more fruitful to consider the devices as voltage amplifiers; and treat their non-linearities on that basis, rather than to endeavour to swamp the input impedance changes by the inclusion of massive input or emitter circuit impedance.

J. L. LINSELY HOOD

References

Stereo gramophone pickups

The most interesting and timely article by Mr. Stanley Kelly on stereo gramophone pickups in the December issue prompts me to raise two points. First, although in reviewing the dynamics of the transducer-stylus-groove system, Mr. Kelly does assume a compliance for the disc material of $3 \times 10^{-6}$ cm/dyne, neither he nor any other authority that I am aware of, tells us very much about the behaviour of disc material. What, for example is the effect of temperature upon it and are there significant differences between various record manufacturers' products in this respect. I have long felt that the characteristics of record material and, above all, resonances which occur within the disc and the effect that different modes of bedding records on the turntable have upon this, are worthy of close examination.

Secondly, Mr. Kelly's reference to novel principles for pickups (strain-gauge and photo-electric) recalls another possibility which must be of particular appeal to readers of Wireless World, because its life-force is h.f. The mono version of this type of pickup uses a conventional stylus flexibly anchored at the rear end carrying, instead of coils or magnets, a single vane of quite negligible mass. The movements of the stylus due to the groove modulation causes relative movement between the vane and a fixed plate or electrode which is continuously energized to emit a constant high frequency e.m.f.

The stylus-driven vane is connected to a tiny "receiver"—merely a tuned miniature pot-core inductance, and semiconductor diode. The amount of h.f. energy reaching this receiver at any instant depends upon the instantaneous position—hence impedance—which the vane forms with the fixed plate or pole; in short the h.f. energy input is amplitude modulated by the movements of the vane. The diode delivers an audio-frequency product to a load resistance of 100kΩ, or so, and this is conducted away to the input of the record player amplifier.

The system is readily adapted to stereo by the employment of two vanes at right angles. The same h.f. pole is easily adapted to energize both vanes; the receiver and diode are, of course, duplicated—one for each vane; the a.f. currents from them are the two inputs to the stereo channels. Unaffected by d.c. or 50-cycle a.c. fields—magnetic or electrostatic—and potentially capable of outputs normally met with in crystal pickups, the advantages are evident and more than overcome the need for the oscillator necessary to energize the "pole". Such an oscillator can easily be housed within the pickup arm if need be. Indeed, why should we not go the whole way to achieve the ideal completely conductorless pickup arm—no filamentary wires, no mercury baths—just two oscillators in the pickup head, frequency-modulated by the same two moving vanes and one common fixed plate; two transmitters, in fact, transmitting over a few inches to two miniature f.m. receivers strategically placed at the side of the turntable.

H. J. N. RIDDLE, Sherborne, Dorset.

The author replies

With reference to Mr. H. J. N. Riddle's letter, the values quoted for disc material were obtained by direct measurement by myself, and are indicative of present day vinyl products. For any given record material the absolute value of compliance is a function not only of the record material, but also of stylus radius, stylus pressure, the mechanical impedance with reference to the stylus tip, and temperature; it not only varies between record manufacturers but to a second order from batch to batch of record material.

Additionally, a given record does tend to harden with time and over a period of years the effective compliance decreases. Although one tacitly assumes that the impedance of the record as seen by the stylus tip is a pure compliance, this is more of a pious hope than fact. There are the inevitable loss components and the variation of impedance with frequency suggests a more complex structure than a simple RC combination.

I agree with Mr. Riddle that the characteristics of the disc material are taken too much for granted and although at various times I have investigated particular facets of this interesting problem, the finances of a private laboratory cannot unfortunately accommodate the detailed investigation that this subject requires.

With reference to the stereo capacitor type of pickup, one such unit has been produced in Japan and during the past few years I have received samples of this device. Unfortunately, the first was damaged in transit, and the second unit exhibited lack of stability, pre-sumably due to frequency variation of the h.f. oscillators. Additionally, the setting up of the two transmitters and receivers was critical if audible beat noises between the two systems were to be eliminated. The mechanical characteristics of the moving vane are not simple, acceptable signal-to-noise ratio controls the minimum change of capacitance and this in turn determines the vane's dimensions, which are larger than would have been expected.

I agree that on paper at least the variable capacitance type of pickup is very attractive, especially if one can fit the complete transmitter within the pickup head shell. My own thoughts on the matter are to use a single r.f. transmitter phase modulated by each channel with suitable decoding systems. Stanley Kelly

Stereo decoder adaptor

We regret that the circuit was omitted from the letter under the above heading on p. 565 in the December issue. To avoid ambiguity we are reprinting the letter with the diagram.

Haven't seen the circuit for a stereo decoder adaptor in "Circuit Ideas" in the September issue I am prompted to send you a much simpler circuit which I have been using for several months.

Instead of having a variable gain amplifier on each channel a 0.5 attenuator is placed before the decoding matrix when a mono programme is being received. With a mono signal $T_m$ saturates and earths one end of the attenuator chain formed by the two 10kΩ resistors. Thus only half the mono sign is applied to the matrix. On stereo $T_m$ is off and the full signal is applied to the matrix. The 100kΩ resistor ensures that the 1df capacitor does not have to change its charge when going from mono to stereo.

A. ROYSTON,
University of Warwick,
Coventry.

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![Stereo decoder circuit diagram](https://example.com/stereo_decoder_circuit.png)
Circuit Ideas

Constant current generator
Dual transistors are used to ensure cancellation of thermally variant transistor parameters in the simple constant current generator shown.

By suitably proportioning the resistor values the drift of the constant current due to variation of transistor base-to-emitter junction voltage, collector-to-base leakage current, and current gain are cancelled out.

For cancellation of base-to-emitter voltages the necessary circuit relationship is:

\[ R_4 = R_2 \]

To assist stable operation with change of leakage current and gain the remaining resistors are proportioned to satisfy the equality:

\[ R_5 = \frac{R_1 R_2}{R_1 + R_3} \]

The output current is given, with good accuracy, by:

\[ I_{cc} = \frac{V_{cc}}{R_5} \left( 1 - \frac{R_3}{R_1 + R_3} \right) \]

The transistors should be operated with equal emitter currents to ensure tracking of the two base-to-emitter voltages with temperature.

The resistors should be wire-wound types with low temperature coefficients. The differential temperature coefficient of the resistor pairs \( R_1, R_2 \) and \( R_3, R_5 \) is more important than the absolute temperature coefficient.

The measured temperature coefficient of \( I_{cc} \) is typically 0.0015%/°C over the temperature range 0 to 100°C.

As shown the constant current is directly proportional to the supply voltage. To make the constant current independent of the supply, resistor \( R_1 \) may be replaced by a temperature-compensated zener diode. An additional resistor \( (R_2) \) is then required in series with the base of transistor \( T_{1r} \), such that \( R_2 = R_1 \).

M. CADWALLADER
London N.W.3

A M.O.S.T. frequency-doubler chain
The high impedance of m.o.s. transistors allows tuned frequency doublers to be cascaded without requiring impedance transformation. The use of enhancement devices eliminates the need for a separate bias supply. The arrangement is shown in the diagram. The potentiometer is adjusted to provide the required bias for maximum efficiency. Since \( C_{ds} \) is not highly dependent on the applied gate voltage, adjustment of \( VR \), does not detract the preceding circuit. Doublers are not prone to feedback and interaction problems so that dual m.o.s. devices such as the Marconi-Elliott E6029 could be used. The circuit will operate up to 150MHz with the high \( f_m \) devices of the E6019, E6029 series.

J. A. ROBERTS,
University College,
Swansea.

Negative resistance of transistor junction
If the emitter-base junction of a silicon planar transistor is reverse biased, it behaves as a zener diode, with a typical breakdown voltage of 7-10V. If the base is left open-circuit and connection is made to the collector instead, the "zener diode" has a negative resistance characteristic. The effect is exhibited by most n-p-n silicon planar transistors, but by few p-n-p types. The relaxation oscillator in Fig. 1 can be used as a test circuit.

The device is also useful for firing thyristors. Fig. 2 shows a simple half-wave lamp-dimming circuit which can be controlled manually, by \( VR \), or by a d.c. input 0 and 10V at (a) or an a.c. input 0 to 10V peak-to-peak at (b).

J. A. H. EDWARDS,
Leicester.

Low-distortion 30Hz-20kHz oscillator
The circuit is a Wien bridge oscillator employing an f.e.t. to reduce damping on the bridge and allow the use of a 300kΩ twin potentiometer. Harmonic distortion of the prototype was reduced to less than 0.05% over the whole band with the aid of the 22kΩ preset resistor.

C. A. Pye,
Exhall,
Warwickshire.

Fig. 1. Test circuit giving ramp waveform.

Fig. 2. Thyristor firing circuit.
Amorphous Semiconductors

An electronic engineer's view after a recent conference at Cambridge

by J. E. Carroll, Ph.D.

About 350 pure and applied physicists with a sprinkling of electronic engineers were in the Cavendish Laboratory, Cambridge, from September 24th to 27th,* to discuss the amorphous and liquid state. Amorphous materials with their lack of obvious structure have for a long time posed fundamental problems of description to the pure physicist, but the applied physicist and engineer are not attracted to a field unless they have a whiff of a practical application. Although negative resistance and switching effects have been reported as long ago as 1962, this whiff of practical utility was not scented by the technical hounds until 1968 when Ovshinsky2 published a letter entitled 'Reversible electrical phenomena in disordered states.' The title appears harmless but the contents suggested the use of amorphous semiconductor material in the application of switches with a high ratio of 'on' to 'off' impedance and also in the application of memory devices. Applications to the communications industry and logic functions in computers are then obvious if the device is a success. At first sight there appear to be several useful technological features: apparent lack of sensitivity of the material to small amounts of impurity, the devices can be used in thin film form that would be compatible with modern integrated circuit technology, no power consumption to maintain the memory, to name a few of the more obvious advantages. This then accounts for a small technical explosion of interest in this field. This article attempts to give a simple account of these amorphous semiconductors and their associated potential devices in the light of the recent Cambridge conference.

The amorphous state

First, let us ask the question, what is an amorphous material? An initial definition would be a material that exhibited no structure or order. So no matter where we looked, we should see a random spacing of atoms in the material. Although partially true, this is too naive. The solid material has to be bound together by some cohesive force. This cohesive force can then impose constraints on the extent of the disorder. It is well known that the outermost electrons (valence electrons) of any atom determine the chemical properties of the atom, or in other words determinate how one atom binds itself to any other. One type of binding together of atoms is called covalent binding. The valence electrons are shared between pairs of neighbouring atoms, lowering the potential energy of the pair and so binding them together. This binding can extend throughout the crystal. Fig. 1(a) indicates such a scheme for say crystalline germanium. Each atom shares four electrons with neighbouring atoms and this completes a relatively stable configuration. In Fig. 1(b) the same scheme is shown in a disordered array but to preserve the binding the bonds are still linked. The technical jargon says that the co-ordination number of each atom is preserved. This imposes constraints on the short-range order (say over a couple or so of atoms spacing). To appreciate this fully one needs to go to quantum theory of electron orbitals, but this is not necessary here. However, over larger distances disorder prevails and the atom spacing and positioning become quite random. A slightly more realistic model is obtained by allowing for several of the valence bonds to be broken, or dangling as they are often referred to. This is shown schematically in Fig. 1(c). It is such covalent amorphous materials, but with more complex structures, that have been causing most interest since in many ways they behave like intrinsic conventional semiconductors. There are, of course, other amorphous materials such as amorphous metals. In this latter case the atoms are bound together by a sea or jellium of almost free electrons shared between a large number of atoms. The binding imposes no long- or short-range order and the conduction is not significantly changed between the crystalline and amorphous states. At present these latter materials are not of interest.

Returning to the covalent amorphous semiconductors, we find further evidence for the short-range order in the absorption of certain wavelengths of light. If a

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photon of light has sufficient energy to break a valence electron bond in a semiconductor then it can become strongly absorbed by the material. Thus if the absorption of light shows a marked edge to it as the wavelength of light is changed (Fig. 2) then this is evidence of a uniform binding energy throughout the body of the crystal. Qualitatively similar optical effects are found in amorphous and crystalline material, though often with different magnitudes. From the existence of these effects it can be inferred that there is considerable uniformity of the electronic structure close to each atom. In other words there is indeed a short-range order in the amorphous material. Now as one of the speakers at the conference asked 'what is a forbidden gap but the binding energy of the valence electrons?' The absorption edge energy is indeed one of the ways of measuring the gap between the valence and conduction band energies in conventional semiconductors. Thus we still expect to find a similar gap in amorphous semiconductors. However, although all gaps are forbidden, some are more forbidden than others! In amorphous material there are lots of broken valence bonds. Although annealing the material can reduce their number, their density is still very high. It is so high in fact that any 'free' electrons, introduced by impurities (on the classical semiconductor basis of creating electrons) become trapped in these dangling bonds. As a consequence the conductivity of the material is not altered even by an appreciable amount of impurity in the material. This is in complete contrast to conventional semiconductors. These traps have a continuum of energies and can in some cases fill up the conventional energy gap. Thus the density of electron states available to electrons with different energies can be drawn schematically as in Fig. 3(a). There is a continuum of states as found in conventional semiconductors but also a high density of localized states forming tails to the continuum. These localized states are in effect the broken valence bonds discussed above. To the electrical engineer who uses frequency filters these tails (or tales) appear most plausible! If one randomly alters the inductances and capacitances of the periodic chain of these elements that form a frequency filter, then one finds that the cut-off frequencies become diffuse and propagation is possible for regions extending into the formal stop band of the filter. Thus changing the periodic structure of the crystal in a random way would be expected to allow a certain amount of propagation of the quantum electron waves outside their normal permitted range of frequencies or energies. The farther away from the formal permitted energies the more likely are the states to be localized (in the filter analogy the states are a result of local resonances in the filter structure). These tails of localized states extend both from the valence band of valence electron energies and the conduction band energies. In some materials these tails can overlap (Fig. 3(b)) so that the whole gap is filled with traps. This latter picture is believed to be the relevant one for the glasses that exhibit switching and memory. Conduction can occur in a conventional semiconductor. The electron moves in an electric field and gains energy, thus moving to a higher energy state. This is readily possible for electrons in the conduction band where there is a continuum of empty states above the electrons' particular state. It is also possible in the valence band provided that there are vacancies, or holes as they are called, in the occupation of the upper electron states in that band. These holes then permit the electrons to gain energy in an electric field and so allow conduction. An important difference between the amorphous and crystalline state is the magnitude of the mobility. The increased disorder implies that the electrons have many more collisions as they move. For a given field the electrons' drift velocity is a good order of magnitude lower than in the useful crystalline semiconductors. The mobility is then around 100 cm$^2$/Vs for these amorphous materials. There is a second mechanism that is called 'hopping'. In the high density of localized electron states in the gap, electrons can hop from one state to another under the action of an electric field. However, this hopping process results in a negligible mobility. We therefore arrive at the picture of a 'mobility gap'. Although there may be a high density of electron states throughout the energy 'gap' in amorphous materials, none of the less the mobility of any electrons filling those states can probably be ignored. The idea is shown schematically in Fig. 4. Since any free electrons become trapped by the unfilled valence bonds one is not surprised to find that these semiconductors only exhibit what is termed an intrinsic conduction. Conduction only occurs in proportion to the amount that the thermal agitation can free electrons from their bonds. The addition of impurities makes little effect on this process. The classical behaviour of an intrinsic semiconductor's conductivity is given by $\sigma = \sigma_0 \exp(-\Delta E/2kT)$ where $\Delta E$ is the band gap energy, or close to this value. This result is also found for amorphous semiconductors of the covalent type. An important consequence of this intrinsic behaviour is that the resistance of any specimen decreases as the temperature increases (more electrons produced to conduct electricity by more bonds breaking). This leads to thermal runaway under some conditions and in turn can lead to negative resistance and switching.

**Practical devices**

Let us now describe two types of device that were being demonstrated in experimental form by Energy Conversion Devices at the Cambridge conference. They both use films (circa 1 micrometre thick) of an amorphous semiconductor known as a chalcogenide glass. The first type of device is the Ovonic Threshold Switch, or O.T.S., named after Ovshinsky who first reported it in 1968. The threshold voltage is around ten volts and the off resistance can be as low as megohms while the threshold voltage is reached so the current rises to a few microamps and then switches to many milliamps. The switching time can be extraordinarily fast and this leads to problems in surge currents through the device that can degrade the performance if they are not limited. In the 'on' state the device impedance drops to around 100 ohms (all these figures depend on geometry and so must only be taken as indicating orders of magnitude). The device then remains in the on state provided that the current is above a minimum sustaining value of around 10 mA, or equally the device voltage does not fall below about a volt. If the current does fall below this sustaining level then the device reverts to its high resistance state. Provided that surge currents are limited it is claimed that these switches can be recycled almost indefinitely. The characteristics for the O.T.S. are shown schematically in Fig. 5(a). It should be pointed out that there is evidence against the existence of a closely defined threshold voltage since some workers find that this varies statistically from one switching operation to another. This point was hardly made at the Conference.

Closely allied to the O.T.S. is the O.M.S. or Ovonic Memory Switch. Energy Conversion Devices were exhibit-
ing an experimental thin film array of these devices. In this type of device the conducting state of the glass is permanently, although reversibly, changed by the application of the switching voltage, which must be maintained for a time measured in milliseconds. The switch will then move to its low resistance state and remain in this state even though the current and voltage are removed. The device can then form part of a memory store. The low resistance state may be changed back by applying a current of around an ampere for about 100 microseconds. This then restores the device to its high impedance state. Fig. 5(b) indicates schematically the action of this device. To read the state of the memory one applies a voltage from a source with a medium impedance. In the low impedance state the fraction of the voltage dropped across the switch is negligible and so a voltage sensor across the switch can register zero. In the off state the full voltage appears across the switch so the voltage sensor indicates a unity value. This 'read' process can be made extremely rapid so that at present the memory could find applications in a 'read mostly' or 'read only' type of memory store. Ovshinsky used a material with a composition of Te₄As₅Si₁₉Ge₁₀ for his switches and reduced the arsenic content to around 5% for the memory devices. However, it is not clear or, at least, reported what determines whether a device will be a memory, a threshold switch, both or neither.

The chalcogenide glasses used for these devices are covalent amorphous semiconductors and so exhibit a negative temperature coefficient for their resistivity. It is natural to think of the switching as possibly being caused by thermal runaway. Indeed at the Cambridge conference evidence was presented that showed the thermal runaway model fitted several experimental facts. It may, at first sight, be thought that such a mechanism could not account for switching in the subnanosecond speeds that are observed with these devices. However, although the speed of switching is fast, there is a delay of the order of a microsecond before the actual switching occurs. Moreover, it is known that a device with a negative temperature coefficient of resistivity will form a current-controlled negative resistance and in these types of negative resistances the current tends to flow in filaments. This bit of physics can be qualitatively understood by considering a set of parallel and equal negative value resistors. If one resistor takes slightly more than its fair share of current then its resistance falls and it will take more current until the whole current is going into the one resistor. Filament formation can imply that the heat required for increasing the conductivity in the filament need only be very small. However, although the thermal runaway theory fits many facts, Professor H. Fritzche maintained that even with filament formation there was not enough heat for the filament to reach the required temperature to explain its low resistance, as measured experimentally. It may be that heat causes some slight reversible structural change so that the conduction is no longer intrinsic.

Professor H. K. Henisch in another paper suggested that electrical charge effects of the carriers could account for the switching with the current maintaining a plateau in the switch when in the off state. The neutral plasma of charge carriers could imply a high current but low voltage while recombination of the holes and electrons would imply that a minimum sustaining current was required for the plasma. Elsewhere Professor Sir Nevill Mott has suggested that tunnelling of charge carriers through Schottky barriers set up at the electrodes could result in switching. It is safe to say that at present there is no definitive theory on the switching effects in these glasses and indeed it may be a combination of effects is required to explain the facts.

The memory type of device is almost certainly connected with a structural change of the amorphous material caused by heating in a filament. A very beautiful bit of evidence for this theory was given by Dr. C. Sie of Energy Conversion Devices in a film shown to the conference delegates. In a particular material (As₅₅Te₃₅Ge₁₀) the switching time is very slow and Dr. Sie filmed the device under a microscope and showed the filament growing from the anode. On first applying the voltage, in excess of the switching threshold, the surface of the semiconductor changed its reflectivity slightly accompanied by a current rise. But then one saw (Fig. 6) a filament growing slowly from the anode towards the cathode contact of the device. As the filament moved towards the cathode the threshold voltage for current switching decreased until, when the filament had fully formed, the threshold voltage was zero and the device was perfectly ohmic in a low resistance state. A microprobe analysis of the composition of the filament showed that it had changed its composition from As₅₅Te₃₅Ge₁₀ to As₃₃Te₃₂Ge₇. Temperature analysis with a micro-radiometer showed that the material heated as the current initially started but that as the filament passed under the radiometer the temperature dropped. The velocity of propagation of these filaments could vary depending on material. Rough orders of magnitude suggested the variation was between 100 cm/sec to 10⁻¹ cm/sec.

Conclusions

It is clear that much technical, technological, and theoretical work remains to be done with many elegant experiments along the way. Some elementary ideas are clear for the amorphous semiconductors but the rigorous theory on which to base quantitative work is lacking. For the practical devices the mechanisms by which they work are only just emerging. The memory device is almost certainly made possible by a change of phase along a filament; this change being induced by heating. The switching device is possibly tied up with a number of effects such as space charge, heating and contact conditions. But as one speaker at the conference said 'although we look through a glass, we look through a glass darkly'. This leaves lots of fascinating questions to be answered. Indeed switching and memory devices may not be the only uses that more knowledge about these materials could bring. It may be possible to develop specific glasses to absorb
harmful wavelengths of radiation or indeed respond electrically to other wavelengths of light that existing technology does not permit. The biggest question for the industrialist is perhaps whether it will be worth the cost. The Cambridge conference probably ensured that firms with a current programme will maintain a holding programme of work. Then at least they have a hand in the field to pluck the flowers if they suddenly bloom in the spring. The lack of technological know-how is unlikely to encourage many new firms to undertake their own research.

Acknowledgements
The author is indebted to Professor Sir Nevill Mott for allowing him to attend the conference at the last moment in spite of a full house.

References

Amateur h.f. band
For many years, amateurs in Europe and Africa have been encouraged by the I.A.R.U. Region 1 Bureau to observe voluntarily an international "band plan" on the h.f. bands in order to reduce mutual interference between amateurs using different modes. While, at times, infringements of the plan can be heard (particularly the intrusion of 'phone operation into the c.w. segments), the plan has undoubtedly played a major role in maintaining orderly operation. The band plan was modified slightly at the Brussels I.A.R.U. Conference a few months ago, and is now as follows: 3.5 to 3.6 MHz c.w. only; 3.6 to 3.8 c.w. and 'phone; 7.0 to 7.04 c.w. only; 7.04 to 7.1 c.w. and 'phone; 14.0 to 14.1 c.w. only; 14.1 to 14.35 c.w. and 'phone; 21.0 to 21.15 c.w. only; 21.15 to 21.45 c.w. and 'phone; 28.0 to 28.2 c.w. only; and 28.2 to 29.7 c.w. and 'phone. Radio teleprinter operation is recommended around 14.09 MHz.

Application Notes
Circuitry selected from device manufacturers' literature

Square-wave generator
The circuit given below operates over the following five frequency ranges: 2-20 Hz, 20-200 Hz, 200 Hz-2 kHz, 2-20 kHz, and >20 kHz. \( f_2 \) is a coarse frequency control and \( f_1 \) is a fine frequency control.

D.C. microammeter
Below is the circuit of a low voltage-drop microammeter which will give an accuracy of 1% at ambient temperature if a good quality meter and accurate resistor values are used. Variation of accuracy with temperature is given as 0.2%/°C. Extracted from: "The Application of Linear Microcircuits", Vol. 1, SGS Ltd.

General-Purpose Amplifier
The gain of this amplifier is set by the resistor \( R_f \). \( R_f = 9k \Omega \times 20 \), \( R_f = 19k \Omega \times 50 \).

50 \( \Omega \times 100 \), \( R_f = 101k \Omega \). Typical drift is quoted as 15 \( \mu V/°C \). Extracted from Plessey Technical Communication No. 7.
Magnetoresistance and its Application

Mean-square ammeter and d.c. transformer

by B. E. Jones*, M.Sc., Ph.D.

The magnetoresistance effect and the related Hall effect displayed by a semiconductor under a magnetic field have become of interest in recent years with the advent of extremely high-mobility materials. Both effects arise from the action of the externally-applied magnetic field in producing a sideways deflection of the mobile carriers taking part in the conduction process.

The magnetoresistance effect is a phenomenon in which the resistivity of a semiconductor material is considerably increased by a magnetic field whenever the carrier mobility has a large value, for example in indium antimonide or indium arsenide intermetallic compound semiconductors. It has been shown that the total resistance of a rectangular specimen of such a semiconductor shows a square-law increase at small magnetic fields (up to about 0.3 T) and a linear increase at high magnetic fields (Fig. 1 and Table 1). The magnitude and characteristics of the effect depend largely on the geometry as well as the material itself. For suitably designed components the typical dependence of $R_{B}/R_{0}$ on magnetic flux density $B$ applies to frequencies well into the gigahertz range. Wafer-shaped configurations exhibit their greatest sensitivity with the field perpendicular to the plane surface.

The electrical properties of a semiconductor are usually sensitive to temperature, and the magnetoresistance effect is no exception. Resistivity usually decreases with temperature and the larger the semiconductor surface area, the smaller the temperature coefficient. In Table 1, one device has a temperature coefficient of $-1.8 \%/^\circ\text{C}$, while a slightly bigger and less sensitive device has a smaller temperature coefficient of $-0.12 \%/^\circ\text{C}$, both figures at $B = 0$, and temperature $25^\circ\text{C}$ (these coefficients increase with $B$).

The linear magnetoresistance effect at relatively high magnetic fields has been used to produce a multiplying action, particularly for power measurement from direct current to microwaves. A transducer for displacement measurement based on the effect gave a large output of 5 V d.c. at 500 $\mu$A displacement, without using large transformers, over a working temperature range $-320^\circ\text{F}$ to $+200^\circ\text{F}$. A magnetoresistance can obviously be used for magnetic-field measurement, particularly weak fields, and has been employed as a modulator of d.c. currents and voltages, as a contactless variable resistor and been applied to a brushless d.c. motor.

Two further application of magnetoresistances are described below. In the first case use is made of the square-law characteristic at low values of magnetic-flux density, to produce a simple clip-on mean-square ammeter (0–25 A) of very low input impedance suitable for measuring practically any current waveform. In the

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Table 1

<table>
<thead>
<tr>
<th>Characteristics of Magnetoresistance Elements</th>
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<tbody>
<tr>
<td>Type</td>
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<tr>
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<tr>
<td>FP92D570</td>
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<tr>
<td>FP92L100</td>
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Note: The magnetoresistance elements are indium antimonide type made by Siemens A. Halsey A.G. and are obtainable in the U.K. from R. H. Cole Electronics Ltd., 7–15 Lansdowne Road, Croydon, CR9 2HB.

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*$^\text{Electrical Engineering Laboratory of Manchester University}$

$^1^\text{T}$ is the symbol of the tesla, the SI unit for magnetic flux density ($= 10^4$ gauss)

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Second case, magnetoresistance is used as a magnetic-flux error detector in a feedback circuit to provide a simple d.c. transformer (0–1 A) for clip-on purposes.

Mean-square ammeter

The circuit used to test the mean-square ammeter scheme employing magnetoresistance is shown in Fig. 2. A gap is cut in one half of the small ferrite ring so that magnetoresistance $R_i$ mounted on silicon grease on a thin copper plate (the airgap also linearises the relation between magnetic flux and cable current; actually flux density in the ring

$$B = \frac{1.26 I}{(i_i + i_o)} \mu T,$$

where $I$ is cable current, $i_i$ and $i_o$ are mean length of magnetic circuit and airgap width respectively in metres, and $\mu$ is the ferrite magnetic relative permeability. To allow temperature compensation a second magnetoresistance $R_s$ is similarly mounted on the plate, but situated outside the magnetic circuit. To provide a meter deflection linearly related to change in $R_i$ caused by flux changes, both $R_i$ and $R_s$ are connected in a bridge circuit whose other two arms are current sources and the choice of out-of-balance detector (resistance $R_d$) depends on accuracy and ruggedness required. The current sources are provided by two silicon transistors in a long-tailed pair arrangement with a well-defined voltage on the bases. With flux at zero ($I = 0$), potentiometer $P_1$ can be adjusted to balance the bridge.

For low flux densities $R_i = R_o + K \mu T$, and for the case $I = i \sin \omega t$, it has been shown that, considering only first-order terms, the mean detector current is given by the expression

$$I_d \approx \frac{K_i}{R_o + R_s + R_d} \left(1 - \frac{3K^2}{2} \left(\frac{R_o + R_s + R_d}{2R_d + R_s + R_0}\right)\right)$$

assuming $I_d = I_1R_1/R_0$ where $I_1$, and $I_2$ are the collector currents of transistors $T_{11}$ and $T_{16}$ respectively. It is evident that the detector current is proportional to the mean-square current $I^2/2$ in the

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*www.americanradiohistory.com*
The magnetic core material, accurately defined in terms of the operating region of the windings, has the advantage of operating the magnetic core material in a small fixed region of its characteristic, so that nonlinearity in this characteristic has negligible effect on performance. The principle has been used for direct-current measurement by employing magnetoresistance to measure d.c. flux.

The basic circuit employed to test the idea is shown in Fig. 4. A square ferromagnetic circuit containing an airgap and winding surrounds the insulated cable whose direct current is to be measured. Two magnetoresistances $R_{e}$ and $R_{a}$ are attached with silicon grease to a thin copper plate to equalize their temperatures. The core is connected in series and driven by a diode low-voltage source $(V_{d})$ to restrict dissipation. The active resistance $R_{e}$ is in the airgap, while the temperature-compensating resistance $R_{a}$ remains outside the gap. Because of the square-law characteristic of $R_{e}$, it is necessary to operate it at a constant bias flux density $(B_{k})$, and this is produced by a stable fixed current $(I_{f})$ in the feedback winding $(W)$.

If a direct current $(I)$ occurs in the cable, a change of flux will occur in the magnetic circuit, $R_{e}$'s resistance will change, and will produce the voltage $(V')$ at the connecting point of $R_{e}$ and $R_{a}$. This voltage on being amplified by $A$ and applied to resistance $R_{m}$, will produce a current $(I_{m})$ in the feedback winding $(W)$, so as to produce a flux in the magnetic circuit to oppose the original flux produced by $I$. If the gain in the flux detector circuit and the voltage gain $(A)$ are high, then the resultant flux change in the magnetic circuit will be very small, and $I_{f}$ and $I_{m}$ will be simply connected by the expression $I = N I_{f}$, where $N$ is the number of turns of the feedback winding. The current $I_{f}$ can be measured by means of a d.c. ammeter in series with the output of the amplifier.

The integrated amplifier has high gain (about 45,000) and produces a noise voltage of about 0.5 $\mu$V referred to its input, so it is necessary to use a 0.5 $\mu$A meter in a low-pass filter circuit. When $I = 0$, zero meter deflection is obtained by adjustment of a stable offset current $I_{o}$.

It has been shown that $I$ and $I_{f}$ are in fact related by the expression

$$I_{f} = \frac{1}{N} \frac{1}{1 + 1/K}$$

where

$$K = \frac{N A R_{e} P B_{k}}{V_{d} R_{e} R_{m} (l_{1} + l_{2})} \times 397$$

the open-loop gain, $P$ is the dissipation in $R_{e}$, $I_{f}$ and $I_{m}$ are mean magnetic-circuit length and airgap width, respectively, and $\mu$ is the ferrite magnetic relative permeability. With values $V_{d} = 0.7$ V, $R_{e} = 100$ $\Omega$, $P = 1$ mW, $B_{k}$ = 0.06 T, $V_{d} = 0.7$ V, $R_{m} = 500$ $\Omega$, $l_{1} = 18.7$ cm, $l_{2} = 89$ mm and $\mu$ = 1,000, $K$ has a value of about 10.

The amplifier gain fall-off is arranged to start at about 20 Hz.
Temperature effects

In both the experimental circuits utilizing magnetoresistances described above, the limit to current sensitivity and measurement accuracy is primarily fixed by drift, due to amplifier drift and magnetoresistance temperature dependence. Low temperature coefficient magnetoresistances, operated with minimum self-heating in compensating balanced arrangements should be used, and if necessary further temperature compensation can be achieved by a series thermistor or a parallel metal resistor. Amplifier drift can be reduced by using a d.c. chopper amplifier arrangement.

The experimental circuits described indicate two further useful applications of magnetoresistances. Both circuits are relatively simple and are useful for measuring currents in insulated cables by clipping a measuring head on to the cable. The mean-square ammeter is suitable for measuring practically any current waveform, while the direct-current transformer will measure low-frequency currents (for example, less than 10 Hz) where ordinary current transformers are inadequate.

REFERENCES


Announcements

“U.H.F./S.H.F. Techniques” is the title of a course of six evening lectures to be held at Norwood Technical College, Knight’s Hill, London S.E.27, commencing February 3rd. Fee £1.5s.

M.E.C.—Electrosil Merger. Miniature Electronic Components Ltd, of Woking, has been merged with the Electrosil Group and all future enquiries and orders should be placed with Electrosil Ltd, P.O. Box 37, Pallion, Sunderland, Co. Durham.

Compat Telecommunications, a wholly owned subsidiary of Compat Corporation of New York, has established offices in Woolmead House, Woolmead, Farnham, Surrey, to handle all of the business of its parent company outside the U.S.A. Compat are manufacturers of computer-controlled data communications equipment.

Radiatron Components Ltd has been formed to operate in association with Radiatron Ltd and to deal with a wide range of components. It will handle the Elma range of collet knobs, stud switches, Elmaset instrument cases and readout counters. Both companies will operate from 76 Crown Road, Twickenham, Middx.

Racial Electronics and Kelvin Hughes have agreed to work in partnership on a range of h.f., s.s.b. marine radiotelephones. Racial have a contract from Kelvin Hughes for the design and manufacture; Kelvin Hughes the world-wide marketing of the products.

Industrial Control Systems Ltd have moved to 78-90 Clarke Road, Northampton. (Tel: Northampton 32417).

The Crawley offices and laboratories of Pye Unicam Ltd have been transferred to the company’s head office at York Street, Cambridge, CB1 2PX.

Microwave & Electronic Systems Ltd, of Midlothian, Scotland, have moved its sales office to 66 Tilehurst Road, Reading, Berks. (Tel: Reading 581937/8).

G. A. Stanley Palmer Ltd have been appointed sole U.K. agents for the range of miniature electrolytic aluminium capacitors manufactured by the International Electronics Corporation of Long Island, N.Y.

Hayden Laboratories Ltd, East House, ChilTERN Avenue, Amersham, Bucks, have been appointed exclusive U.K. agents for Spinner GmbH, of Munich, W. Germany, manufacturers of radio frequency connectors, directional couplers and other specialized items associated with radio-frequency cables and waveguides.

Nobel Electronics, of Welling, Kent, has signed a three-year agreement as sole U.K. and European agents for Plastic Capacitors Ltd, Maydown, Co. Londonderry, N. Ireland.

Montclair Electronics Inc, of New York, have appointed G. A. Stanley Palmer Ltd as sole U.K. agents for a range of magnet reed relays and switches from the General Reed Company.
Low-distortion Bias and Erase Oscillator

Evolving a current switching design to give a predictable and stable output level and with no trimming requirement for low distortion

by D. Griffiths, Ph.D.

The design of a good bias and erase oscillator for a tape recorder is not easy. For stable biasing a constant output voltage is required, yet any limiting action in the oscillator must not be allowed to distort the sine-wave drive since this would increase the background tape noise. The circuit should be efficient so that the least expensive semiconductors can be used and, ideally, it ought to be designed to work straight off without any complex setting-up procedures, especially those required to minimize the distortion.

The oscillator was required to operate a Ferrograph Series 6 tape deck but using the procedure outlined below it should be possible to alter the component values to make it suit almost any other recorder.

**Specification**

The Ferrograph handbook gives the inductance of the two-track FE16 erase head as 1.5mH (per track), requiring 80mA at 27–30V and 68kHz; the record head only requires about 5mA at 15V. The power required from the drive circuit is fortunately not 0.08 x 30 = 2.4 watt but depends only on the losses in the heads; a perfect inductor can not have a net dissipation of energy. Since the erase head has a mu-metal core it is only useful to measure its losses under actual working conditions, for it is quite hopeless to try to extrapolate data on iron-cored inductors.

In the absence of a suitable measuring bridge the losses in this head were assessed by observing their damping effect on a tuned circuit resonating at 68kHz with 30V across it.

The inductance of this test circuit should be less than, say, one fifth of that of the tape head so that the resonant frequency is not too greatly changed by the extra head inductance, but the waveform need only be roughly sinusoidal.

It was found that each winding of the FE16 head introduced the same damping effect on the test circuit as did a 3.3kΩ resistor. Under operating conditions in a parallel resonant circuit the head could thus be thought of as a perfect 1.5mH inductor in parallel with a 3.3kΩ resistor, resulting in power dissipation of about 0.25 watt.

At this point one has to face firmly the problem of ensuring a constant output voltage. The necessary limiting action can use the "curvature of the characteristics" of the active circuit elements but designability is sacrificed and well stabilized power supplies are required to maintain operation in the critical region. Some form of a.g.c. could be employed but amplitude overshoot at switch on must be avoided. This is also a problem with thermistor stabilization. The alternative scheme chosen here is to send constant current pulses of a suitable shape through a tuned circuit coupled to the tape heads and rely on a reasonable Q value to reduce the harmonics sufficiently. This filtering is more effective than one might imagine since the harmonic amplitudes decrease with increasing order, while the attenuation of the tuned circuit also rapidly increases with rising frequency.

With transistors or valves it is a simple matter to generate well enough regulated driving pulses for this application but the feasibility of the scheme depends entirely on maintaining a good Q in the filter despite the loading of the losses in the tape heads.

**Current switching**

Ideally the reader should now turn up *Wireless World* for November and December 1962 to an article by R. C. Foss and M. F. Sizmur which gives an admirably lucid account of current switching sine wave oscillators. Their first diagram is reproduced here as Fig. 1 and is a good starting point. When the current generator is first connected to the tuned circuit the voltage at point (A) will swing below +E with a period governed by the resonant frequency. The size of this swing depends on the losses in the LC circuit, as well as the magnitude of the drive current. Eventually the voltage at (A) swings back up towards +E, even with the constant current generator still connected. When the voltage across the resonant circuit is zero (i.e. when the point (A) is at +E again) we choose to switch the current supply into a bypass resistor $R_b$. The point (A) then continues its upward voltage swing and but for the losses this would take it as far positive above +E as it had been below +E half a cycle earlier; the current generator has infinite output impedance and cannot load the LC circuit. When the voltage at (A) eventually falls to +E again we reconnect the current supply to the tuned circuit and the cycle repeats.

As a step to a practical realization Fig. 2 shows the next stage of complication and is also from Foss & Sizmur's article. Here the tail current $I_1$ is alternately switched between the transistor and the diode by the action of the voltage induced in the base winding $N_b$ which is coupled to the tuned circuit. As indicated, a phase reversing connection is necessary so that when the point (A) is below +E the base end of $N_b$ is positive with respect to ground and the transistor conducts as required. But for this base winding voltage and

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Fig. 1. Principle of a current switched LC oscillator.

Fig. 2. Tail current is switched between the transistor and the diode.
Wireless World, January 1970

The tail current driving the LC resonator would be \( E/R_t \). The tuned circuit is only lightly damped by the transistor as the collector is a high impedance point.

In Fig. 3 the diode is replaced by another transistor with its collector connected to a similar LCR circuit as that on the left hand side. Except for the brief instant of current changeover, the tail current flows only through either \( T_r_1 \) or \( T_r_2 \). Whichever transistor is off will have its collector above \(+E\) while the other collector is equally below \(-E\). That is, the voltages at (A) and (B) are equally shared by the positive supply rail.

It is now only a small step to the final arrangement shown in Fig. 4. A single tuning capacitor is employed across a centre tapped inductor which has an additional winding to provide the required bias and erase voltages. As only a positive supply rail was available, the bottom of the tail resistor is connected to ground and the centre tap of the base winding supplied with a suitable potential stabilized with a zener diode. A pair of plastic encapsulated transistors is used for each switch to give the collector dissipation required when both erase heads are simultaneously connected in two channel operation. The 15Ω emitter resistors help to equalize the current in each pair and are useful inspection points at which to observe the individual current waveforms. The 2.2kΩ base resistors are a personal whim to reduce possible excessive base currents when trying out the prototype.

We choose to make the reference voltage defining the tail current about 2.5V above common. There are two reasons for using such a small value. First, that the collector voltages can have a large excursion which will entail a lower step-up ratio to achieve the desired output volts and hence a lower reflected loss from the heads, giving a better \( Q \) factor in the filter. The second reason is connected with reducing the output distortion, as discussed later.

To see if the negative going excursions are bottoming the transistors one does not check the voltage waveform at the collectors (!) since the flywheel effect of the high \( Q \) tuned circuit dominates the response; it is more useful to examine the tail voltage across \( R_t \) as shown in Fig. 5, and look for the 'dents' indicated. It must be remembered that during the off half cycle the transistor experiences a maximum collector voltage equal to the supply plus the amplitude of the downward swing. 12V r.m.s. is about the maximum reasonable collector excursion with the circuit values shown in Fig. 4. The maximum collector voltage is thus about \( 22 + (12 \times 1.4) \) V. Even allowing for a peak emitter voltage of 3V (see Fig. 5), this uncomfortably exceeds the maximum recommended \( V_{ce} = 30 \) V of the 2N3704 transistors used in the prototype.

If the tail current is assumed to be constant during each cycle, the collector dissipation can be easily calculated once the mean collector-emitter voltage is known over the conducting half cycle. Since the average value of a half-sine wave is 0.64 times its peak value and if the collector peak swing is \( 12 \times \sqrt{2} \) volts, then the collectors are on average \( 12 \times \sqrt{2} \times 0.64 = 11 \) V below \( +22 \) V when conducting, i.e. 1.1V. When operating, an Avo indicated 2.6V d.c. across the tail resistor, giving a tail current of 52mA. On average, \( V_{ce} = 11 - 2.6 = 8.4 \) V and if the current is equally shared between each pair of transistors, the mean collector dissipation is \( 8.4 \times 0.052 \times 0.5 \times 0.5 \approx 110 \) mW, with the second factor of 0.5 arising from the on-off time ratio.

If the two erase tracks are in use together, the extra drive can be achieved by suitably reducing the tail resistor and there is still a reasonable margin of collector dissipation in hand. This circuit is not very efficient in terms of power consumption; the four transistors dissipate \( 0.45 \) mW to overcome a head loss of 250mW.

Although a good \( L/C \) ratio is needed to minimize losses in the tuned circuit primary, the maximum allowable primary inductance is set by the \( Q \) value which has to be maintained in spite of the damping effect of the tape head losses. With a 1:2 step-up ratio between primary and secondary the equivalent loss resistance of 3:3kΩ looks like 82Ω across the primary circuit. If the circuit shows a \( Q \) value of \( Q_r \) at resonant frequency \( f_r \), the dynamic resistance of the circuit is \( Q_r \omega L \). Clearly, in this case, we need \( Q_r \omega L = 820 \) Ω.

How much \( Q_r \) is needed? Foss and Sizmur show that with square current pulses the ratio of the \( n \)th harmonic voltage \( V_n \) to the fundamental \( V_1 \) is given by:

\[
\frac{V_n}{V_1} = \frac{1}{(n^2 - 1)} Q_r
\]

As a square wave can only generate odd harmonics, the third order one will be the principal component and with \( Q = 10 \) its amplitude will be 1.25% of the fundamental. Since it is planned to use something a little less brutal than square driving pulses, this \( Q \) value should suffice. For operation at 68kHz this fixes \( L \) at 0.25μH. A 30mm diameter ferrite pot core, Mullard LA 2202, was used (with a permeability of 63) giving 1mH for 60 turns. The primary was wound in bifilar fashion to give 30 turns centre-tapped, with 60 turns on the secondary. 28 s.w.g. enamelled copper wire was used for both windings. The working flux density in this application is in the region of 50-100 gauss.

The tuning capacitor has to be larger than the value required to tune the 0.25μH primary inductance to 68kHz since the inductance of the tape head is reflected into the resonant circuit with a magnitude reduced by the square of the
step-down turns ratio; the total inductance is thus lowered since "inductors in parallel add like resistors in parallel". The secondary winding itself does not behave as a separate inductor since the inductance in it is solely determined by that needed to balance the primary applied voltage. If the a.c. voltage across a coil does not depend on the rate of current change through it, then it does not have inductive properties.

Although Ferrograph quote a nominal eroded inductance of 1.5mH, their suggested operating point of 80mA and 30V r.m.s. indicates a working inductance more like 0.9mH. As the Vinkor pot core was used without an adjuster, its inductance would be about 10% below nominal. Together with the slight contribution from the recording head, the total effective inductance would thus require about 51,000pF to tune it to 68kHz; in practice 10% tolerance 47,000pF and 10,000pF capacitors were used in parallel. If tuned filters are used as bias rejectors in the recording amplifiers, it will be important to keep the same bias frequency on single and two track operation. The extra inductance of a square head would lower the frequency further and a suitable extra tuning capacitor would have to be switched in.

It must be confessed that there is a little bit more complication in Fig. 4 than was admitted in earlier paragraphs and this concerns the shape of the current pulses. A square pulse with its sharp edges is obviously a rather poor approximation to the required output waveform and something a little more sinewave-like would ease the filtering problem. Now one cannot go to the limit and use an exactly sinewave current drive derived from the output waveform since there is then no limiting action, other than unintentional clipping and bottoming, etc. As a compromise we use a current pulse which is "partly square and partly sinewave". This is illustrated in Fig. 5 which shows the alternating voltage waveform across the 50Ω resistor, superimposed on the calculated d.c. level which could not be observed with the a.c. coupled scope available.

The sinewave-part of the current waveform is developed by the long tail switching action; the sinewave part has a similar amplitude and is derived from the filtered output. This is achieved by giving the base windings a suitable number of turns so as to inject an appropriate amount of sinewave signal in series with the steady d.c. reference level. However, one must be careful in selecting the amplitude of this a.c. component otherwise the maximum reverse bias rating of the emitter-base junctions will be exceeded and extra protective diodes will be needed; the reverse emitter-base rating for the 2N3704 is given as 5 volts. It is important to recognize that the "off" base junction sees both base windings in series generating the reverse voltage.

Fig. 6 shows the base of T2 + V B above Vref derived from the zener diode. But for the V B of this 'on' transistor and the voltage drop across its 15Ω emitter resistor the top of the tail resistor would also be +V B above its d.c. level, taking the emitter of T3 with it (in the positive going direction). Meanwhile the voltage -V B on the left hand base winding is holding the base of this transistor down - V B below Vref.

The 1.55V d.c. level in Fig. 5 assumes a V B of 0.7V and allows for the two 15Ω resistors in parallel. The mean level of the a.c. component is 1.8 x 0.64 = 1.15V and thus an Avo on a d.c. range across the tail resistor should register (1.55 + 1.15) = 2.7V. This agrees well with the 2.6V observed. Evidently the steady current component is 32mA and the r.m.s. a.c. contribution is 25mA. In a Fourier representation of a square wave, the first harmonic has an amplitude of 4/π times the amplitude of the square wave. Adding these two contributions to the voltage developed across the dynamic resistance seen in the primary circuit, one can estimate the loss resistance at 570Ω, corresponding to a working Q of 6—which is rather below the design figure.

The 500μF reservoir capacitor in Fig. 4 ensures that the oscillation decay smooths when the circuit is switched off, thus helping to keep the tape heads demagnetized. The decay time is 0.5s.1s. Switch S2 is controlled by the deck selector knob and operates via the series 2N3704 to minimize peak current through the switch contacts. The 22Ω resistor ensures that the initial charging current of the 500μF capacitor does not greatly exceed the maximum transistor current rating of 80mA.

Performance

After all that story, how does it do its job? The amplitude of the output slowly increases by 2-3% during the first half minute or so after switch on and this is probably due to heating of the transistors. A 40°C rise in junction temperature would lower V B by about 90mV and thus increase the standing tail current enough to account for this observed rise in output. This effect could be reduced by increasing the tail voltage, remembering to add diodes to protect the base-emitter junctions from excessive reverse voltages arising from the necessary accompanying increase in sine wave drive. It is doubtful if the present small change in biasing could possibly be detected by its effect on the recorded signal. Changes in the supply voltage only slightly affect the oscillator output as might be expected; a 10% reduction in supply potential reduced a 28V output by just under 15%.

In the absence of a wave analyser, a simple passive twin-T rejector was used to filter out the fundamental. Fig. 7 shows the circuit, and Fig. 8 shows a sketch of the residual signal from the 16V bias at a recording head on single channel operation. The amplitude of this residual is 0.06% of the input level and appears to be largely 3rd harmonic as expected. A sine wave input of 3 x 68kHz in the filter was attenuated by about 72dB as seen on the voltmeter, so it seems likely that these distortion products do not have an amplitude exceeding, say, 0.2% of the fundamental. This seems quite satisfactory and shows that the idea of using current pulses with the "edges rounded off" does indeed greatly reduce the output distortion while still retaining an adequate stability of output level. With a working Q of 6, square drive pulses would have given a 3rd harmonic component of an order of magnitude greater at 2% of full output. Judged audibly, the tape hiss is very low and BASF double play tape on the Ferrograph appears to give a peak signal-to-hiss ratio in the upper fifties of decibels.

Fig. 5. Waveform across tail resistor. 'Dents' in the peaks indicate that the collectors are bottoming.

Fig. 6. How base-winding voltages add to build up reverse emitter-base voltage.

Fig. 7. Twin-T filter for 68kHz.

Fig. 8. Residual waveform at the base winding after passing through the twin-T filter.
Industrial Telemetry

Some recent supervisory and control schemes

by R. E. Young

The early 1960s saw major developments take place in industrial telemetry1, largely as the result of the wide introduction of solid-state equipment and digital techniques. Rapid expansion then followed in step with the accelerating demand for these forms of automation backed by the extremely high reliability that they had been shown to give.

Much of this expansion occurred in the public utility field, authorities being strongly influenced in their policy by the almost overwhelming growth of "service" distribution networks, e.g. for electricity and water, and the increasing cost of manning them in the conventional way.

In general, the economy shown by the adoption of supervisory telemetry methods increases with the size and complexity of the project. Furthermore, the most favourable conditions for setting up such remote control systems are usually found with high concentrations of population and industry.

Thus in a large scale installation for electricity supply in the Far East control is exercised over the distribution network for the urban area of Kuala Lumpur2, three bulk supply stations and a total of fifteen substations being covered by the first phase of the scheme.

Recently commissioned, this is a classical digital supervisory system with time-division multiplexed telemetering and telecontrol, and employing the interrogation/reply, or responder, techniques which are used almost exclusively for this work3. With time-division operation, each information source is scanned in turn, and in these systems this is achieved by interrogating each source in terms of the unique (digital) address allocated to it.

Measurement or equivalent data points are grouped in blocks of addresses according to priority, so that the period which elapses between successive scans of a given point represents the "updating" time for its particular address block. With the exception of control functions, the various groups of addresses are interrogated in accordance with a pre-determined scan cycle, system programming being arranged to interface these addresses within the overall scan period. Typically, an updating period of 11 seconds is realized for some 80 measurement addresses; while alarm indication (e.g. for abnormal transformer oil temperature), carrying more urgency, is given a block updating time of 5 seconds.

Control instructions are also sent out by interlacing, but this is done by interrupting the routine scan cycle and thereby extending it for the additional time-sharing to take place. The same system word format is used for the control "way" addresses as for monitoring, and in both cases the encoded replies sent back from the outstation follow the same pattern.

Obviously, measurements and monitoring information generally must be presented as far as is possible without any likelihood of there being any ambiguity or misinterpretation of the intelligence. It is of interest that the network electrical measurements, viz. voltage, power, reactive power and current, are displayed in analogue form on conventional d.c. moving-coil meters. This involves the use of an individual digital-analogue convertor for each meter as the incoming signals are handled digitally throughout the logic system. It may be taken that the factor of additional cost is considered more than offset by the advantages accruing from working with a familiar form of display. Also it may be noted that the eight-bit binary number d.a.c.s which are employed, and are of the "successive approximation" type, act as information stores over the measurement updating period.

Communication between master and outstations is by "four-wire" working using special modems4 developed to give maximum speed data transmission over nominal 3kHz bandwidth circuits. These links are set up either in existing pilot cables where suitable spare cores are available or in the main communication cables running along the power network routes. Protection against extraneously induced high voltages is provided at all station line terminations by lightning arrestors and isolation transformers.

The other main area of application for supervisory telemetry systems is the monitoring and control of oil and natural gas pipe line schemes. Here inaccessibility of wellheads and pumping stations is a

1 modulator-demodulator (unit), "four-wire" working demands two conductor pairs, one for "go", one for "return".

Control room at the Shell shore terminal at Bacton for their North Seas gas project.
major driving force in the adoption of such schemes; these conditions, compared with those associated with most public utility networks, tend to impose more severe restrictions on the choices open to the telemetry system designer. Thus with projects such as the North Sea installations, the virtually inescapable use of radio links produces a "design constraint" which affects the whole system.

The same basic time-division digital techniques are employed, however, for these installations as for the public utility networks, and logic circuit blocks and address-reply methods are essentially the same. The telemetry installation for the B.P. group of wells in the West Sole field is typical of such practice for North Sea operations, the outstations on the project’s threewellhead platforms—"A", "B" and "E"—being under the supervisory control of the shore station at Easington, Yorks. As commissioned, the system capacity is 22 measurements, 120 monitor and alarm indications, together with 41 well control functions; the routine scan updating time is 25 seconds.

One of the main system operational requirements arising from its production control function is the calculation of mass flow for each of the eleven wellheads involved. These correct values have to be obtained in terms of differential pressure type flow measurements and corresponding manifold pressures, and initially a study was made of using an individual analogue computer at each wellhead. However, it proved possible to centre this function on a single digital computer which is fed with the data in digitized form, and which gives flow rates as a 3-digit numerical indication up to a maximum per wellhead of 59.9 million cu.ft./day.

In general, measurements are displayed on the mimic control panel with three-digits representation for temperature and four for pressure, a "scaling" facility being incorporated in the transfer from binary code input to the decimal reading output. Accompanying this implied degree of resolution, a 12-bit format is used for both addresses and replies, each carrying three additional parity bits for error checking. With the system parameters obtaining in this case, the address/reply cycle time becomes 570 milliseconds. For transmission over the radio links, the address and reply pulse trains are converted in a frequency shift keying modem to a "tone" input for the transmitter—2.3 kHz for binary '0' and 2.7 kHz for binary '1'.

The u.h.f. radio link scheme adopted for this project operates in the 460-MHz band and inevitably invites comparison with the offshore wellhead control scheme at Das Island in the Arabian Gulf (Unm Shaif oilfield). Described originally in 1964, this employs a microwave, 3cm ('K') band link based on a commercially available transmitter magnetron with a rated peak power output of 2.5 kW in the centre of the band. The main point of interest in the present context is that in this earlier scheme a single transmitter is used with radiation from a "cheese" reflector giving a half power beamwidth of about 40° in azimuth to cover the fan-like sector in which the wellheads are grouped.

In contrast the North Sea u.h.f. system utilizes a two stage "hand-on" arrangement for signal transmission between wellhead platforms. The primary link is established between the Easington master and the outstation on platform A, working between this platform and both platforms B and E1 being on a "broadcast" as distinct from a beamed mode. Thus the transmitters on B and E1 operate on a shared frequency, and, in order to avoid radiating together, "come on the air" only when their own plant addresses are received.

Helical aerials mounted on 200-ft towers are used for transmission and reception on shore and at the platforms. The 11-turn helical elements, made by C & S Antennas Ltd, have a rated beamwidth of 30° to half power points with a v.w.f.r. of 1.5 over the operating bandwidth of 400-500 MHz.

The radio link equipment itself is solid-state throughout, Standard Telephones and Cables type HTR20 f.m. transmitter/receivers being employed with a nominal transmitter power output of 5 watts. This output is obtained from a varactor tuned to act as a trebler stage fed at 133.3—163.3 MHz from two preceding trebler stages which have a modulated input at 14.8—17.8 MHz. This latter input is obtained from a two-stage phase modulator with crystal oscillator reference drive. Two stages of amplification are interposed between the modulator and the first set of treblers which is followed by three more stages of amplification to give the input to the final varactor trebler. A tunable bandpass filter is placed in the output from this varactor stage to act as a harmonic suppressor.

In the double superheterodyne receiver the first mixer is preceded by a two section bandpass filter and two stages of r.f. amplification. The bandpass filter is largely responsible for the degree of r.f. selectivity and second channel rejection achieved. A single crystal oscillator feeds both mixer stages, the higher local oscillator frequency required for the first mixer being obtained by multiplication by six (doubler followed by trebler). This avoids the production of spurious beats which is possible with two separate oscillators, "spurious responses" being given as below—80dB. Intermediate frequencies are 70MHZ and 10.7MHz with an initial local oscillator frequency of 55—68MHz, fed to the second mixer, and multiplied to 330—408MHz for the first mixer. The output of the second mixer, nominally at 10.7MHz, is fed into a crystal filter to give selectivity at this frequency and thence to a wideband amplifier which provides the input to the limiter and discriminator stages. Both the wideband amplifier and these stages are constructed as linear integrated circuits. Performance criteria are based on a minimum acceptable signal/noise ratio of 20dB; while, for the individual radiation requirement of the broadcast mode, carrier "on" switching time is given as not more than 1μS.

"Telegrid" master programming control System

As already indicated for the two schemes described, system working speed (data handling speed) is kept relatively low, i.e. the equivalent of a narrow-band telephony channel is generally required for communication. This present generation supervisory telemetry projects. Nevertheless, these communication links must be highly "secure" and, equally important, economic in the full sense of the word, and with the ever growing demand for telecommunication channels, this latter condition is becoming increasingly difficult to meet. This difficulty is encountered whether line or radio working is adopted because of limited capacity—scarcity of installed cables, particularly in built-up areas, and on the radio side, severely restricted channel allocations for such applications.

It is with this background that the Telegrid proposals were put forward as a means of "multiplying" the number of existing communication channels by what may be called supra-multiplexing under the control of a master programming source. The scheme, proposed by G. S. Kermack, managing director of Network Controls, makes use of specific communication channels available to users, grouped on a network basis, in accordance with a time sharing schedule held in sequence by narrow band synchronizing signals. Planning of such a scheme would have to be on a national scale, although operation might be on a regional basis within the national framework.
In one suggested embodiment of the scheme (Figs. 1 and 2), four networks are time multiplexed under the control of broadcast synchronizing signals. Network allocation, as shown, would be electricity, gas and water for a distribution group, together with an emergency or stand-by network available to take over from any one of the other three. Alternatively, network 4 could be utilized to give a low speed data transmission facility over a large area in the event of, say, major floods occurring.

The programming of these networks is carried out by a combination of imposed synchronization and delay timing. For this the networks are grouped into two pairs, with the first member of the pair taking the external synchronizing signals, and the second becoming operative after a predetermined time delay following the commencement of the first network scanning cycle or sub-programme.

The main technical feature of the system is the form of coded signals used for programming the networks. These signals are built up from "pips", i.e. short bursts, of tone which can be broadcast from a low-frequency (say 300kHz) transmitter to cover a regional area. In addition to their task of time division synchronization, these master-programming signals perform two other functions:

(i) Designation and identification of the network to be activated;
(ii) "Start" the individual network scanning cycle after receipt of the correct combination of signals.

The latter provision is achieved by arranging that the five pips must have been preceded by the six pips before the "five-pip" group is opened up, and conversely. If this sequence is not maintained owing to the absence of a signal or the presence of spurious signals, then the networks are not activated until the correct sequence is re-established, i.e. the system has been made to "fail-safe".

From the diagram it will be seen that guard spaces form part of the timing pattern. These take care of short-term variations and fault condition in individual sub-programmes.

Other developments employing these techniques can be envisaged, as, for example to arrange for each pip or burst of tone to contain a predetermined number of cycles, and, by counting at the receiving end, to obtain further complementary checking and possibly more precise synchronization.

One of the main advantages of the system is that with an accurately maintained pip (tone) frequency, say at 400 Hz, the signal extraction band-pass filters can be made extremely sharp and only a "crevasse" is required within the synchronizing channel transmission spectrum. Furthermore, with such band-pass filters (e.g. crystal or mechanical type) high rejection of spurious signals is obtained.

**Television Link on Low Bandwidth Cable**

Television, as a time-division system, is part of the telemetry family; and in presenting visually inaccessible conventional gauges and similar instruments fulfils a specific telemetering function. One of the main attractions of such presentation is that effectively there is no updating delay, and—often of more importance—rapid changes in quantities can be seen on analogue displays via a television link, whereas they are beyond the capability of the comparatively slow scanning telemetry system.

To speed up these telemetry scanning rates to give the equivalent of a television system, though theoretically possible, becomes prohibitive in cost. There are instances, therefore, when a television scheme provides the most economic way of tackling an unconventional instrumentation problem, this being much more marked when it can be used for other monitoring duties as well.

A variant of such a scheme is represented by the East Anglian Water Company's closed-circuit television installation at Lowestoft where the emphasis is on surveillance rather than instrument monitoring. The outstanding feature of this project is the video link. As far as is known, this is the first time that a link has provided operationally acceptable picture quality over a 5.2 mile (8.35 km) length of "telephone grade" cable without intermediate repeaters.

This link is of interest on two counts. The first is the potential offered by the equalization and allied techniques which have been developed and shown to be effective under these conditions for high-speed pulse transmission. This aspect bears directly on the problem of obtaining maximum data transmission speed on restricted bandwidth circuits, and also on the improvement in error rate produced by equalizer correction of signal distortion.

The second point is that compromise on picture standards had to be reached but that it proved possible to use a field rate of 50 per second instead of the much lower rate proposed at first in view of the "no-repeater" and other limitations. It was clear that a 405-line interlaced structure was the absolute maximum that could be attempted in terms of frequency and this had the advantage that comparatively low-cost U.K. standard camera and monitor equipment could be employed.

The S.T.C. ten-pair cable installed by the water company between its intake and borehole station at Belaugh and the Horning master control for both
Telemetry and television supervisory control position at the Horning master station of the East Anglian Water Company showing monitor picture as received over the low bandwidth cable link.

telemetry and television signal transmission is of the polythene insulated type with outside steel tape armouring acting as a screen. Diameter overall is some 22mm, individual conductors being of 0.9mm diameter. Conductor resistance is given as 44.2 ohms per mile at 15°C, with attenuation at audio frequencies of 1.20 dB/mile and crosstalk between pairs better than —80dB measured on site. Attenuation reaches a value of some 80dB down at 1.2MHz with an unequalized frequency response approximating to the form 1/frequency.

In the final solution, the video circuit was established as two conductor pairs diametrically opposite each other in the cable and connected in parallel. This was found marginally better than a single pair circuit; and at the output of the receiving end equalizing amplifier a uniform response within 2dB is obtained up to 1MHz. The overall response is about 6dB down at 1.2MHz with relatively sharp cut-off thereafter.

It should be noted that a contribution to improved high-frequency response is made by including pre-emphasis in the transmitting characteristic. This amounts to 10dB with a 3dB point at 200kHz. The necessary phase equalization is carried out at the receiving end, some 0.5 microsec. correction being given at 1MHz.

Finally a “crispen” is incorporated to sharpen up fast edges in the video waveform by speeding up their rise times in a non-linear network. The crispen unit embodies an input filter to extract the fast edges from the equalized video waveform for feeding to the non-linear system. This filter operates by signal subtraction referred to a wideband delay line to give a Gaussian type response. After leaving the non-linear network, the artificially sharpened edges are recombined with the original video waveform, the delay time in the filter being compensated by introducing a corresponding delay in the main video path.

The results obtained in respect of signal/noise ratio, better than “dusk” type with outside telemetry and unequalized better than about 80dB down at 1MHz. Transmission to give a picture quality of meter reading (10 foot—candles), can be ascribed to the precautions taken, e.g. with regard to common mode rejection (receiving head amplifier rejection ratio of 70dB), and to the maintenance of electrical balance about earth at the appropriate points in the system. The picture reproduction gains considerably from the crispening technique, although quite acceptable without it; a rise time of less than 800 nanosec being obtained on a 10kHz square wave as measured at the input to the crispen. The overall picture quality also benefits from the use of a monitor with a black level clamp.

Acknowledgement must be made to L. G. Davis, of Glenn Sound Services, who was responsible for the special television link equipment described, and to Serck Controls for supplying details of the two supervisory systems covered in the first part of the article.

REFERENCES
2. “The remote control and supervision of urban power Distribution in Kuala Lumpur”, by P. J. White, to be published in Electrical Review.

Reprints from W.W.

We regret the delay in the publication of the reprint of the articles covering the Bailey 30-W and 20-W amplifiers and pre-amplifier. This is now available. For the convenience of new readers we give below the full list of W.W. reprints obtainable from the Trade Counter, Dorset House, Stamford Street, London S.E.1. Prices include postage and packing.

No. 1. High fidelity Amplifiers by A. R. Bailey (Nov. and Dec. 1966, and May, June and Nov. 1968). Contains articles on 20- and 30-W amplifiers; a pre-amplifier; and an output transistor protection plus modifications and relevant correspondence. Price 5s.

No. 2. Stereo Decoder and Simulotor by D. E. O'N. Waddington (Jan. and Oct. 1967). Describes the construction of a stereo decoder for positive or negative power supplies and contains details of an instrument for producing a stereo multiplex signal. Price 3s.

No. 3. Portable 1-MHz Frequency Standard by L. Nelson-Jones (Feb. 1968). Presents a design for a frequency standard which is phase locked to the 200kHz Light Programme transmissions. Price 3s.

No. 4. Wide-range General Purpose Signal Generator by L. Nelson-Jones (April 1968). Range 150kHz to 120MHz in five bands; output attenuator range 100dB in 20dB steps (+0.5dB); modulation depth 0 to 50% (can be set to within ±5% of meter indication); max. output: 100mV (from 75). Price 3s.

No. 5. Low-cost High-quality Loudspeaker by P. J. Bazandall (Aug. and Sept. 1968). Can be built for a few pounds! Excellent performance above 100Hz but is improved if used with a woofer for the low frequencies. Price 5s.


In addition, the following reprints from earlier issues are still available: Wireless World Oscilloscope: Main frame, X amplifier, E.H.T. unit (March, June, July and August 1963), price 5s; No. 1 (audio) Y amplifier (April 1963), price 2s 6d; No. 1 (audio) Timebase Unit (May 1963), price 2s 6d; Calibration — Alternative E.H.T. Unit (Feb. and Oct. 1964), price 2s 6d; Wide-band Amplifier (March and April 1964), price 2s 6d.

Active Filters
6. Lead-Lag network and positive gain
by F. E. J. Girling* and E. F. Good*

The well-known Sallen-and-Key low-pass and high-pass circuits provide two of the most useful building blocks for applications where only low or moderate values of Q factor are needed. They are practical examples of the second type of active system analysed in Part 4, a lead-lag or lag-lead network and positive gain, with input connections changed to give low-pass or high-pass response as the case may be.

A notch (or zero) in the stop band is easily obtained by adding a parallel path. This gives a section with a characteristic useful in the realisation of a high-order filter as a cascade (or product) of factors.

Adaptations which give "tuned-circuit" response are also described.

The Sallen-and-Key circuit
The lead-lag network in a loop with positive gain, K, has been analysed in general terms in Part 4. This analysis can be applied to the Sallen-and-Key low-pass circuit, Fig. 1(a), by reference to Fig. 1(b), which shows the same circuit with the input V1 shorted out and a floating generator V2 introduced into the feedback path. If now the loop is supposed opened at X and the freed end of V2 earthed, it can be seen that µ is given by the transfer function of the lead-lag network, eqn. (19), Part 3, multiplied by K, i.e.

\[ \mu = \frac{KpT_2}{1 + p(T_1 + T_2/b) + p^2 T_1 T_2}, \]  

where

\[ T_1 = C_2(R_2 + R_3), \]
\[ T_2 = C_2 R_2 R_3/(R_1 + R_2). \]

With the loop closed, therefore, since \( \beta = 1, \)

\[ V_{out} = \frac{1}{{1 - \mu}} V_2 = \frac{K p T_2}{1 + p(T_1 + (1 - K)T_2/b) + p^2 T_1 T_2}. \]  

Now the argument used in Part 4 for deriving eqn. (39) from eqn. (38) gives, if proper note is taken of the change of suffixes as between Fig. 11(b), Part 4, and the present Fig. 1,

\[ \frac{V_2}{V_1} = \frac{1}{p C_2 R_2} = \frac{b}{p T_2}. \]  

Hence

\[ \frac{V_{out}}{V_1} = \frac{K}{1 + p T / q + p^2 T^2}. \]  

where

\[ T^2 = T_1 T_2 \]

and

\[ \frac{1}{q} = \left( \frac{T_1}{T_2} \right) + \frac{1 - K}{b} \left( \frac{T_1}{T_2} \right). \]  

Alternative analysis as a series-feedback system
The Sallen-and-Key circuits are commonly used with \( K = 1 \) (nominally), obtained from an amplifier controlled by 100% series negative feedback. Such an amplifier is most simply represented by the cathode follower, as explained in Part 1 and as used again in the present Part in Fig. 4. Figs. 2(a) and (b) are a reminder of the identity between a cathode follower and a high-gain sign-inverting amplifier with 100% series feedback, and show that essentially the only difference is in the practical matter of where the circuits are earthed. To clarify the identity the output-current circuit in each case is completed by including \( R_2 \) and by drawing a short circuit through the h.t. batteries X and any other bias supplies, since it must be assumed that they show negligible impedance to signal frequencies. Ordinarily, of course, the cathode follower, Fig. 2(b), is drawn with the "earthed", or common, line at the bottom. Since

\[ K = A(A + 1) \]  

\( K \to 1 \) only as \( A \to \infty. \)

By using the enhanced emitter follower, Fig. 3(a), values of \( A \) of several hundreds are readily obtained; and it may sometimes be useful to extend this type of connection to triples, etc. If an operational amplifier is to be used, one with differential input and which can take 100% feedback is needed, Fig. 3(b). An operational amplifier should give the low voltage drift obtainable from a long-tailed-pair input stage, which would be useful in an l.p. filter required to pass zero-frequency (d.c.) signals.

In the ideal case, \( K = 1 \), eqn. (6) reduces to \( q = (T_1/T_2)^1 \) and hence \( T_3 = qT_1 \) and \( T_4 = qT_2 \). For finite \( A \), substitution from eqn. (7) into eqn. (6) gives

\[ \frac{1}{q} = \left( \frac{T_1}{T_2} \right) + \frac{1}{b(A + 1)} \left( \frac{T_2}{T_1} \right). \]  

This is the same as eqn. (39) of Part 5, and is algebraic proof of the identity of

\[ V_2 = \frac{A+1}{A} V_0 \]

\[ V_1 = \frac{1}{A} V_0 \]

\[ V_{out} = \frac{V_0}{A} \]

\[ V_{in} = \frac{V_0}{A} \]

Fig. 2. Example of an active device—a valve: (a) in common-cathode connection, i.e. as a high-gain amplifier, \( V_0/V_1 = -A; \) (b) in common-anode (cathode-follower) connection, i.e. with 100% series negative feedback, \( V_0/V_2 = A/(A + 1). \)
the Sallen-and-Key circuit and the lag-and-integrator loop with series feedback (Fig. 15 of Part 5), which was mentioned in Part 1. The identity may also be demonstrated graphically as shown in Fig. 4. This is an application of the identity shown in Fig. 2. The only difference between the two circuits is that in (a) terminal 2 of the output is shown earthed, and in (b) terminal 1. But since in neither—in so far as the diagrams tell the whole truth about the circuit—does any current flow in the earth lead, the change makes no essential difference and may be regarded as only a device for marking the node which is to be taken as the reference point of potential.

The triode valve in Fig. 4, as elsewhere, is intended as a universal symbol for a three-terminal amplifier. When more complex amplifiers are used, the identity may not be seen so clearly. A multistage amplifier used as a voltage follower will be wired up somewhat differently from when it is used as a high-gain sign-inverting amplifier, because of the practical requirement in each case for operation from an earthed power supply. Similarly if an operational amplifier with differential input is used, the internal workings are somewhat different in the two connections. But as all are close approximations to an ideal three-terminal amplifier the essential identity remains. The two separate drawings of Fig. 4 are, moreover, not really needed. The change of earth point can be made by the disconnection marked X and the reconnection marked with an arrow head.

Compensation for finite internal gain

If $A$ is finite and positive, application of 100% feedback gives $K < 1$, since $K = A/(A + 1)$. The theoretically best way of making $K \rightarrow 1$ very closely is to make $A \rightarrow \infty$. But in some situations it may be helpful to use an amplifier of moderate internal gain and reduce the feedback, Fig. 5(a), so that

$$K = \frac{A}{A + 1} \left(\frac{r_5}{r_1}\right) = 1,$$

which is obtained when

$$r_5 = r_1/A. \quad (10)$$

This artifice, which is easily applied when the amplifier $j_5$, for example, an enhanced emitter follower, Fig. 5(b), allows the use of the ideal design values. It is important to remember, however, that $K$ (and consequently $q$) is just as sensitive to changes in $A$ as before. Caution is needed, therefore, if this method is used to obtain certain values of $q$ much beyond the reach of the same amplifier without compensation. There is no complete substitute for high internal gain.

In the alternative analysis (or synthesis) (i.e., as a lag and an integrator in a negative-feedback loop) the parallel argument is that finite gain, $A$, in the integrating amplifier can be compensated by applying positive feedback (feedback fraction $1/A$) to the amplifier to make its gain approximately infinite, and further that the adjustment is no more critical in the one case than in the other.

In both methods of analysis over compensation produces a regenerative term (negative damping) which subtracts from the positive damping designed into the circuit, and $q$ is higher than intended; but only if the magnitude of the negative term exceeds the positive will the system oscillate, although, of course this is no criterion of satisfactory performance.

It follows also that working the Sallen-and-Key circuit with $K > 1$ is equivalent to working the integrating amplifier in the lag-and-integrator circuit with $A > \infty$ (if mathematicians will allow the statement), meaning that the amplifier gain at zero frequency, $-A$, has gone positive, since $A = K(1 - K)$, and that the circuit is working in the region above the diagonal in Fig. 9, Part 5. This further emphasizes the regenerative nature of the situation when $K > 1$.

Use of Sallen-and-Key circuit with $K > 1$

When $K = 1$, $T_2/T_1 = q^4$. Hence when $R_1 = R_4$, $C_2/G_1 = 4q^4$. This may give an inconveniently large value for $C_1$. By using $K > 1$ a lower value for the ratio $T_2/T_1$ and hence of $C_1/G_1$ is needed for a given $q$.

Let $C_1 = C_1/q$, and $C_2 = xC$. Then $T_2 = CR/x$, $T_1 = x/(1 - b)CR$, and substitution in eqn. (6) gives

$$\frac{1}{q^4} = \frac{1}{x(1 - b)} \left(\frac{1}{b(1 - b)}\right)^4,$$

which can be rearranged to give $K$ in terms of $x$, $q$, and $b$. Thus, for example, the circuit may be designed for $C_1 = C_1$, but at the cost of providing components (both $C_5$ and $R_5$) of sufficient accuracy in initial selection and in long-term stability to meet the increased sensitivity to errors in component values (Fig. 9).

Part 4), which can be interpreted as the result of balancing negative and positive resistance.

Lead-lag network with resistive loading

The network in the feedback path (Fig. 1) is as shown in Part 3, Table 1, diagram (a). As the ratio $C_2/C_1$ is increased, $k \rightarrow 1$. Hence, when $K = 1$, the loop gain at $\omega_r$ also tends to unity, (i.e., $kK \rightarrow 1$), and $q \rightarrow \infty$ (theoretically without limit) as shown by the diagonal lines in Fig. 9 of Part 5, $q$ being proportional to $\sqrt{(C_2/C_1)}$. Up to this limit the active circuit behaves like a passive circuit: no matter what the component values the circuit cannot become unstable (oscillate), and errors in component values are not magnified.

When the network is loaded by resistance $R_1$ as shown in Fig. 6, $k \rightarrow R_3/(R_3 + R_1)$ and the limiting case

* It is interesting to notice that increasing $C_2/C_1$ reduces $q$, the $Q$ factor of the passive network. However, over the useful working region (i.e., to the left of the points of maximum $\omega$) and always when $K > 1$, the increase in $k$ dominates.
is therefore reached when \( K = (R_3 + R_1)/R_2 \). This may then be considered as a practical maximum value for \( K \), since in general magnitude of errors is to be avoided. The presence of \( R_4 \) also alters \( \omega_0 \) and design equations are given in the appendix. This compensation for resistance loading by increasing \( K \) will be most useful when the resistances are effectively accurate and stable, and the ratio \( K \) is therefore accurately known. If \( R_3 \) is the input resistance of the amplifier, it may be subject to considerable uncertainty. It is then desirable that \( R_5 \gg R_3 \) (and \( \gg R_3 \)), so that if compensation is attempted \( K \) will be only slightly \( > 1 \) (Fig. 7).

**High-pass filters**

Any low-pass filter can in principle be transformed into a high-pass filter by substituting \( 1/pT \) for \( pT \); which means changing a lag into a lead, an integrator into a differentiator, and so on. Operating thus on eqn. (4) of Part 5 gives

\[
\mu = \frac{pT/q}{1 + pT/q} \frac{pqT}{1} = \frac{pT/q}{1 + pT/q} \frac{pqT}{1} (12)
\]

and the schematic shown in Fig. 8. The transformation does not necessarily yield a practical filter however. Fig. 9 is formally the h.p. counterpart of Fig. 13, Part 5, and if checked by conventional linear circuit analysis gives the expected h.p. transfer function. As it stands, however, it is unlikely to give a satisfactory performance. At high frequencies it is a shunt feedback system with ratio arms \( C_1 \) and \( C_{1'} \). As the impedances of these fall indefinitely with increasing frequency, and as the response is required to remain level, indefinitely increasing current is called for. An upper limit to these currents can be set by padding out \( C_1 \) and \( C_{1'} \) with \( r \) and \( r' \) inserted at the points \( X \), making \( C_1' r' = C_r \). The presence of these resistors must however to some extent reduce both loop gain and loop phase shift in the region of \( \omega_0 \) and the circuit is now Winter treated as a two-lead loop, time constants \( C_r r \) and \( C_{1'} r' \) with negative gain (\( R_1/r \) if \( A \rightarrow \infty \)), to which the formulae for two lags and negative gain derived in Part 4 can easily be adapted.

The theoretical schematic of Fig. 8 does not show the same difference. At high frequencies (well above \( \omega_0 \)) \( V_{out} \rightarrow V_{in} \) and the "error" \( (V_{in} - V_{out}) \rightarrow 0.0 \). There is therefore no call for indefinitely increasing current through \( C_1 \) with increasing \( \omega_0 \) and the same is true for the series-feedback arrangement shown in Fig. 10. Fig. 10(a) shows the functional schematic of a straightforward circuit with no buffer between the lead and the differentiator; c.f. Fig. 15, Part 5. The design values given are for the ideal case \( A \rightarrow \infty \). Reversing the procedure shown in Fig. 4, we redraw the circuit with change of earth point and obtain the Sallen-and-Key high-pass circuit shown in Fig. 10(b). The only serious doubt the designer should have about these circuits is that in theory the amplifier should have a level response up to infinite frequency. As however, it can be of the voltage-follower type, and as high internal gain is of importance only in the vicinity of \( \omega_0 \), it will generally not be difficult to give the amplifier a satisfactory performance up to the highest intended signal frequency. It may, indeed, be thought desirable in these and other active high-pass systems, especially when the internal gain is high, to define the final high-frequency cutoff (with added components) rather than leave it to the chance values of stray capacitances. For finite values of \( A \)

\[
\frac{1}{q} = \frac{T_1^2}{T_1} \frac{b(A + 1)}{T_2^2} (13)
\]

The notation is in conformity with Part 3, Fig. 8 and eqns. (28) to (31), and the primes serve to draw attention to the inversion of the positions of the suffixes compared with the low-pass case, eqn. (8). For \( K > 1 \) the appropriate substitutions can be made in the low-pass results.

**Input impedance**

For low \( q \) (say \( < 1 \)) the input impedance of a Sallen-and-Key filter is not very different from that of the network when passive. At higher values of \( q \), because \( T_1/T_1' \) or \( T_2/T'_2 \) become \( \gg 1 \), at the resonant frequency the voltage across the element behind the input terminal is equal to \( q \) times the input voltage approximately, and it is necessary to take account of the relatively heavy current that will flow if the filter itself and the preceding circuit are to operate satisfactorily.

**Notch factors**

A notch filter with a symmetrical amplitude vs. frequency response may be used to reject a particular frequency, or be combined with others to form a broader band-stop filter. One with an asymmetrical response may be used as a section of a higher-order filter (e.g., Fig. 1 of Part 1) to give a sharper transition from pass band to stop band. In either case the notch is associated with a quadratic factor with a numerator zero.

Passive CR notch networks, with and without buffer amplifiers, have been described in Part 3. For such networks \( q > 1 \); and Fig. 11(a) shows an example which gives a symmetrical notch,

\[
\frac{V_{out}}{V_{in}} = \frac{1 + p^2 T_1 T_2}{1 + p T_1 T_2} (14)
\]

with a zero at \( \omega_0 = 1/(T_1 T_2) \), if the necessary equal-time-constant condition is met, \( T_2 = T_1 \), i.e.,

\[
Q_2 R_2 = Q_1 R_2 (R_1 + R_3) \]

(15)

For \( q > 1 \) the circuit can be made active (i.e., feedback can be applied) as shown in Fig. 11(b). The part of the circuit above and to the right of the dotted line through \( X \) is the standard Sallen-and-Key l.p. circuit (Fig. 1), if the assumption is made that the output impedance of the buffer amplifier \( (1) \) is negligible; while the circuit to the left of the dotted line through \( X \) is the circuit of Fig. 11(a), unaltered if the assumption is made that the output impedance of the amplifier \( (K) \) is also effectively zero. There must therefore be zero transmission at the same frequency as for eqn. (14); while signals once injected into the upper part of the circuit, whether through \( R_2 \) or through \( C_2 \), are subjected to the \( q \) of this active part of the circuit. The complete transfer function is, therefore,

\[
\frac{V_{out}}{V_{in}} = \frac{1 + p^2 T_2^2}{1 + p T_1' q + p^2 T_2^2} (16)
\]
where $T^2 = T_1 + T_2$, and $q$ is given by eqn. (6). Preferably the amplifier $K$ is a high-gain amplifier with 100% feedback. Then, as before, $K = A/(A + 1)$, and $q$ is given by eqn. (8).

For an asymmetrical notch, low-pass type, the numerator becomes $(1 + a^2T^2)$, where $a < 1$, and

$$\omega_n = \sqrt{(a^2T^2)} = \omega_0 \sqrt{a} \quad (17)$$

($\omega_0$ is the frequency of the notch, $\omega_n$ the undamped natural frequency of the system.) The required attenuation in the high-pass path is easily added by connecting the buffer amplifier 1 to a tap on $R_2$; i.e., the network in box $B_1$ is replaced by the network shown in Fig. 11(b), which has the transfer function $a'pC_1R_2/(1 + pC_2R_2)$. $T_3 = C_2R_2$ must of course still be $T_2$, eqn. (15). For an asymmetrical notch of high-pass type, attenuation can be introduced into the low-pass path as in Fig. 19 of Part 3, so that, as for the passive network,

$$\omega_n = \sqrt{a}/T = \omega_0 \sqrt{a} \quad (18)$$

Fig. 11(b) is the standard Sallen-and-Key l.p. filter with an added h.p. path. A notch can just as easily be obtained by taking a standard Sallen-and-Key h.p. filter and adding a l.p. path, in other words by starting from Fig. 15 of Part 3, and turning the lower tee into an active filter. The result is shown in Fig. 11(c). As (theoretically) the gains at zero frequency and at infinite frequency are equal, the response is a symmetrical notch. Fig. 11(e) shows attenuation added into box $B_1$ of Fig. 11(c) (i.e., into the low-pass path) to give asymmetrical notch response, high-pass type. This arrangement may be slightly preferable to that described in the previous paragraph, as high-frequency signals need to pass through only one amplifier.

It is not essential to have a buffer amplifier in the added parallel path. The networks of Fig. 22 of Part 3 can be turned into active filters (e.g., Fig. 12) and the transfer functions are easily derived by making use of those for the passive networks. It is found, however, that for $K = 1$, $q = b(T_1/T_2)^2$ or $q = b(T_1/T_2)^2$. This results in a greater spread of component values, since $b$ and $a$ are $< 1$ (often $\frac{1}{11}$). Also $q_{max}$ is smaller for a given internal gain $A$ when $K = 1$ nominally. It seems likely, therefore, that the circuits with the buffer amplifiers will usually be preferred.

In the filters with a buffer amplifier, $q$ is a function of the active part of the circuit only, and, as in the simple l.p. and h.p. filters, depends on the ratio of two time constants ($T_1$ and $T_2$) and on the amplifier gain $K$. $T_2$ is isolated from the active part of the circuit, and so errors in $T_2$ do not affect $q$, although they do affect the accuracy of the required match ($T_2 = T_3$) and hence the depth of the notch. If the gain of the buffer amplifier (1) is appreciably greater or $< 1$, $\omega_n$ is moved accordingly, eqns. (17) and (18), but its gain affects neither $q$ nor the depth of the notch (as long as its output impedance is effectively zero).

So in this sense its internal gain is not a critical factor. And in the notch filters without a buffer amplifier, although $T_3$ cannot vary independently, still $q$ does not depend critically on the balance of components or of time constants, at least for $K < 1$. This contrasts with the behaviour of some rather similar-looking circuits based on the CR parallel-tee network, which can give higher values of $q$ for a given value of the internal gain, $A$, when $K = 1$ nominally, and which will be the subject of a later article.

Simple bandpass (tuned-circuit) response

As shown at the beginning of this article, Fig. 1(b) and eqn. (4), the standard Sallen-and-Key l.p. filter can be arranged to give tuned-circuit (1st-order bandpass) response by injecting the signal voltage in series with $C_1$; and, as shown in Fig. 4, for the case $K = A/(A + 1)$, (i.e., $K < 1$), by moving the earth point a more convenient arrangement with one side of $V_a$ earthed is obtained. Similarly the h.p. filter, Fig. 10, is converted to band-pass by injecting the input at the point $X$. The strange appearance of the circuits is partly remedied by a change of layout as shown in Figs. 13(a) and 14(a), which show the circuits as having feedback networks of familiar form (e.g., Fig. 3, Part 1), only the input connections being unusual.

Because of the limitation

$$q_{maix} = \frac{1}{2}\sqrt{b(A + 1)} \text{ or } \frac{1}{2}\sqrt{b'(A + 1)}$$

the circuits are likely to be of limited application; for band-pass filters usually require higher $Q$ factors than low-pass or high-pass. For values of $q$ well below $q_{maix}$, however, the circuits are interesting in being fully "designable" while using the minimum possible number of components, one amplifier, two capacitors, and two resistors. This very economy, however, makes the circuits unaccommodating; e.g. the gain at resonance which for $K = 1$ is equal to $q^2/b$ or $q^2/b'$ (i.e., $2\times 2$ when $b$ and $b'$ = 1) cannot be varied independently of $q$.
and to overcome this inflexibility additional components must be added.

An ab initio analysis of the circuits, for 

\( A = \infty \), \( K = 1 \), could be made as follows: (a) write down the current flow caused by \( V_{1n} \), assuming both the input of the amplifier (the virtual earth) and the output are shorted to ground; (b) write down the current flow caused by \( V_{out} \), assuming that both the virtual earth and \( V_e \), are shorted to ground; (c) set the sum of the currents converging on the virtual earth to zero.

The useful part of the current flow (a), i.e. the equivalent exciting current, is the current through \( R_1 \) (in Fig. 13) and through \( C_1 \) (in Fig. 14), i.e.

\[
I_{equiv} = \frac{V_{1n} p T_1}{R_1 (1 + p T_2)}
\]

and

\[
I_{equiv} = \frac{V_{1n} p C_1}{1 + p T_2}
\]

where \( T_1 \) is the time constant given by \( C_1 \) in combination with \( R_1 \) and \( R_2 \) in parallel (Fig. 13), and \( T_2 \) is the time constant given by \( R_2 \) in combination with \( C_1 \) and \( C_2 \) in parallel (Fig. 14).

These equations, as could be foreseen, represent the current a voltage source would drive through a series CR branch; and so the same response will be obtained if the source \( V_1 \) is replaced by the source \( V_{1n} \) feeding in through a branch \( C_{1n} \), \( R_1 \), of time constant as specified, Figs. 13(c), 14(c). For the magnitude (gain) to be the same, \( R_2 \) should equal \( R_1 \), or \( C_2 \) should equal \( C_1 \), for the two cases respectively. But the advantage of having the added branch is that now the gain can be varied independently by varying the impedance of the branch while keeping the product \( C_2 R_2 \) constant.

Alternatively the response to an input \( V_{1n} \) may be calculated. Thus, for Fig. 13,

\[
\frac{V_{out}}{V_{1n}} = \frac{R_1 + R_2}{R_3} \frac{1 + q p T}{1 + p T/q + p^2 T^2}
\]

whence by equating currents the response to \( V_{1n} \) can be obtained,

\[
\frac{V_{out}}{V_{1n}} = \frac{R_1 + R_2}{R_3} \frac{q p T}{1 + p T/q + p^2 T^2}
\]

if \( C_2 R_2 = q T = T_2 \). By the same type of argument it is easily shown, Fig. 13(d), that low-pass response may be obtained by feeding in a signal \( V_{1n} \) through a low-pass (simple-lag) tee network, again of the same time constant, \( T_2 = q T \).

From the other circuit similar derivations can be made as indicated in Fig. 14. Here it is found that

\[
\frac{V_{out}}{V_{1n}} = \frac{R_1}{R_3} \frac{1 + q p T}{1 + p T/q + p^2 T^2}
\]

and consequently that \( C_2 R_2 \) should now equal \( T/q = T_2 = (C_1 + C_2) R_2 \).

Although all these derived circuits are extravagant in the number of components used, they can be a convenient practical choice. The extra components cause some reduction in \( q_{max} \) but usually the effect is slight. Component values for \( C_2 R_2 \) are not critical, since the input branch is effectively isolated from the resonant feedback loop by the virtual earth and has almost no effect on \( q \).

**Appendix**

The transfer function giving \( V_{out}/V_{1n} \) for Fig. 6 is readily obtained from eqn. (1) by substituting the impedance of the parallel combination of \( R_2 \) and \( C_1 \), i.e. \( R_2/(1 + p C_2 R_2) \), and by making the following convenient substitutions:

\[
k_1 = R_2/(R_1 + R_2 + R_3),
\]

\[
k_2 = R_2/(R_1 + R_3),
\]

\[
T_1' = k_1 T_1
\]

i.e., \( T_1' \) is the CR product formed from \( C_1 \) and \( (R_1 + R_3) \) in parallel with \( R_2 \).

[Note: \( k_1/k_2 = k_1(1 - b + b) \).] Thus it is found that

\[
\frac{V_{out}}{V_{1n}} = \frac{k_1 K}{1 + p T/q + p^2 T^2}
\]

where

\[
T_2 = T_1' T_2',
\]

\[
1/q = (T_1' T_2') + (k_1/k_2)(1 - k_2 K)/T_2' T_1'.
\]

In the special case \( K = 1/k_2 \), \( 1/q = (T_1' T_2') \) and \( T_1' = q T_2 \). \( q T_1' \) which have the ideal form of the corresponding equations for a simple LCR passive prototype. Thus the sensitivity to errors in capacitor values is the same as that of the circuit with an unloaded network, although, since \( K > 1 \), there is additional sensitivity to errors in the values of the resistors that determine \( K \) and \( k_2 \).

**Corrections to Parts 3 and 4**

In Part 3, October issue, in the caption to Fig. 16 \( C T_1' \) was printed instead of \( C R_1 \).

In Part 4, November issue, the following have been noticed. In Fig. 2, in the box representing the passive network, only the denominator of the transfer function appears. This should read \( 1/(the \ expression \ printed) \). In Fig. 5(a), \( 1 + \) has been omitted from the denominator of the transfer function in the box representing the passive network; and in the last full column (p. 525) references to Figs. 10(a) and 10(b) should read 11(a) and 11(b) respectively.

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![Fig. 13. Derivation of band-pass filter and an alternative form of low-pass filter from the standard l.p. filter (Fig. 4).](www.americanradiohistory.com)
Personalities

Professor C. W. Oatley, O.B.E., F.R.S., professor of electrical engineering at the University of Cambridge, has been awarded one of the Royal Society's three Royal Medals for 1969/70 "for his distinguished work in the wartime development of radar and latterly for the design and development of a highly successful scanning electron microscope." Professor Oatley has occupied the chair of electrical engineering at Cambridge since 1960. He was in charge of basic work on radar transmitters and receivers at the Government Radar Research & Development Establishment during the war and from 1945 until receiving his professorship was lecturer in electrical engineering at the University.

The University of Edinburgh has appointed P. L. Kirby, D.Sc., F.Inst.P., who is research director of Welwyn Electric Ltd, of Bedlington, Northumberland, as its second visiting industrial professor in the newly established Microelectronics Liaison Unit within the School of Engineering Science. Dr. Kirby graduated from Durham University during the war and after two years working on radar systems at T.R.E., Malvern, returned to the North East where he worked on the physical properties of glasses. During this period in industry he took the further degrees of M.Sc., and D.Sc. from Durham and then in 1936 moved to Welwyn Electric Ltd. Professor Kirby has maintained a personal interest in the measurement and interpretation of noise and non-linearity effects in resistive materials.

Peggy Lilian Hodges, head of Guided Weapon Simulation and System Analysis at the Stanmore Laboratories of GEC-AEI (Electronics), has been elected to the Fellowship of the Royal Aeronautical Society in recognition of the contribution she has made to avionic and guided weapon technology. Miss Hodges was born in 1921 and educated at Westcliff High School, Essex, and Girton College, Cambridge. She joined GEC-AEI (Electronics) in 1930, and her work at Stanmore has been centred largely on the performance of guided weapons. She has worked on many projects, notably Seaslug and Sea Dart, with a particular interest in weapon simulation techniques. Miss Hodges is a senior vice-president of the Women's Engineering Society.

Charles Kao, B.Sc. (Eng.), Ph.D., M.I.E.E., has been appointed an honorary senior research fellow at Queen Mary College, University of London. This is the second such appointment from Standard Telecommunication Laboratories in recent months with a view to bringing industrial experience to University affairs. From time to time Dr. Kao will lecture on his specialist subjects including topics in optical communications, coherent wave optics, and electromagnetic problems. Dr. Kao, who is 36, has been with S.T.L. since 1961, where latterly he has been mainly concerned with problems associated with the transmission of coherent light down optical waveguides for future telecommunications systems.

Alan Hall has joined Osley Developments Company, of Uxbridge, as a promotional sales manager. He was until recently in the Electronic component division of Johnson Matthey, prior to which he was with Murihead. Mr. Hall operates an amateur radio station with the call G3UWA.

John L. Carroll, who joined Data Recognition Ltd in 1966 as general manager and has been responsible for the development of their recent range of document readers, has been appointed technical director. Prior to joining Data Recognition, Mr. Carroll was with English Electric Computers where he was responsible for the development of document handling peripheral equipment, and before that he worked for Solartron on the development of character recognition equipment.

G. Ross Watson appointed by the Video Systems Division of Bell & Howell as international marketing manager, was until recently sales engineer responsible for marketing television camera tubes with the English Electric Valve Company. For three years from 1958 Mr. Watson, who is 44, was manager of a mobile television unit frequently used to demonstrate the value of closed-circuit colour TV at surgical operations.

Peter Smitham who joined ITT Electronic Services, Harlow, Essex, in July 1967 has been appointed manager. He was previously materials manager. He studied at University College Swansea and spent a postgraduate year at Salford University.

William J. Charnley, appointed deputy controller of guided weapons in the Ministry of Technology, was educated at Oulton High School, Liverpool, and at Liverpool University where he obtained a first class honours degree in electrical engineering. Mr. Charnley, who is 47, joined the Civil Service in 1943 at the Royal Aircraft Establishment, Farnborough, where he was successively a scientific officer, superintendent of the Blind Landing Experimental Unit in 1955. Six years ago he became head of the Instruments and Electrical Engineering Department at R.A.E. and two years later was appointed head of the Weapons Department. Since 1968 he has been head of the Establishment's Research Planning Division where he is succeeded by Harold G. Robinson, O.B.E., who has been head of the Avionics Department since 1965. Mr. Robinson, who is 45, was educated at H.M. Dockyard School, Portsmouth, where he was awarded a Whitworth Scholarship to Imperial College, London University. He obtained a 1st class honours degree in electrical engineering, and joining the Civil Service at the R.A.E. in 1948 continued his post-graduate studies during 1951-52 at the Californian Institute of Technology. In 1955 he took charge of the Black Knight research rocket project. From 1960 until 1965 he was in charge of the satellite launcher division at Farnborough.

Tudor Jones, M.I.E.E., aged 42, has joined Cambion Electronic Products Ltd, manufacturers of electronic components, as sales manager. He joins Cambion from the English Electric Co, Stafford, where he was manager of the Production Systems Department.

Peter L. Mothersole, F.I.E.E., M.I.E.E., has joined Pye T.V.T. Ltd, Weybridge, as engineering manager of the Audio & Vision Division. Mr. Mothersole, who is 40, has been with the Mullard

Paul Spring, who joined Grundig (Great Britain) Ltd on its formation in 1952, has been appointed managing director. Mr. Spring has successively been chief engineer, general works manager and, since 1964, technical director.

Geoffrey E. Beck, B.Sc., F.I.E.E., for the past two years chief engineer of Marconi's Electronics Group is appointed technical manager of its Aeronautical Division, based at Basildon, Essex. Mr. Beck, who is 53, graduated at Birmingham University in 1938 and joined the Marconi Research Division, where he worked on the design of naval radar equipment throughout the war. In 1949, Mr. Beck began his long association with the pioneering work into the development of Doppler navigation equipment, which provides pilots with continuous position information without the use of ground-based aids. In 1962, Geoffrey Beck and Mervyn Morgan, who were jointly responsible for this work, were awarded the Johnston Memorial Trophy by the Guild of Air Pilots and Air Navigators in recognition of their service to aerial navigation. From 1965 to 67, Mr. Beck was manager of the group responsible for the development of the television guidance system for the Martel guided missile. He is vice-president of the Institute of Navigation.
Progress in Tape-recording Techniques

by Sidney Feldman

Exhibits at the Audio Engineering Society's 37th Convention, held in New York City in October, were predominantly of interest to recording studio engineers. Several 8-track one-inch and 16-track two-inch studio recorders were on operational display. Two machines (Gauss and Magnetic Recording Systems) employed d.c. capstan-drive systems, with the motor-speed controlled precisely by a magnetic tachometer referred to a high stability oscillator. Thus the recorder is not affected by power line frequency variations. The Magnetic Recording machine has a switch-selected speed-range of 32 to 1, permitting operation from 1\( \text{i.p.s.} \) to 60 i.p.s., and also allows any intermediate speed to be obtained using an external variable-frequency source. Fig. 1 shows the basic servo-system employed.

In the Gauss recorder, external synchronization is possible for variable-speed operation, with possible pitch changes of \( \pm 7\% \). This tape machine utilizes the "focused gap" system of recording, which was marketed, under licence, by Fairchild Recording several years ago, in a series of tape recorders. The bias frequency is approximately 1MHz, and specifications call for a signal-to-noise ratio of 70dB, record input to reproduced output, measured with ASA curve \( A \); peak record level set for 1% distortion on 3M Company 201 tape, at 15 i.p.s.

Of the high-speed tape duplication equipment, Gauss utilizes an endless-loop tape bin, "focused-gap" head, and a bias frequency of 10MHz. Duplication takes place at speeds to 240 i.p.s. Running from a 1200ft master tape at the highest speed, the system can produce 55 copies/hour/slide, utilizing the "stagger loading" system at the slaves. These copies would be at 1\( \text{i.p.s.} \) tape. The tape would then have to be loaded into the appropriate cassette or cartridge. Console designers are now using, mainly, operational amplifiers in their modules. The modules are completely wired by the manufacturer, saving labour and inter-wiring when a system is built-up. These console "building-blocks" are usually strips 1.5in wide and about 14in long, and they provide functions of equalization, reverberation level control, main-channel level control, input attenuator, and microphone/line input switching. A typical module will accept microphone level at the input and provide up to +24dBm output with less than 0.5% t.h.d. from 20Hz to 20kHz.

The large recording consoles in use today with loss-less mixing, are only possible using operational amplifiers. A typical mixing circuit, as shown by Melcor (Fig. 2), provides 114dB of isolation between inputs at 20kHz, rising to 134dB at 1kHz. Distortion is 0.25% from 20Hz to 20kHz, at full output of +20dBm. Gain can be adjusted to a maximum of 10dB.

Most tape recorders for the professional market are using transistors for switching functions, and the Quad-Eight Company even have a logic system for track switching on their large console designs. This logic switching can also be interlocked with the tape recorder and the monitoring system, so that operating one button will switch all functions simultaneously.

Distortion analyser

Crown International have developed an i.m. distortion analyser to test, on a production basis, the Crown DC-300 dual-channel recorder. Typical i.m. distortion, per channel, (60Hz-7kHz, mixed 4:1) is below 0.05% from 0.01 watt to 150 watts r.m.s. into \( \Omega \). The analyser permits rapid measurements of i.m. distortion over a wide range of input levels and power ratings. Active Butterworth filters replace conventional hum-sensitive LC filters. The residual distortion in the analyser itself is typically 0.003%. Ganged input and output controls are employed to facilitate production line testing of amplifiers and other equipment.

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Fig. 1. Speed control system employing magnetic tachometer.

Fig. 2. Mixer using operational amplifier.
World of Amateur Radio

Licences and "pirates"

Of every five new British amateur licences now being issued, rather more than three are for Class B operation on v.h.f. telephony only. The licence statistics to the end of October show that in the previous six months there was an increase of 311 Class B licences to a total of 1841, compared with an increase of 198 Class A licences (permitting h.f. operation and requiring the passing of a Morse test) to a total of 13,373. Taking into account the 180 amateur television licences British amateurs now total nearly 15,400.

That there is still an appreciable number of people who attempt to operate in amateur bands without the formality of a licence is shown by the fact that, in the first nine months of 1969, the Post Office successfully prosecuted more than 70 persons and warned 50 others for offences involving wireless transmitting apparatus being used contrary to Section 1 of the Wireless Telegraphy Act. The fines imposed on these "pirate" stations ranged up to about £100 and the penalties often included forfeiture of the apparatus. The Post Office has indicated that some of the illicit transmissions are regarded as representing a potential hazard to safety of life; they are equally unpopular with licensed amateurs who have sometimes been subjected to deliberate interference and embarrassed by such tricks as the tape recording of genuine amateur "contacts" which are then replayed on transmissions outside the limits of the amateur bands. The Post Office welcomes information which would help in tracing and apprehending the pirates.

Good tropospheric "openings"

During the spell of pronounced tropospheric propagation in mid-October—conditions which brought many complaints of co-channel interference to broadcasting organizations—large numbers of amateur v.h.f. contacts were made between stations in the U.K. and many countries of Western Europe. The contacts extended from Sweden and Finland to Austria and Switzerland as well as the almost routine links with France, Holland and West Germany. While most of the contacts were made in the 144-MHz (two-metre) band, the conditions extended also to the 432-MHz (70 cm) band; many of the contacts exceeded 1000 miles. Some amateurs believe that the "tropo" conditions of the 1969 Indian summer were among the most pronounced yet recorded. Peter Blair, G3LTF, of Chelmsford, has raised his total of countries worked on 144 MHz to 28 and on 432 MHz to 19. From January 1st the new voluntary divisions of the 144-MHz band are 144.0—144.5 telegraphy only; 144.15—144.5 south-west region; 144.5—145.1 south-east region; 145.1—145.5 midlands; 145.5—145.95 north, Scotland and Northern Ireland; and 145.95—146 beacon transmissions.

R.S.G.B. president for 1970

Dr. John Saxton, director of the Science Research Council's Radio and Space Research Station (Slough) and this year's chairman of the I.E.E. Electronics Division, is to be installed as the 36th president of the Radio Society of Great Britain during the course of a social evening at the Bonnington Hotel, London, on Friday, January 16th. Dr. Saxton, although not himself the holder of an amateur licence, has a keen interest in the relationship between meteorology and radio propagation, and for a number of years has attended many amateur v.h.f. functions.

It is clear from the latest Society accounts that the 1970 Council, despite the recruitment in recent years of several thousands of additional members, faces problems of the type which are seriously affecting many national and local societies. In each of the past four years expenditure has exceeded income: to a total in the four years of some £8500. Fortunately, the Society has substantial reserves but nevertheless it faces acutely the paradox that even with the present record membership, costs are still rising faster than revenue.

In Brief: There has been a good response from British amateurs to a proposal—"Project Trident"—to design and build in the U.K. an amateur radio communications satellite capable of receiving on the 144-MHz band and retransmitting the signals on the 432-MHz band; it is recognized that such a project will take a considerable time to complete. It is now hoped that the Australian-built amateur satellite "Australia—Oscar 5" will be launched during December or early January on the Thor-Delta rocket used to put a Tiros weather satellite into orbit; Australia is expected to radiate on 144.050MHz and 29,450MHz for a number of weeks.

The R.S.G.B. 1.8 MHz Affiliated Societies' Contest is due to be held on January 10th and 11th between 18.00 and 22.00 G.M.T. each day. This season's 1.8MHz "Transatlantic Tests" will be continued between 05.00 and 07.30 G.M.T. on December 28th, January 11th and February 1st and 15th. A Boy Scouts station on the Caribbean Island of Anguilla, with the callsign VP2EQ, is being operated in the 14-MHz band. Indian stations have recently been using the special prefix VU0 instead of VU2 as part of the Ghandi centenary celebrations. Mike Matthews, G3JFF, is operating as a maritime mobile station on board the Far East flagship H.M.S. London and is expected to visit many Far East and Pacific areas during the next 15 months.

The Royal Naval Amateur Radio Society, with the callsign G3BZU, transmits a monthly Morse proficiency test at 19.00 G.M.T. on the first Tuesday of each month on 1.875MHz for practice runs and 3.520 MHz for speed proficiency tests.

PAT HAWKER, G3VA

Since the war, amateur radio in Japan has developed greatly. Station of Yoshio Samechina, JA2CLI, has many 1.8MHz ("Top Band") achievements to its credit: contacts include the U.S., Hawaii, Canada and Australia (photo, courtesy of Stewart Perry W1BB).
Electronic Metronome

An efficient circuit giving a speed range of 30 to 240 beats per minute

by D. T. Smith

The timing pulses are generated by a complementary-pair form of multivibrator \( T_{R_1}, T_{R_2} \). Both transistors conduct or are cut off together and the conduction time can be made a very small part of each cycle. The conduction time (about 10ms) is used to generate the "tick" and the off time (0.25 to 2s) the interval between ticks. This form of multivibrator is useful in many applications where short pulses, relative to their separation, are required. Low frequencies can be obtained with relatively low capacitor values, and a good range of frequencies obtained by varying a single resistor.

As this form of multivibrator may be unfamiliar to some readers, its operating cycle is described. During the conduction period the base of \( T_{R_1} \) is forward biased and therefore held near zero volts, while \( T_{R_2} \) is conducting hard and charging \( C_2 \) via \( R_4 \) towards +4.5V. The conduction period of \( T_{R_1} \) is limited by the time \( C_1 \) can supply enough base current to drive \( T_{R_2} \). This time is set primarily by \( C_1 \) and \( R_1 \). When \( T_{R_1} \) is cut off \( R_4 \) and \( R_5 \) pull the collector of \( T_{R_2} \) down to zero so that the charge on \( C_2 \) gives a negative voltage on the base of \( T_{R_1} \). \( T_{R_1} \) is thus cut off, and no base current flows. The off time is that taken for \( V_R \) and \( R_6 \) to discharge \( C_6 \) and then generate a forward bias at the base of \( T_{R_1} \) to start conduction. As current starts to flow in \( T_{R_1} \) it feeds current via \( R_6 \) and \( C_4 \) to the base of \( T_{R_2} \), which in turn feeds current via \( R_6 \) and \( C_2 \) to the base of \( T_{R_1} \) and so closes a regenerative feedback loop. Both transistors are switched hard on, and the cycle is repeated.

There is no point in having a good quality amplifier to drive the loudspeaker, so a simple two-stage amplifier \( T_{R_3} \) and \( T_{R_4} \) is used. This is direct coupled with both transistors cut off when the multivibrator transistors are off, and both conducting hard when the multivibrator transistors are conducting. Any medium- or high-gain silicon planar transistors can be used for \( T_{R_1}, T_{R_3} \), and \( T_{R_4} \). A medium or high power germanium p-n-p transistor capable of switching about 1A—AC128, OC83, OC25 etc.—can be used for \( T_{R_2} \).

There are no special precautions necessary in wiring the circuit, and Veroboard is convenient to use. \( C_1 \) should be a paper or polyester type and not electrolytic, as variations of capacitance with age or leakage would upset the calibration. The circuit with loudspeaker and battery are fitted in a suitable box. A low value variable resistor, say 25 \( \Omega \), may be included in series with the speaker to act as a volume control.

A Digital Christmas Tree

Using a large number of many coloured lamps switched in pseudo-random sequence, an elegant and fascinating twinkling effect is produced which can be exploited by arranging the lamps around a Christmas tree. In the prototype a 7-stage shift register is used to generate the 'M' sequence, an exclusive OR gate being used to provide feedback to the input from stages 6 and 7. The length of the sequence is 127 clock periods \( (2^7-1) \). It is arranged that fourteen lamps are controlled by transistor switches from the shift register stages (7 from the \( Q \) and 7 from the \( \bar{Q} \) outputs). Transistors can, of course, replace the micrologic elements in the sequence generator. Small pea lamp bulbs (model railway type) are used in the original.

H. N. GRIFFITHS
D.C. Bias in Push-Pull Power Amplifiers

A feedback amplifier controls the working point of a directly coupled driver and output pair

by R. A. Smith

A bias circuit, conventional to many amplifiers, and consisting of d.c. feedback from the collector to the base of the drive transistor, is shown in Fig. 1. A typical practical arrangement is given in Fig. 2. However, the circuit is very sensitive to changes in the current gain of the driver transistor, and hence \( R_f \) must be adjusted for the particular driver transistor used.

Since the prices of suitable transistors are now very low, extra low-current transistors in a circuit present no problem. Hence a transistor can be used whose sole purpose is to stabilize the d.c. level of the output. The requirements of this transistor are:

(i) High output impedance, so as not to shunt the a.c. signal at the base of the driver transistor.

(ii) A positive current gain to ensure that the d.c. feedback is negative. (The driver transistor changes the sign of the signal.)

Its input impedance is not important since it is to be driven through a filter from the low-impedance output of the voltage amplifier, which is capable of supplying large currents; i.e., its loading effect on the amplifier output will be negligible even if the extra transistor has a low input impedance.

In order to satisfy (i), the collector of the stabilizer transistor must be connected to the driver's base; in order to satisfy (ii) a common base circuit must be used. For such a transistor to conduct at all, it must be of opposite polarity to the driver transistor. Also, the a.c. level of the output must be filtered from the d.c. to prevent excessive a.c. feedback. Using a simple RC circuit for this, we obtain the arrangement shown in Fig. 3.

\( R_z \) must be chosen so that the potential across it is small compared with the supply voltage. The current passing through this resistor is approximately \( V/2R_z \beta \).

Thus \( V = V_{R_z} = iR_z = R_zV/2R_z\beta \)

\( 2R_z\beta/R_z \gg 1 \) and \( R_z \ll 2R_z\beta_{\text{min}} \) in the worst case.

With \( R_f \) as \( 2k\Omega \), \( \beta_{\text{min}} = 20 \) and a factor 20 for \( "\approx" \), this gives \( R_z = 4k\Omega \).

The \( R_C \) time constant must be long compared with the lowest frequencies being used.

Fig. 4 shows a circuit used as an a.f. power amplifier. The values given are for a 3Ω speaker and 25-V power supply.

High output impedance amplifier

With high output impedance amplifiers we are trying to drive a current in a load irrespective of the potential across it. In an inductive load, for example, the potential may vary considerably depending on the waveform of the input. For the output to be at high impedance, the drive should be from the collectors of the

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Fig. 1. Arrangement where driver stage \( T_{\text{d}} \) controls d.c. level of output pair.

Fig. 2. Typical low-to-medium power output stage.

Fig. 3. Use of common-base stage to control d.c. level of amplifier output.

Fig. 4. Practical circuit using p-n-p output transistors.
transistors, since the currents in these are the least sensitive to variations of potentials across them.

To apply feedback, the current in the load is passed through a resistor in series with the load, as shown in Figs. 5(a) and 5(b), and hence converted into a voltage which is compared with the input voltage to the amplifier at the emitter-base junctions of one of the driver transistors, depending upon which half of the circuit is conducting.

As will be seen from Fig. 5(b) each part, upper and lower, is an emitter follower across \( R_f \), however, the largest part of the current in \( R_f \) comes from the collector of the output transistors (high impedance). There is also a small current in \( R_f \) which flows in the emitter of whichever driver transistor is conducting and this current is approximately the same as the collector current, i.e. \( 1/\beta \) times the current through the load in series with \( R_f \).

\( R_f \) should be chosen so that the maximum current in the load (and hence also in \( R_f \)) produces a voltage across \( R_f \) of, say, a tenth of the power supply voltage. In this case, there is a maximum potential swing of approximately \( \pm 0.4 \) of the supply voltage across the load, and the back e.m.f. of an inductive load must not exceed this value if the amplifier is to work in its linear region.

The bias circuit described above can be incorporated in the circuit as shown in Fig. 6.

In a practical circuit, the standing current in the output transistors can become intolerably large if bias resistors are not included as shown in Fig. 7. Resistors \( R_A \) reduce the quiescent current of the driver transistors and resistors \( R_B \) bleed much of the remaining driver transistors' current to the supply rails rather than through the bases of the power transistors. Values shown are for an amplifier driving \( 0.25 \)A into an inductive load; it was for driving the scan coils of a magnetically deflected c.r.o.

### More Announcements (see also p.19)

Hewlett-Packard Ltd have installed a £20,000 patient monitoring system at Walsgrave General Hospital, Coventry. The system includes a cardiac catheterization unit, bedside monitors for coronary care, defibrillator trolleys and two nurse's central stations.

Pye Telecommunications Ltd, has received contracts worth £75,000 for radio telephone equipment to be supplied to Government departments. The orders include u.h.f. fixed and mobile f.m. equipment for airports, v.h.f. motorcycle and personal transmitter/receivers, and v.h.f., h.f. and m.f. marine transmitter/receivers. STC Mobile Radio Telephones Ltd has been awarded a contract valued at approximately £700,000 by the Home Office for the supply of several thousand mobile a.m. radio telephones for police use.

Plessey Electronics Group has received an order from the North of Scotland Hydro-Electric Board for the supply of radio relay equipment. Operating in the 1500MHz band, the equipment will link the Board's head office in Edinburgh with its main control room at Port-na-Craig, Pitlochry, and communications centres at Burghmuir, Perth and Tealing near Dundee.

A telecommunications project. A contract worth £1.4M has been awarded to S.T.C. by the Ministry of Posts, Telegraphs and Telephones of Kuwait for the provision of a number of broadband microwave and coaxial cable links from Basra, Iraq, into the telecommunications centre at Kuwait City.

Microwave Associates Ltd. have announced an agreement whereby they will provide a complete marketing service for the products of Microwave Semiconductor Corporation, Somerset, New Jersey, U.S.A.

Electron microscopes worth more than $1M have been ordered from AEI Scientific Apparatus Ltd for the United States and Canada. These orders have been placed by Picker Nuclear, the company's associates in the United States.
1970 U.K. Conferences and Exhibitions

Further details obtainable from the addresses in parentheses

LONDON
Jan. 19–23 Bloomsbury Centre Hotel
American Data Communications Equipment
(U.S. Embassy, Grosvenor Sq., London W1A 1AE)
Mar. 2–3 Alexandra Palace
Physics Exhibition
(I.P.P.S., 47 Belgrave Sq., London S.W.1)
Mar. 10–12 Camden Town Hall
Sound '70 International
(Association of Public Address Engineers, 394 Northolt Rd., South Harrow, Middx.)
Apr. 17–19 Savoy Place
Electrical Methods of Machining, Forming and Gouging
(I.E.E., Savoy Pl., London W.C.2)
Apr. 8–15 Earls Court
Electrex '70
(Electrical Engineers A.S.E.E. Exhibition, Museum St., London W.C.1)
Apr. 13–16 University College
Atonie and Molecular Physics
(I.P.P.S., 47 Belgrave Sq., London S.W.1)
Apr. 23–26 Skyway Hotel
High Fidelity Exhibition
(Polarisation of British Audio, 49 Russell Sq., London W.C.1)
Apr. 28 & 29 Royal Garden Hotel
Microelectronics Conference
(Business Conferences & Exhibitions, Mercury House, Waterloo Rd., London S.E.1)
May 4–7 Royal Festival Hall
London Engineering Congress (LECO '70)
(Council of Engineering Institutions, 2 Little Smith St., London S.W.1)
May 5–13 Earls Court
Mechanical Handling Exhibition
(British Exhibitions, Dorset House, Stamford St., London S.E.1)
May 15–18 Middlesex Hospital Med. School
Television Measuring Techniques
(I.E.R.E., 8-9 Bedford Sq., London W.C.1)
May 11–16 Olympia
Instruments, Electronics & Automation Show
(Industrial Exhibitions, 9 Argyll St., London W.1)
May 19–21 Savoy Place
Signal Processing Methods for Radio Telephony
(I.E.E., Savoy Pl., London W.C.2)
June 9–11 Savoy Place
Electrical Interference in Instrumentation
(I.E.E., Savoy Pl., London W.C.2)
July 13–17 Olympia
Ships' Gear International Show
(Helicopters Exhibitions, 3 Clements Inn, London W.C.2)
Sept. 7–11 Grovenor House
International Broadcasting Convention
(International Broadcasting Conventions, Savoy Pl., London W.C.2)
Sept. 15–18 Olympia
Bio-Medical Engineering Exhibition
(U.T.P. Exhibitions, 36-37 Furnival St., London E.C.4)
Sept. 15–18 Savoy Place
Electrical Discharges in Gas
(I.E.E., Savoy Pl., London W.C.2)

Sept. 29–Oct. 2
Trunk Telecommunications by Guided Waves
(I.E.E., Savoy Pl., London W.C.2)
Oct. 15–21
Olympia
Audio Festival & Fair
(International Audio Festivals and Fairs, 42 Manchester St., London W.1)

BANGOR
July 6–10 University College
Microwave Spectroscopy
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

BIRMINGHAM
Apr. 14–16 The University
Automatic Test Systems
(I.E.R.E., 8-9 Bedford Sq., London W.C.1)

BRIGHTON
Mar. 2–6 Exhibition Halls
Engineering Design Show
(Business Conferences & Exhibitions, Mercury House, Waterloo Rd., London S.E.1)

CAMBRIDGE
Mar. 19–22 Churchill College
Television Tomorrow
(Royal Television Society, 166 Shaftesbury Ave., London W.C.2)

CRANFIELD
Mar. 23–26 College of Aeronautics
Aerospace Instrumentation Symposium
(N. O. Matthews, Dept. of Physics, College of Aeronautics, Cranfield, Beds.)

EDINBURGH
Mar. 17–20 The University
Management and Economies in the Electronics Industry
(D. J. T. Williams, Ferranti Ltd., Ferry Rd., Edinburgh 5)

HARWELL
Apr. 2–3 A.E.R.E.
High Voltage Electron Microscopy
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

MANCHESTER
Jan. 6–8 The University
Solid State Physics
(I.P.P.S., 47 Belgrave Sq., London S.W.1)
Feb. 23–27 Belle Vue
Labex Northern
(U.T.P. Exhibitions, 36-37 Furnival St., London E.C.4)
May 19–22 Belle Vue
Industrial Training Exhibition & Symposium
(John Clarke (P.R.) Ltd., St. James House, 44 Brazenose St., Manchester 2)

OXFORD
Apr. 6–11 The University
Biological Engineering Conference
(J. Gasking, Dept. of Pharmacology, St. Bartholomew's Hospital Medical School, Charterhouse Sq., London E.C.1)

Teddington
Feb. 25–26
N.P.L.
Trends in Diffusion Conference
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

UXBRIDGE
Apr. 14–16 Brunel University
Computer Graphics International Symposium
(R. Elliott Green, Brunel University, Uxbridge, Middx.)

Overseas

JANUARY-APRIL
Jan. 14–16 Honolulu
System Sciences Conference
(Dr. R. H. Jones, 2563 The Mall, University of Hawaii, Honolulu, Hawaii 96822)
Jan. 20 & 21
Chicago
Soldering Technology Seminar
Feb. 6–11 Paris
Audiovisual Techniques, Electroacoustics & Electronics Show
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15)
Feb. 16–19 Tampa Fla.
Computer-Aided Circuit Optimization
(Dr. G. W. Zobrist, Dept. of Elect. Eng., University of South Florida, Tampa, Florida 33620)
Feb. 24–Mar. 5
Philadelphia
Solid-State Circuits Conference
(I.E.E.E., 345 E. 47th St., New York, N.Y. 10017)
Mar. 10
Paris
Audio Festival
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15)
Mar. 11–13 Washington
Scintillation and Semiconductor Counter Symposium
(Louis Correct, Radiation Physics Inst. Section, N.B.S., Washington, D.C. 20234)
Mar. 18–21 Nairobi
Electro 70 Show
(Electronics Institution of East Africa, P.O. Box 9690, Nairobi, Kenya)
Apr. 3–8
Paris
Electronic Components Show
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15)
Apr. 6–10
Paris
Advanced Microelectronics Conference
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15)
Apr. 14–17 Washington
Geoscience Electronics Symposium
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)
Apr. 21–24 Budapest
Microwave Communication Colloquium
(Microcol—Technika Haza Budapest, V. Szabadsag ter 17, Hungary)
Apr. 27–29 Atlantic City
Frequency Control Symposium
(Electronic Components Lab., U.S. Army Electronics Command, Fort Monmouth, New Jersey 07703)

Sept. 14–16
The University
Photo-electron Spectroscopy
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

WIRELESS WORLD, January 1970

www.americanradiohistory.com
New Products

General Purpose Audio Amplifier

The Elcom GPA general purpose amplifier module—available in two different supply voltage versions—is a low-power high-quality amplifier intended for rack mounting and capable of driving a speaker to 4W mean power. Output is unbalanced, but an external transformer is available for balanced loads. Power supplies required are 50V for the GPA50 and 24V for the GPA24. The ac-coupled output has an impedance of 7.5 Ω (GPA24) and 15 Ω (GPA50). The transformer-coupled output has an impedance of 3/4, 7.5 Ω and 15 Ω for both voltage versions. At 4W output, sensitivity is quoted as 20kΩ maximum, noise level 100μV, and distortion 0.3% (GPA24) and 0.1% (GPA50). Frequency response from 30Hz to 20kHz is within ±1dB, and the amplifier is provided with remote or local gain control facilities. Elcom (Northampton) Ltd, Weedon Road Industrial Estate, Northampton.

WW 310 for further details.

Auto-range Digital Voltmeter

The SM 212/C digital voltmeter from S.E. Laboratories is designed specifically for data logging and the automatic testing of equipment systems. Selecting “auto” on the front panel gives complete automatic continuous monitoring over the full range of the instrument (from 10mV to 1kV). The instrument up-ranges at a reading of 9,000 and down-ranges at a reading of 800. All control switches are front-mounted push-buttons. As well as having automatic selection, the instrument’s ranges can be selected manually by five push-buttons, and remote ranging for external programming via the B.C.D. output socket. Maximum resolution is 10mV, input impedance >1000MΩ on direct ranges, and accuracy ±0.01%. Reading rate is 25 per sec synchronized to mains frequency. Series-mode rejection is >60dB without filter, and common-mode rejection >140dB.

S.E. Laboratories (Engineering) Ltd, North Feltham Trading Estate, Feltham, Middx.

WW 315 for further details.

Turns-counting Dial

R.C. Knight Ltd introduce a range of turns-counting dials for use with multi-turn potentiometers. The model 33-30 illustrated can be used on 10-, 20-, or 30-turn potentiometers. Mating with the potentiometer shaft is accomplished using a tapered collet arrangement. Small quantities of up to 100 off are available from stock and prices range from 41s 9d to 47s 3d each, depending on the quantity ordered.

R.C. Knight Ltd, 20 Solent Avenue, Lymington, Hants.

WW 336 for further details.

Constant-current Power Sources

Direct currents as small as 1mA and as large as 500mA are supplied with extreme accuracy by two constant-current power sources—models 6177B and 6181B—from Hewlett-Packard. Current regulation is such that the output current changes less than 25 p.p.m. (±5 p.p.m. of range setting) with a load change that swings the output voltage from zero to maximum. Current-setting and voltage-limiting controls are independent and can be preset before the load is connected. Maximum output for Model 6177B is 500mA, with voltage limiting continuously adjustable between 0 and 50V. Model 6181B has a maximum output of 250mA with 0-100V limiting. Current output is selected with high resolution (0.2% of range) by a 10-turn control and 3-position ×10 range switch. Either of the floating output terminals may be grounded to provide current of either polarity. For systems use, these instruments can be programmed by either external voltage or resistance changes. Extremely high output impedance is maintained without use of reactive elements, resulting in fast programming speed. 500 s from 0 to 99% of programmed output.

Hewlett-Packard Ltd, 224 Bath Road, Slough, Bucks.

WW 316 for further details.

Light-emitting Diode

The MV50 from Monsanto, is a diffused planar gallium arsenide phosphide light-emitting diode which peaks at 6,500K. It can be used in place of incandescent lamps as small as the T3/4 size. The life-time of the unit is said to approach 100 years. Light output is 750ft lamberts with a forward current of only 20mA. Turn-on time is Ins. The MV50 is available in the U.K. from Semiconductor Specialists Inc, Airpark House, 127 Station Road, West Drayton, Middx.

WW 330 for further details.

Electromyograph

Iisleworth Electronics have developed an electromyograph suitable for use in clinical medicine practice. The type 7 Electromyograph is a solid-state design, with plug-in units. Four plug-in positions are provided: two amplifiers, a timebase and a stimulator. Two types of amplifier are available—a single channel and double channel. With various combinations, between two and four signals may be displayed simultaneously on the cathode-ray tube. Each channel carries its own built-in calibration signal. Comprehensive camera recording facilities are...
provided by a second cathode-ray tube at the rear of the instrument. The remote cable-operated camera shutter is synchronized electrically with the machine. Five modes of operation are possible: single sweep, continuous, superimpose, scan, and autograph. All modes are electrically interlocked to prevent overlapping exposure. Film wind-on after each exposure is automatic. Outputs are provided for data recorder, external loudspeaker (to supplement the unit's own internal sound channel), and trigger pulses to synchronize peripheral equipment.

Isleworth Electronics, Frederick Street, Waddesdon, Bucks.

WW 320 for further details.

Binary Ladder Networks

Morganite Resistors have produced two binary ladder networks. Model 215 is an eight-bit high-speed ladder with a standard resistance of 10kΩ in the binary R-2R configuration. Setting time is less than 100ns with a maximum output voltage ratio error of ±0.25 bit over the temperature range -55 to +125°C. Three application circuits, raised to the ladder, are also included for bipolar operation and amplifier summation. Model 213 is a 10-bit binary resistor array designed to be compatible with the Fairchild IA 722 current source for D/A and A/D applications. Resistance values correspond directly with those specified on the A 722 data sheet. The resistance temperature coefficient is 0 to -200 p.p.m.°C with resistance tolerance of ±2% over the temperature range -20 to +85°C. Morganite Resistors Ltd, Bede Industrial Estate, Jarrow, Co. Durham.

WW 334 for further details.

Analogue Computer Teaching System

Analogokit is a system which combines digital and analogue techniques and is intended for the designer, technician and university graduate. The equipment includes operational amplifiers, feedback, summing, scaling and initial condition elements. An introductory handbook explains the arithmetical aspects of summing, scaling and integration with simple illustrative experiments leading to the construction of differential equations with practical examples of simulated systems. An advanced book deals with the mathematical aspects for degree course students. A complete teaching kit for analogue work, including a mounting deck with power supplies, costs £65 in the U.K. Feedback Ltd, Park Road, Crowborough, Sussex.

WW 308 for further details.

Automatic Counter

All models in the Dana series 8100 automatic counters measure frequencies from 0.05Hz to 50MHz (d.c. coupled) and 5Hz to 500MHz (a.c. coupled), but models 8120, 8130, 8124 and 8134 have an additional a.c. coupled range from 10 MHz to 500MHz. Models 8110, 8130, 8114, 8134 have a facility for time interval measurement in the range 0.1 s to 10s (up to 100s as an option). When using one of these automatic counters, all that is necessary is to connect the input signal, and set an input voltage range switch to PRESET. The remainder of the measurement process is then controlled by computer logic. Automatic resolution during the reading time is effected, and decimal points and units are automatically indicated. In one second, reading accuracy approaches ±2 x 10^-7. It is claimed the accuracy of the 8100 is better without operator adjustment than that of a manually controlled counter which requires function selection and period-to-frequency calculation. Dana Electronics Ltd, Bilton Way, Dallow Road, Luton, Bedfordshire.

WW 305 for further details.

32-MHz Counter

The GR 1192 counter measures time intervals, frequency and period from d.c. to 32MHz to a resolution of 0.1 μs, and frequency ratio. If the 1157-B scaler is used, the frequency range can be extended to 500MHz. Models are available with 5, 6 or 7 digit presentation. When measuring frequency from d.c. to 32MHz, the counting gate times are 100μs to 10s, and Hz, kHz, and MHz can be displayed with positioned decimal point. Accuracy is ±1 count ± time base accuracy. The stability of the 10MHz time base is less than ±2 parts in 10^-4 per month. Measurement of period is limited by the digit presentation and is up to 100s, 10s and 1s in the 7-, 6- and 5-digit models, respectively. Single and multiple periods up to 10^40 are covered, and time periods can be displayed in μs, ns and ps with positioned decimal point. The ratio of two frequencies, A and B, can be measured from 1 to 10^12. Frequency A from d.c. to 32MHz is measured over 1 to 10^12 periods of frequency B, 50Hz to 10MHz. Trigger error in time measurements is defined at ±0.3% of one period divided by the number of periods averaged for a 40dB input signal-to-noise ratio, and assumes no noise internal to the counter. For input signals of extremely high signal-to-noise ratio, the trigger error in μs is 0.0003 divided by the signal slope in Vs/μs. Price of the three models is £726 (5 digits), £832 (6 digits) and £937 (7 digits). General Radio Company (U.K.) Ltd, Bourne End, Buckinghamshire.

WW 303 for further details.

3mm Jack Receptacle

Sealectro have developed a 3mm s.r.m. series jack receptacle which prevents r.f. radiation. Designated part number 30-645-4520-31, the receptacle is constructed of gold plated stainless steel, Teflon, and gold-plated beryllium copper. It meets all requirements of MIL-C-39012 regarding contact and dielectric torque and capacitance. R. F. Components Division, Sealectro Ltd, Walton Road, Farlington, Portsmouth, PO6 1TB.

WW 317 for further details.

DC/DC Converters

A range of d.c./d.c. converters for changing an available low d.c. voltage (between six and sixty volts in multiples of six volts) to a much higher d.c. voltage is available from Plessey. General use of the component is in transistor instruments incorporating a cathode-ray tube for display purposes. Normal voltages up to 8kV with power up to 0.3W are available in the unit size of 12.7 x 3.1 x 8cm, and ranging up to 10kV and 2W in a unit measuring 13.4 x 5.9 x 4.5cm. Plessey Wound Components Division, Titchfield, Hants.

WW 321 for further details.

Portable Instrumentation Recorder

A portable instrumentation magnetic tape recorder, especially designed for use by non-skilled personnel, has been introduced by Bell & Howell. Suitable for a wide range of industrial and research applications, the VR-3200 is available in both 4-track and 6-track versions with speeds ranges of 1μ to 15 ips and 3μ to 30 ips respec-
Switch selection of free tuning or of complete synthesis. Another feature is a dynamic range of over 120dB. This accommodates a correspondingly wide variation in levels of input signals. The use of two inter-coupled r.f. systems enables the R551 to receive wanted signals at sensibly constant level despite adjacent unwanted signals. A high degree of front-end protection, independent of whether the receiver is switched on or off, permits the R551 to be installed and operated in close proximity to high-power transmitters. Redifon Ltd, Broomhill Road, London S.W.18. WW 312 for further details.

**S.S.B. Manpack**

The TRA 6929 Minical s.s.b. manpack from Racal-BCC has a power output of 1W p.e.p. and six operating channels covering frequencies from 2 to 7MHz or 2.6 to 9MHz. Complete with batteries, handset, aerial and havensack, the manpack measures 190 x 76 x 210 mm and weighs 3.6 kg.

Intended for military use, Minical has been specifically designed for simplicity of operation with a minimum number of controls. Changing channel takes only a few seconds, and it is claimed that unskilled operators are able to use it after a few minutes instruction. Tuning is effected with the aid of an internal noise generator. By this means, the possibility of radiation during tuning is avoided. The manpack operates from either U2/D type dry cells or rechargeable NiCad cells. If required, a vehicle 12V supply can be used to power the manpack or for recharging the NiCad cells. Racal-BCC Ltd, Western Road, Bracknell, Berkshire.

WW 301 for further details.

**Integral-cycle Zero-voltage Switch**

The CA3059 integral-cycle zero-voltage switch is contained within a 14-lead dual in-line plastic package and operates direct from the a.c. line. This RCA device is capable of driving triac gates directly, and by providing a triac gating signal at zero-voltage crossings minimizes r.f. interference. A fail-safe circuit is incorporated to guard against an accidentally opened or shorted sensor, and an optional output control is available. Electrical characteristics include, d.c. gate-trigger current of 40mA for $V_{GTh}$ of 3V and $R_{GTh}$ of 70Ω; gate-trigger pulse width of 80μs before and after 'O' for $C_x = 0$, a gate-trigger pulse width of 20μs before 'O' and 170μs after 'O' for $C_x$ of 0.01μF; an on-off accuracy of 1% and 3% for sensors of 5kΩ and 100kΩ, respectively. RCA Ltd, Sunbury-on-Thames, Middlesex.

WW 309 for further details.

**Dual-trace 10-MHz Oscilloscope**

The D54 is a solid-state-circuit oscilloscope. Intended for general purpose laboratory and production line testing applications the Telequipment D54 solid-state oscilloscope has a vertical amplifier bandwidth of d.c. to 10MHz within — 3dB when d.c. coupled,
and 2Hz to 10MHz within –3dB when s.c. coupled. A 2-position frequency compensated input attenuator calibrated direct in V/cm can be set for sensitivities of 1mV/cm to 50V/cm in a 1-2-5 sequence. The range of timebase sweep speeds is 200ms/cm to 2s/cm covered in 22 calibrated steps. A variable uncalibrated control provides continuous overlap between steps and reduces slowest sweep speed to approximately 5s/cm. The D54 can be operated in the following four modes: channel 1 only; channel 2 only; alternate during which the input to the vertical output amplifier is synchronously switched between channel 1 and channel 2 during flyback; and chopped during which the input to the 2-position frequency output amplifier is continuously switched between channel 1 and channel 2 at approximately 100kHz. Telequipment Ltd, 313 Chase Road, Southgate, London N.14.

WW 302 for further details.

Over-voltage Protection Unit

New from ITT is an over-voltage protection unit designed to give semiconductor devices protection against voltage surges of 1μs or greater duration. The unit employs a reference amplifier and variable potential divider to sense applied voltage. The trip point is continuously variable between 4.5 and 60V, with resolution better than 0.1V. An excess voltage triggers a crowbar across the supply. In the event of a fault the unit will handle 500A peak—250A mean half cycle. Provision is made for limiting the surge current to lower values if desired. Connected across the two supply terminals, the unit takes less than 10mA drain at all voltages. The unit is compact—approximately 65 x 40 x 50mm. Access to the voltage adjustment potentiometer is through a hole adjacent to the terminals. The unit will operate in an ambient temperature range from –40° to +65°C. ITT Components Group Europe, Rectifier Product Division, Edinburgh Way, Harlow, Essex.

WW 319 for further details.

Colour Monitor Calibrator

The Grafkon calibrator is a hand-held optical instrument that enables the white point of a colour monitor or receiver to be visually set. The instrument is offered up to the tube face and the monitor controls are adjusted to make the colour picture match the instrument’s reference colour. The comparison between the monitor and the reference is seen in a Lummer Brodhun photometer cube. The reference colour is obtained from a tungsten halogen lamp and glass filter and is diffused to form a very even reference field. The lamp current is electronically stabilized to ensure that its col-

our is the same each time it is switched on while the tungsten halogen cycle in the lamp maintains its long-term colour stability. A mechanical iris is incorporated to adjust the brightness of the reference field to any grey scale step. This ensures that the reference colour remains the same for all values of brightness. Grafkon Engineers Ltd, 73 South Western Road, Twickenham, Middx.

WW 331 for further details.

Transportable Insulation Tester

Miles Hivolt offer a transportable insulation test set for measuring leakage currents down to 0.01 A at up to 30kV d.c. It can be driven from the mains or from rechargeable 24V batteries which give four hours’ use at full load, the equivalent of many days’ normal use. Mains input is 100-125V or 200-250V at 45-66Hz. The output voltage is available in two ranges 0.5-5kV and 3-30kV. The output voltage is measured at two ranges 5kV and 30kV with full-scale deflections. Maximum output current is 200 A at full voltage with higher currents at lower voltages. The equipment weighs 11.5kg with either battery or mains power unit fitted. Miles Hivolt Ltd, Riverbank Works, Old Shoreham Road, Shoreham-by-Sea, Sussex.

WW 313 for further details.

40-MHz Counter/Timer

A solid-state 40MHz counter/timer, the TF2414A, with 10μV sensitivity is available from Marconi Instruments. Advantages include time interval measurement down to 1μs, period and multi-period measurement, 1M → input impedance and display memory. Direct frequency measurement is provided up to 40MHz. A special version TF2414A/2M is designed for use with the M.I. frequency converters (TF2400 series) which extend the frequency range up to 500MHz. Another version, TF2414A/1 provides a printer output facility supplying a 1-2-4-8 b.c.d. output code for each digit displayed. Stability and accuracy are determined by an oven-controlled crystal oscillator. Circuits incorporate discrete and integrated silicon semiconductors on plug-in printed boards. The display memory maintains the readout while the count is in progress, thus giving a continuous coherent readout. The crystal oscillator has stability of typically 1 x 10⁻⁴ over three months and temperature co-efficient of ±5 x 10⁻³ per °C. A standard frequency output is available from the internal reference oscillator through a front panel socket over a range from 0.1Hz to 1MHz (selected by the range switch). Price £298 f.o.b. U.K. Marconi Instruments Ltd, Longacres, St. Albans, Herts.

WW 311 for further details.

Add-on Transmitter Amplifier

A wideband untuned solid-state linear transmitting amplifier covering the frequency range 2-30MHz, intended as an add-on unit to a low-power transmitter/receiver such as a packset, has been developed by The M.E.L. Equipment Company Ltd. It has an output of 100W p.e.p. and is designed for a transmitter, the output of which is not less than 5W p.e.p. It operates from d.c. supplies of 10-30V without need for voltage adjustment. The power supply is self-contained, and provides a supplementary output of 20W at 24V d.c. for the associated packset. It is sealed, operable at ambient temperatures from –15°C to +55°C and meets the durability requirements of DEF 133 (L3). Designed type BA.1013/01 the amplifier measures 310mm wide by 300mm deep by 116mm high. The M.E.L. Equipment Company Ltd, Manor Royal, Crawley, Sussex.

WW 335 for further details.

Educational Oscilloscope

An oscilloscope, Mitre type EA0699-1, intended for use in schools, in service workshops and in other equipment as a built-in monitor, has a Y bandwidth of d.c.

to 100kHz. The instrument costs £24. 10s. (discount for schools) and features a Y sensitivity of approximately 100mV/cm as maximum gain with full Y shift. The time-base range covers approximately 100ms/cm to 1μs/cm and is automatically synchronized. The X input required is 1V/cm with full X shift when the timebase is switched off. Flyback suppression and access to Y plates
are also featured. Power supply required is 25W at 200 to 250V, 50 to 60Hz. Mitre Electronic Products, 22 Powsim Terrace, London W.11. WW 304 for further details.

Broad-band Travelling-wave Amplifier

The TW523 travelling-wave amplifier from the M-O Valve Company has an output of greater than 10W flat to better than 3dB and at a gain of at least 26dB in the frequency range 2.0 to 4.0GHz, whilst, by adjusting helix voltages, it is possible to obtain power outputs of over 20 watts at spot frequencies. The tube is packed in a permanent magnet focusing mount, and r.f. coupling is by means of a type N 50 connector. Cooling may be by either conduction or convection, according to specification. The M-O Valve Co. Ltd, Brook Green Works, London W.6. WW 322 for further details.


Advance Industrial Electronics have available a low-cost general purpose Zeltex operational amplifier, Model 134D which can be used in differential, inverting and non-inverting circuits. Typical voltage drift is 50 nV/C. Typical input bias current is 50pA. Initial offset voltage can be adjusted to zero with an external potentiometer. The unit is short-circuit proof to ground. The amplifier housed in a plastic/epoxy case can be mounted directly on a p.c. board or plugged into a mating connector. Specification includes an output of ± 5V at 4mA, a d.c. gain of 50,000, and a gain/bandwidth product of 1.3 MHz. Frequency at full output is 100kHz. The slew rate is 6V/s and operating temperature 25 to 85°C. Price is £59. Advance Institute Electronics, Rayham Road, Bishops Stortford, Herts.

WW 331 for further details.

V.L.F. Third-octave Analyser

AIM Electronics have announced a third-octave frequency analyser (TOF 260A) with a frequency range extending from 0.5Hz up to 100kHz, and covering any eight octaves in this frequency range. The octaves covered are pre-set to customer requirements. The unit consists of twenty-four filters, each covering one-third of an octave, designed in accordance with BS2475:1964 (which recommends centre frequencies and equivalent bandwidth of the filter elements). Each filter may be attenuated by 0-100% by adjustment of a ten-turn calibrated potentiometer. The outputs from all the filters are combined at the output socket. Thus any combination of filters may be selected by adjustment of the attenuators. Typical applications include extraction of third-octave information from unknown waveforms and simulating the characteristic noise of any low-frequency excitation (e.g. vibrations) by selective filtering of white noise. Price £500. AIM Electronics Ltd, Bar Hill, Cambridge, CB3 8EZ. WW 323 for further details.

Transistor Amplifier for 1—2 GHz

Electro/Data Inc. have developed a broad-band transistor amplifier for the range 1 to 2 GHz. The new amplifier, designated Model A-12, has a 15dB gain response from 1 to 2 GHz with greater than 10dB of gain from 700 MHz to 2.2 GHz. The amplifier's noise figure is 6dB typical with a maximum value of 8dB. It has miniature 50 R input and output connectors and a shielded d.c. bias input. A single, negative 12V, 14mA source is required for biasing. Two or more units can be cascaded to provide increased gain, with minor changes in passband ripple and bandwidth. The amplifier has linear gain for output signals up to ±10dBm. Electro/Data Inc., 1621 Jupiter Road, Garland, Texas 75040, U.S.A.

WW 314 for further details.

Modulation Meter

Type 785 modulation meter from Dymar is a solid-state instrument for the measurement of the depth of modulation in a.m. transmitters or the frequency deviation in the case of f.m. transmitters. It is specifically designed for narrow deviation transmitters in mobile and portable v.h.f. radiotelephones, the most sensitive deviation range being 3kHz f.s.d. The frequency range covered is 30—480kHz and the sensitivity over the whole of this range is better than 2.5mV in 50 (—40dBm) which permits loose coupling to the transmitter under test. The residual f.m. noise of the local oscillator is typically —44dB below 3kHz deviation with the a.f. "voice" filter switched in. Auxiliary outputs are provided at the i.f. (500kHz) and the demodulation audio frequency. This permits viewing of the modulation waveforms on an oscilloscope or applying it to distortion analyzers. Price £420 Dymar Electronics Ltd, Colonial Way, Radlett Road, Watford, Herts.

WW 327 for further details.

Analogue Switches

A range of m.o.s.i.c analogue switches, the ML150 series, has been introduced by Plessey. The switches, with full gate-control isolation and gate-oxide protection, are available in 6-way multiplexer, dual sample/hold and 3-bit digital-to-analogue configurations. The MP130 series provide matching drive circuits for ML150. The large negative output voltage swings of these circuits (30V) are particularly suited to driving m.o.s pudding switches. Plessey Microelectronics, Cheney Manor, Swindon, Wilts.

WW 324 for further details.

Continuous Tape-Transport System

A continuous magnetic tape-transport system—MTD 10500—is announced by Recording Designs Ltd. The system comprises three basic models, write only, read only and write/read. Each has variants to suit a range of requirements. The same tape-transport technique is used for each with modular electronics to give particular system characteristics. Seven- and nine-track versions are available each with bi-directional transport speeds from 4 to 37.5 i.p.s. as standard, and an optional speed-range of between 1 and 75 i.p.s., if required. Slew-mode speed (for high-speed inter-block gap detection) is 120 i.p.s. Start and stop speed times are less than 20ms in the standard speed range. Recording densities of 200, 556 and 800 b.p.i. are available. Recording Designs Ltd, Blackwater Station Estate, Camberley, Surrey.

WW 332 for further details.

Low-pass Active Filters

Lionmount are manufacturing low-pass active filters which can be varied continuously throughout the passband. Two types are available; one of which covers the range 1 to 10kHz in one band; the other covering the frequency range 1Hz-10kHz in four switched bands. The designs are based on

9th order Butterworth or Chebychev configuration and can realize 80dB/decade attenuation at cut off. The filters will accept an input voltage of ±10V peak and may be loaded with a minimum of 2,000 Ω. Lionmount & Co. Ltd, Bellevue Road, New Southgate, London N.11.

WW 318 for further details.
January Meetings

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

LONDON
7th. I.E.E.— Discussion "On the Haslegrave report on technician courses and examinations" at 18.00 at the London School of Hygiene and Tropical Medicine, Keppel St., W.C.1.
7th. R. Soc.— Juvenile lecture "Television at school" by Dr. R. G. G. Williams at 14.30 at John Adam St., W.C.2.
13th. I.E.E.— Discussion "Prospects for ultra-high-frequency f.e.t.s" at 17.30 at Savoy Pl., W.C.2.
13th. I.E.R.E./I.E.— "Physiology for engineers—control of circulation" by Dr. I. Gabe at 18.00 at St. Bartholomew's Hospital Medical Coll., E.C.1.
14th. I.E.E.— "Changing relations between science and technology, and their effect on international co-operation" by Dr. A. P. Speiser at 17.30 at Savoy Pl., W.C.2.
20th. I. Electr.— "Power semiconductor electronics" by R. G. Dancy at 18.00 at the London School of Hygiene, Keppel St., W.C.1.
21st. S.E.R.T.— "The new I.V.C. colour video tape recorder" by R. A. Cailar at 19.00 at London School of Hygiene, Keppel St., W.C.1.
22nd. I.E.E.— "Devices using tunnelling super-currents" by Dr. B. D. Josephson at 17.30 at Savoy Pl., W.C.2.
30th. I.E.E.— "Radar echoes from clear air in relation to refracting-index variations in the troposphere" by J. A. Lane at 17.30 at Savoy Pl., W.C.2.
BELFAST
21st. I.E.R.E.— "Air traffic control" by David Evans at 18.30 at Ulster Institute, Queens University, Stranmillis Road.
BIRMINGHAM
26th. I.E.E./I.P.O.E.— "Operational experience with p.c.m. systems" by D. Cleobury at 18.00 at M.E.B., Summer Lane.
BOLTON
12th. I.E.E.T.— "The origins of electrical communications" by J. Dalton at 19.30 at Institute of Technology, Deane Rd.
BRISTOL
CAMBRIDGE
29th. I.E.E./I.E.— "Tuning of gun effect oscillators" by P. W. Crane at 18.30 at University Engineering Laboratories, Trumpington Street.
CARDIFF
14th. I.E.R.E.— "Electronics for process control instrumentation" by J. Seers at 18.30 at University of Wales Institute of Science and Technology.
22nd. R.T.S.— "Television transmission equipment in education" by W. D. Kemp at 19.00 at B.B.C., Llandaff.
CHATHAM
15th. I.E.R.E.— "The engineer in management" by F. Oakes at 19.00 at Medway College of Technology.
CHELMSFORD
EDINBURGH
7th. I.E.R.E.— "Pulse code modulation for point-to-point music transmission" by E. Rout at 19.00 at Napier College of Science and Technology, Colinton Road.
20th. I.E.E.— "The electronics industry in Scotland—past, present & future" by J. MacDonald at 18.00 at the Carlton Hotel.
FARNBOROUGH
22nd. I.E.R.E.— "Speech and vocoders" by L. C. Kelly at 19.00 at the Technical College.
GLASGOW
8th. I.E.R.E.— "Pulse code modulation for point-to-point music transmission" by E. Rout at 19.00 at the Institution of Engineers and Shipbuilders, 183 Bath St., C.2.
LEEDS
6th. I.E.E.— "The automatic landing of aircraft" by S. A. W. Jolliffe at 18.30 at the University.
LEICESTER
20th. I.E.R.E.— "Static inverters and their applications" by E. W. Porter and R. J. Green at 18.30 at the University.
29th. I.E.E.— "The latest techniques in computer-aided electronic design" by E. Wofsendale at 18.30 at the City Polytechnic.
LIVERPOOL
5th. I.E.E.— "Communications for people at work and at play" by D. G. Holloway at 18.30 at the University.
LONDON
19th. I.E.E.— "Electronics in automobiles" by W. G. Hill at 18.30 at the University.
29th. I.E.E.— Faraday Lecture "People, communications and engineering" by J. H. H. Merriman at 10.15 and 14.30 (students) and 18.45 (public) at the Philharmonic Hall.
MANCHESTER
28th. I.E.E. (Grads.)— "Radio interference from high-voltage transmission line conductors" by M. G. Faulkner at 18.45 at U.M.I.S.T.
NEWCASTLE-UPON-TYNE
14th. I.E.E.— "Electronic telephone exchanges" by V. E. Mann at 18.00 at Dept. of Physics and Physical Electronics, Rutherford Coll., Ellison Pl.
14th. I.E.E.T.E.— "Decca navigational system" by A. Brooker-Carey at 19.30 at Rutherford College of Technology, Ellison Place.
26th. I.E.E.— "The application of electronic engineering to road safety" by D. G. W. Macie and S. Penoyre at 18.30 at the Polytechnic.
NEWPORT
NOTTINGHAM
13th. I.E.E.— Faraday Lecture "People, communications and engineering" by J. H. H. Merriman at 14.30 (students) and 19.15 (public) at Alber Hall.
OXFORD
14th. I.E.E.— "Tomorrow's world—use of satellites for communication" by W. J. Bray at 19.00 at College of Technology, Headington.
PRESTON
14th. I.E.E.— "Metrocisions" by T. C. Campbell at 19.30 at Yorella Restaurant.
READING
15th. I.E.E.— "M.O.S. devices in i.s.i." by G. E. Stevenson at 19.30 at J. J. Thomson Physical Laboratory, the University, Whiteknights Park.
RUGBY
20th. I.E.E./I.E.— "Brain cell to microcircuit (pattern recognition)" by Dr. I. Aleksander at 18.15 at the College of Engineering Technology.
SOUTHAMPTON
27th. S.E.R.T.— "Field effect transistors" by G. A. allcock at 19.30 at the College of Technology, East Park Terrace.
STEVENAGE
12th. I.E.E.— "Current electronic developments in the deep sea fishing industry" by P. J. Hearn at 19.30 at the College of Further Education.
STOKE-ON-TRENT
SUNDERLAND
22nd. I.E.E. (Grads.)— "Pulse code modulation" by J. Hutton at 18.30 at the Polytechnic.
WEYMOUTH
WOLVERHAMPTON

www.americanradiohistory.com
Test Your Knowledge


20. Colour

In all the questions it is assumed that the viewer has normal colour vision.

1. Select from the colours quoted below the one which does not appear in the spectrum of white light:
   (a) orange
   (b) yellow
   (c) purple
   (d) violet.

2. From the spectral colours below select the one which is associated with the highest frequency of radiation:
   (a) red
   (b) blue
   (c) green
   (d) blue-green.

3. Three light sources of the same area give monochromatic radiation of colours red, green and blue respectively, and have equal luminosity (appear equally bright). The intensity of radiation:
   (a) is the same for all three
   (b) is least for the red
   (c) is least for the green
   (d) is least for the blue.

4. Evidence suggests that the human brain distinguishes between different colours by the relative stimulation of optical receptors having different frequency responses, in the eye. The theory is that:
   (a) each "cone" in the retina has a frequency response curve which is slightly different from all the others
   (b) a separate type of receptor responds to each spectral colour
   (c) only three distinct frequency-response characteristics are involved
   (d) only two distinct frequency-response characteristics are involved

5. Monochromatic light of wavelength 580µm is seen as yellow. It therefore follows that any light entering the eye which appears to have the same hue:
   (a) must consist of monochromatic light of wavelength 580µm
   (b) may contain many frequencies, but must have maximum energy flux at 580µm
   (c) must contain some energy at wavelength 580µm, but not necessarily have maximum energy flux at this wavelength
   (d) need not contain any energy at 580µm wavelength

6. True white light is:
   (a) light with equal energy at all frequencies in the visible range
   (b) light with a spectral distribution the same as that emitted by the sun
   (c) the light emitted by a "black body" at a temperature of 5200 K
   (d) an inexact concept which is defined differently in different circumstances.

7. A single monochromatic light can be rendered colourless (giving the sensation of white) by the addition of a suitable quantity of another monochromatic light:
   (a) whatever the colour of the original light
   (b) unless the original light is in the red region of the spectrum
   (c) unless the original light is in the green region of the spectrum
   (d) unless the original light is in the blue region of the spectrum.

8. White light falls on an object which absorbs in the blue, but reflects other frequencies. The colour of the object will be seen to be:
   (a) yellow
   (b) green
   (c) red
   (d) purple.

9. Monochromatic yellow light from a sodium lamp falls on an orange (fruit). The colour of the orange when viewed in this light will be:
   (a) very pale orange
   (b) low intensity orange
   (c) yellow
   (d) black.

10. If white light is added to light of any given colour the result is:
    (a) a change in hue, but no change in saturation of the colour
    (b) a change in saturation, but no change in hue
    (c) a change in both hue and saturation
    (d) if the original light was monochromatic a change of saturation only, otherwise a change of both hue and saturation.

11. A particular green light has a radiant flux density of 1 watt per square metre. To this light is now added 1 watt per square meter of pure violet light. The effect will be:
    (a) a considerable change in colour, but little change in luminance
    (b) a large increase in luminance, but little change in colour
    (c) little change in either colour or luminance
    (d) a large change in both colour and luminance.

12. Discounting luminance information, the colour of a light can be specified entirely using:
    (a) one variable
    (b) two variables
    (c) three variables
    (d) seven variables.

13. If three colours are located on the chromaticity diagram, then mixtures of varying (positive) quantities of light of these three colours will produce only:
    (a) all colours within the spectral locus (all realisable colours)
    (b) all colours inside the triangle having the given three colours at the corners
    (c) all colours outside the triangle having the given three colours at the corners
    (d) all colours on straight lines joining the three given colours.

14. By mixing, in appropriate quantities, fully saturated red, green and blue light it is possible to produce light:
    (a) of all colours (all hues and saturations)
    (b) of every hue, but not all saturations
    (c) over a restricted range of hues, but with all saturations in that range
    (d) over a restricted range of both hues and saturations.

15. If ideal phosphors could be developed which produced monochromatic red (700µm), green (520µm) and blue (450µm) light, these could be used, with advantage, at the output of a colour television system. The camera filters at the input of the system would require:
    (a) to pass bands of frequencies, as narrow as possible, at the quoted wavelengths
    (b) to have broad overlapping frequency transmission characteristics with maximum transmissions at the quoted wavelength values
    (c) to have pass-bands which met but did not overlap, so as to divide the visible spectrum into three bands centred on the three quoted wavelengths
    (d) to have pass-bands between the quoted wavelength values.

Answers and comments, page 47
Literature Received

ACTIVE DEVICES

"The use of Coaxial-Packaged Transistors in Microstrip Circuits" is the title of Application Note AN-4025 which has been published by RCA Electronic Components, Harrison, New Jersey 07029, U.S.A. WW401

Dickson Electronic Corp's field-effect and bipolar transistors in l.d.d. chip assemblies are described in a 19-page brochure which may be obtained from Dage (Great Britain) Ltd, 1 Penn Place, Rickmansworth, Herts. WW402


Ferranti Ltd., Gem Mill, Chadderton, Oldham, Lancs, have produced some additions for their Microspot c.r.t. manual. This includes a contents sheet and provisional data on the types IB/97, 12H/40, 14/06, 16A/19, 16A/40, 21B/10 cathode-ray tubes, the DY605 electronic display equipment and the PD5002 solid-state light source. WW404

The semiconductor products of SGS (UK) Ltd, Planar House, Walton Street, Aylesbury, Bucks, are listed in two catalogues which are available price 2s. each.

Consumer devices. Professional discrete devices

PASSIVE COMPONENTS

Airpax Electronics, of Cambridge, Maryland 21613, U.S.A., have produced the following two leaflets.

"The Choice of Protection" discusses the use of mechanical methods of protecting electrical and electronic circuits from the effects of short circuits. WW405

A catalogue listing semiconductor fuses WW406

A new edition of the Amphenol catalogue describing miniature circular connectors has just been released. It is available from Amphenol Ltd, Thanet Way, Whitstable, Kent. WW407

Programming systems produced by Oxley Developments Co., Priory Park, Ulverston, Lancs, are the subject of a new catalogue. WW408

"Professional Communications Antenna Systems" is the title of a catalogue available from Antenna Specialists UK Ltd, 1 Euston Road, London N.W.1. WW410

Full details of a range of edge connectors are given in the well illustrated catalogue "Metal Plate Connector Guide", available from Elco Corporation, Willow Grove, Pa. 19090, U.S.A. WW412

An article entitled "Understanding Thermocouples" that originally appeared in our sister journal Instrument and Control Engineering has now been reprinted and is available from IPC Business Press (Sundry Sales Department), 161-166 Fleet Street, London E.C.4. Price 6s 9d, including postage.

EQUIPMENT

An effects generator which can be used to produce sound effects for radio and TV programme inserts, and public address announcements is described in a leaflet from the manufacturers Meliotronics Ltd, 28-30 Market Place, London W.1. WW414

"Gramophone-record reproduction: development, performance and potential of the stereophonic pickup" is the title of an article reprinted from Proceedings I.E.E., Vol. 116, No. 8, August 1969, which is available from Shure Electronics Ltd, 84 Blackfriars Road, London S.E.1 WW415

Photain Controls Ltd, Radalls Road, Leatherhead, Surrey, have produced a leaflet which describes their range of photocontrol lamp modules intended for use in automatic gain control circuits, stepless speed control for motors and modulation circuits, etc. WW416

The eight digital electronic counters in the Dana series 8100 range of automatic counters are described in a brochure from Dana Electronics Ltd, Bilton Way, Dallow Road, Luton, Bedfordshire. WW417

The new 7000-series of oscilloscopes from Tektronix, which includes two oscilloscope main-frames with a choice of six vertical amplifiers, four timebase units and three sampling units, are described in a booklet which may be obtained from Tektronix UK Ltd, Beavertons House, Harpenden, Herts. WW418

We have received the following publications from Marconi Instruments Ltd, Longacres, St. Albans, Herts.

Catalogue 1969-70. A very large catalogue which lists a vast range of electronic measuring equipment. WW419

"MI Bargain Buys". This month's special offers WW420

H.F. Predictions—January

Winter season conditions will continue with a large differential between day and night frequencies except on some routes which show a secondary peak a few hours before dawn. At sunrise and sunset, therefore, the rate of change of MUF is at its greatest and it becomes difficult to maintain satisfactory communication over these periods. On shorter routes, generally less than 2000 km, the daytime MUFs in winter may be lower than in summer when propagation is via the E layer.

The LUFs shown were calculated by Cable and Wireless Ltd for reception in the United Kingdom of point-to-point telegraph services. For other services the curves would be displaced vertically, the exact amount depending on service and equipment parameters.
Answers to “Test Your Knowledge”

Questions on page 45

1. (c) No single monochromatic radiation produces the sensation purple; it requires a mixture from the two ends of the spectrum. If monochromatic red light of wavelength 700 mp and monochromatic violet of wavelength 400 mp (the normally accepted ends of the spectrum) are mixed in various proportions, then the range of “pure” purples is produced.

2. (b)

3. (c) Since the eye is most sensitive to light in the green part of the spectrum, far less energy flux density is required to produce a given luminance of green light than is required for the same luminance of red or blue. Note that the term “monochromatic” is used to describe radiation of one single wavelength (or, in practice, since this is impossible, over a very narrow band) even though in the present context it may seem inappropriate.

4. (c) The details of the mechanism are still not known.

5. (d) Suitable quantities of light of other wavelengths can produce a similar stimulus in the colour receptors. If spectral green and red are used, the result will have the same saturation as well as the same hue.

6. (d) The lights described in (a), (b) and (c) are all forms of white light, although their spectral energy distributions are somewhat different. The standard of white used in television is the colour of a light produced by a particular combination of a tungsten lamp and a filter, known as “standard illuminant C”.

7. (c) The complementary of green is purple, which is non-spectral.

8. (a) Yellow is the complementary of blue, so that removing blue from white leaves yellow.

9. (c) The orange, like most natural coloured objects, reflects light over a range of wavelengths, so that its colour, when illuminated by white light, is determined by the total effect of these on the eye. Since the orange is here illuminated with pure yellow it can only reflect yellow.

10. (b) This, and most other properties of colour are well illustrated by the chromaticity diagram.

11. (a) Although wavelengths at the blue end of the spectrum contribute very little to the brightness of a light they have a very significant effect on its colour.

12. (b) These can be dominant wavelength and purity, or chromaticity co-ordinates (as in the chromaticity diagram). This is why colour information in colour television can be carried by two signals.

13. (b)

14. (b) Reference to the chromaticity diagram shows that no triangle with its corners on realisable colours, even on the spectral locus, can include the whole diagram.

15. (b) The total transmission characteristics for each of the three colour channels in the camera would require to be such that any incident radiation would produce relative responses in the three channels equal to the relative outputs from the three phosphors at the receiver required to produce its colour as nearly as possible.
Real & Imaginary

by Vector

"Yellow, and black, and pale and hectic red."

As I write, the persuaders have just begun their honeyed blandishments in the Press, on sound radio and on television.

Like those purposeful citizens who make a crust by robbing strongrooms, the colour vendors use an oblique approach. Just as cracksmen traditionally begin operations in the cellars of the house next door to the bank, so do our persuaders tunnel into your private strongroom at your weakest point, namely the Little Woman and to some extent the kids, because these, as a generalization, look at the box a lot more than you do.

At present several of the channels are hard at it, backed by powerful newspaper and magazine campaigns—"it" in this case being the task of making you feel a second-class citizen if you are still viewing in unnatural monochrome.

Every day now, and far into the night, the B.B.C. and I.T.A. are firing continual salvos extolling the merits of colour. What does astonish me is that, at the time of writing, I haven't seen any advertisement emanating from a radio manufacturer on any of the channels.

Should any reader be reaching for his pen to remind me that the I.T.A. is the only organization permitted to carry advertising, stay your hand. While it is true that the B.B.C. does not lend itself to the sordid business of raking in money in return for advertising time, there are other, and more gentlemanly, ways of going about it, as any press relations officer worth his salt could tell you.

One such is for the would-be advertiser to latch on to some national sport or cult. One of your first acts is to present a handsome trophy which has the name of your product indissolubly attached to it; all you have to do then is to sit back and wait for the event to be televised.

Another method is to plaster the railings of the more dynamic association football clubs with advertisements of your product. Try as he may, the cameraman will have to have the railings in the picture for a good deal of the time and, given a little luck, you have a free plug both on B.B.C. and I.T.A. for about nine months in any given year.

I see the B.B.C. is making a platform of 'natural television.' They did something similar some years ago in a drive to popularize the v.h.f. sound service. 'High quality' was the torch carried then, but this was soon extinguished by the radio manufacturers, who shoved cheese-pared circuits into a small box, together with a tinpot loudspeaker, and tried to sell it as hi-fi.

And what is natural television, pray? If the term means anything it signifies that, colour-wise, the picture on the home screen is identical with the scene in the studio. That being so, I must say that I'm surprised that the B.B.C.'s technical boys have allowed their advertising colleagues to get away with it. For, given an additive system with all its registration problems, the inclusion of band-saving techniques, and colour filters with transmission characteristics which only approximate to those of the home receiver's phosphors, then even the best colour monitors will not stand comparison with the actual scene.

It's a pity to have selected such a sales story because it looks as if the experience of v.h.f. sound is going to be repeated with colour television, if the criminally maladjusted receivers to be seen all too often in dealers' showrooms are anything to go by.

The public will swallow it of course for the same reason that, in 1922, it subscribed to the belief that an unbiased three-valve receiver feeding a 'sugar-lout' horn loudspeaker was giving perfect quality. They believed it because the only standard of comparison was the acoustic gramophone and the quality of the 'wireless' was, in its day, marginally better than that. By the same token, today's standard of comparison with a colour set is the monochrome receiver and therefore any colour, however unreal, is better than no colour at all. Provided that the sky is some shade of blue and the grass approximates to green, who cares about fidelity? Electronics engineers, certainly, and artists, perhaps, but precious few else. So there was really no need for the B.B.C. to overlook on fidelity.

Sticking my neck into the prophet's noose, my guess is that colour television will take several years to become the norm in the average home and that not a few manufacturers will catch colds in the process.

What, I wonder, would happen if someone came up with a colour system that was miles ahead of PAL? If there is any such lone inventor reading this, I would advise him that he is most unlikely to see his brain-child come into general use. For, with about £150M already invested in the present system, nobody is going to look kindly upon an invention that sets everyone back to square one.

What are the prospects of such a happening? Who knows? What would it be like, this super system? This also is anybody's guess. Almost certainly, I would think, it would embody a subtractive colour system. It would also employ a translating interface which is much more in accord with the human eye-brain complex than is today's television camera.

Our present system is a hangover from Clerk Maxwell, who was the first to show that three black-and-white transparencies can, under certain conditions, provide a picture in full colour. This is an application of the Young-Helmholtz trichromatic theory which is generally believed to form the basis of human colour vision in spite of some anomalies which cannot easily be explained away. No one, for instance, has yet identified three types of cone structure in the eye, one red-detecting, one green and one blue; all the cones seem pretty much the same.

Then, a few years ago Dr. Edwin ("Polaroid") Land demonstrated that two colours, or even one red light and one white, can interact to provide a gamut of colour. Black body radiating from comfortable concepts where, for instance, 500 mu always equates with green light to quicksands where a body radiating at 500mu-appears to the eye as brilliant red. (Yes, I know it sounds daft but it can be done by interfering with the signals which trigger the brain into registering colour.) These coded signals are the core of the matter; if only the code could be broken, all sorts of possibilities exist. It might even be compatible with conventional displays and, instead, feed signals to the area behind the retina.

This sounds crackpot until we come to terms with the thought that colour sensations needn't derive from incident light-frequency radiation. The coded signals to the brain can be applied in various ways; by mechanical vibration; by the application of external voltages or currents or by hallucinatory drugs. In the last-mentioned case manifestations occur which have every semblance of three-dimensional reality. Given an exact control of the input signals, what might not be possible? Even a degree of sight to the blind seems to be feasible.
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SPECIFICATIONS OF JR-310
* FREQUENCY RANGE: 3.5-29.7 MHz (7 Bands)
* SENSITIVITY: 1µV (at 10dB S/N)
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ADDRESS:
AGE:

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### Forced-air Cooled

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### Vapour Cooled

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EXTENSION

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Telex: 99103 Grams: Enelectico Chelmsford

Send for full details of the complete range of EEV amplifier klystrons.

Please send me full details of your range of UHF TV amplifier klystrons.
I am interested in a klystron with the following parameters:

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Mullard
Mullard Limited, Industrial Electronics Division,
Mullard House, Torrington Place, London WC1. 01-580 6633

New Buyers' Guide
There's a new wallchart on Mullard special quality receiving valves. It gives comprehensive equivalents information, and it's free from any Mullard Industrial Distributor, or just use the reader enquiry service.
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DC-to-50 MHz, dual-beam, sweep-delay oscilloscope

The Type 556 and rack-mount Type R556 use any combination of Tektronix letter or 1-series plug-ins.

The UPPER BEAM can display a signal from either left or right plug-in; with either Time Base A, Time Base B, or external signals; triggered from a composite vertical signal, plug-in single channel signal (with 1A1 or 1A2), external, or line.

Independent Vertical Systems use Type 1A1 or 1A2 Plug-in Units for 50 MHz operation; also accept any other 1-series or letter-series plug-in units.

Independent Sweep Systems provide 24 calibrated steps from 0.1 μs/cm to 5s/cm; the X10 Magnifier extends the fastest sweep rates to 10ns/cm. Calibrated Sweep Delay extends continuously from 0.1 microsecond to 50 seconds.

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4 Decade plus Air Spaced Capacitor - Cat. Ref. VC5 - 50 pf to 1.1115 mfd. infinitely variable.
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The TA401 is similar to the TA601 (as illustrated)

SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>TYPE TA401</th>
<th>TYPE TA601</th>
<th>TYPE TA605</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAIN</td>
<td>40dB ± 0.1dB</td>
<td>60dB ± 0.1dB</td>
<td>20, 30, 40, 50 and 60dB ± 0.2dB.</td>
</tr>
<tr>
<td>BANDWIDTH ± 3dB</td>
<td>1 Hz-3MHz</td>
<td>3Hz-1.2MHz</td>
<td>20-40dB, 1Hz-3MHz; 50dB, 2Hz-2MHz; 60dB, 4Hz-1.5MHz.</td>
</tr>
<tr>
<td>BANDWIDTH ± 0.3dB</td>
<td>4Hz-1MHz</td>
<td>10Hz-300kHz</td>
<td>20-40dB, 4Hz-1MHz; 60dB, 10Hz-300kHz.</td>
</tr>
<tr>
<td>INPUT IMPEDANCE</td>
<td>&gt; 5MΩ, &lt; 40pF</td>
<td>&gt; 1MΩ, &lt; 50pF</td>
<td>&gt; 5MΩ, &lt; 40pF</td>
</tr>
<tr>
<td>(from 100Hz to 1MHz)</td>
<td>(from 100Hz to 300kHz)</td>
<td>(from 100Hz to 300kHz)</td>
<td></td>
</tr>
<tr>
<td>INPUT NOISE</td>
<td>&lt; 15 µV, zero source:</td>
<td>&lt; 15 µV, zero source:</td>
<td>As TA401 and TA601 at 40dB and 60dB.</td>
</tr>
<tr>
<td></td>
<td>&lt; 50 µV, 100kΩ source:</td>
<td>&lt; 40 µV, 100kΩ source:</td>
<td></td>
</tr>
<tr>
<td>POWER SUPPLY</td>
<td>PP3 battery, life 100 hours</td>
<td>PP9 battery, life 1,000 hours, or A.C. Power Unit.</td>
<td></td>
</tr>
<tr>
<td>AVAILABLE OUTPUT</td>
<td>1V up to 1MHz, 300mV at 3MHz, into load of 100kΩ and 50pF</td>
<td>1.5V up to 2MHz, 1V at 3MHz, into 100kΩ and 50pF.</td>
<td></td>
</tr>
<tr>
<td>OUTPUT IMPEDANCE</td>
<td>100 Ω in series with 6.4 µF</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SIZE AND WEIGHT</td>
<td>3&quot; x 1½&quot; x 1½&quot; 7 oz.</td>
<td>2½&quot; x 4&quot; x 5½&quot; 2½ lb.</td>
<td></td>
</tr>
<tr>
<td>PRICE with Battery and input lead</td>
<td>£17.0.0</td>
<td>£17.0.0</td>
<td>£27.0.0 (Optional A.C. Power Unit £7.10.0 extra).</td>
</tr>
</tbody>
</table>

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STEREO 'COMPACTS'
The newest additions to the Heathkit range are two "stereo compacts". The AD-27, pictured left includes a turntable unit with a Shure magnetic cartridge, an FM stereo tuner and a 30 watt stereo amplifier. The whole is built into an attractive compact teak or walnut veneered cabinet - all for a kit price of only £82! The AD-17 compact is similar but does not have the FM radio facility and uses a simpler but still attractive cabinet. This kit only costs £54.

STEREO TUNER AMPLIFIERS
If you need a Tuner-Amplifier, we can offer models to suit any pocket. Pictured on the left is the very popular Heathkit AR-14. This is a solid-state stereo Tuner-Amplifier with a sensitive FM tuner, a built-in stereo decoder and a 30 watt stereo amplifier (15 watts I.H.F.M. per channel). It is wonderful value at a kit price of £54.

STEREO 'SEPARATES'
If your preference is "separates", or perhaps you want just a stereo amplifier without a tuner, again Heathkit offers a selection. Typical is the TSA-12 stereo amplifier, illustrated. This is a solid state stereo amplifier (15 watts I.H.F.M. per channel) at a kit price of only £32 16 0. We have radio tuners to match either for FM reception only, or for FM and Long and Medium wave. The Stereo Tuner, model TFM-15 costs only £28 14 0 in kit form.

LOUDSPEAKER SYSTEMS
All the units described above can be used with any good hi-fi loudspeakers. To cover this need, the Heathkit range includes several hi-fi loudspeaker kits. The Berkeley kit features a 12 in. bass loudspeaker and a 4 in. high-frequency unit, a ready finished teak or walnut veneered cabinet, and the kit price is only £21 4 0. The 'Avon' mini kit is only £13 8 0.

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Specification

- **Power Output:** 25-30 watts at 100V line.
- **Inputs:** Two microphones, 30-50Ω balanced.
- **Auxiliary switched gram, tape, or medium impedance microphone.**
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- **Height less legs:** 1' 0".

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- **STYLISH PRESENTATION**

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and this is the Peak Sound Specification Guarantee

Peak Sound guarantee that their equipment meets all specifications as published by them and that these are written in the same terms as are used in equipment reviews appearing in this and other leading high fidelity journals. Audio output powers are quoted at continuous sine wave power in terms of Root Mean Square values (R.M.S.) into stated loads at stated frequencies.

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Using two Peak Sound PA 12-15's, driven simultaneously at 1 kHz from 240 V. mains supply.

- Output per channel: 11 watts into 15Ω, 14 watts into 8Ω (see spec., guaranteed)
- Frequency bandwidth: 10Hz to 45 kHz for 1dB at 1 watt.
- Total Harmonic Distortion at 1 kHz at 10 watt into 15Ω = 0.1%.
- Input sensitivities: Mag. PU 3.5 mV imp. R.I.A.A. equalized into 68 kΩ Tape, 100 mV linear into 100 kΩ.
- Radio, 100 mV linear into 100 kΩ.
- Overload factor: 29 dB on all input channels.

Using two PA 25-15 amplifiers, output is then 25 watts into 15Ω or 60 watts total output at 1 kHz.

- Power bandwidth for 1 dB at 20 watts R.M.S. Into 15Ω at less than 0.2% distortion is 20 Hz to 20 kHz.

THE MODULES

Englefield Amplifier Cabinet with front panel, knobs, sockets, cut and stripped wire, fuses, edge connectors, etc.

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Two PA. 12-15 power amp. built modules

- £11 19 0

SCU/400 Pre amp/Control module, built

- £15 15 0

PB/45 Power Supply kit

- £4 10 0

£38 4 0

Using two PA 25-15 modules at £11/15/- each and PB/48S Stabilized Power Supply Unit at £13/10/- total price for complete system comes to £58 15 0
Some notes on Bridge Measurement by WAYNE KERR

Number 6

Radio-Frequency Bridges

The first five issues in this series of notes have described some of the basic principles of low frequency bridges and also their application to the measurement of components using two, three and four terminal techniques.

Transformer Ratio Arm bridges can be designed to operate at radio frequencies up to about 250MHz where other forms of bridge based on transmission lines become practicable.

The design of a bridge required to operate at high frequencies demands careful attention to every aspect of the layout, and in particular to the series inductance introduced by connections between component parts of the bridge. Short lengths of conductor which are insignificant at low frequencies can resonate and introduce immense errors as the frequency is increased.

However, the neutral connection which is available from transformer ratio arms can be used to effectively cancel the series inductance of conductors in the following manner. If two strip connections are made to, say, a bridge standard, these are placed side by side and mounted above a plate connected to neutral. The loop current flowing in the strips will induce, in the plate, an equal and opposite current which cancels the magnetic field, thus reducing the loop inductance.

Figure 1 illustrates a practical circuit for a bridge capable of operating at frequencies up to 100MHz.

The unknown impedance is connected to the blocks shown in the diagram which represent a shunt capacitance on the unknown side of the bridge. This capacitance is balanced by the standard variable capacitor and its value is so chosen that the capacitor is half engaged when the dials are at zero. An unknown reactance can therefore be balanced either by increasing the setting of the capacitor or decreasing it in the case of an inductive reactance. This feature is of particular value when transmission lines or aerial arrays are being evaluated.

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The loop is connected to a winding which forms part of the left hand transformer shown in Figure 1. An auto-transformer is connected across the loop and several taps are connected to give a predetermined voltage distribution round the loop. Separate loops can be used to drive resistive and reactive standards and one interesting feature of the arrangement is its ability to create a continuously variable inductance standard. In this case an air cored toroid can be employed whose external field is so small that the presence of metal objects near the coil has no measurable effect.

Radio-frequency bridge measurements require that considerable care should be taken in setting-up the apparatus. Any leakage of power from the source to the detector which by-passes the bridge network will give errors. Furthermore, if an aerial assembly is being measured, radiation from the aerial may be picked up by a badly screened detector and subsequently cancelled by a voltage of opposite phase in the operation of the bridge which will now balance at a false point on its scales. However, with a well screened detector and with soundly constructed connecting cables coupling the source and detector to the bridge, highly accurate measurements can be performed on both active and passive assemblies.

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The IC-10 is primarily intended as a full performance high fidelity power and pre-amplifier, for which application it only requires the addition of such components as tone and volume controls and a battery or mains power supply. However, it is so designed that it may be used simply in many other applications including car radios, electronic organs, servo amplifiers (it is d.c. coupled throughout), etc. Once proven, the circuits can be produced with complete uniformity which enables us to give a 5-year guarantee on each IC-10, knowing that every unit will work as perfectly as the original and do so for a lifetime.

**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:** 1 mV
- **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 AB 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 cross-over 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.

**SINCLAIR IC-10**

- with IC-10 manual
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**59/6**
Project 60 an exciting alternative

The buyer of an amplifier today has a remarkably wide variety to choose from. It is unlikely that a purchaser would have real difficulty in finding a unit that met all his requirements, although the price might not be as low as could be wished. The only snags are that one's needs can change and that the technically correct amplifier may be physically inconvenient. If you are confident that there is an amplifier available, of the right size and price, which will meet all your needs for the forseeable future, then that is your best buy. If not, however, we can offer you another possibility which we believe to be an exciting alternative approach. That alternative is Project 60.

Project 60 is a range of modules which connect together simply to form a complete stereo amplifier with really excellent performance. So good, in fact, that only 2 or 3 amplifiers in the world can compare with it in overall performance.

The modules are:
1. The Z-30 high gain power amplifier, which is an immensely flexible unit in its own right.
2. The Stereo 60 preamplifier and control unit.
3. The PZ-5 and PZ-6 power supplies. A complete system comprises two Z-30's, one Stereo-60 and a PZ-5 or PZ-6. The power supplies differ in that the PZ-6 is stabilised whilst the PZ-5 is not. This means that the former should be used where the highest possible continuous sine wave rating is required. In a normal domestic application there will not be a significant difference between using either power unit unless loudspeakers of very low efficiency are being used.

All you need to assemble your system is a screwdriver and a soldering iron. No technical skill or knowledge whatsoever is required and, in the unlikely event of you hitting a problem, our customer service and advice department will put the matter right promptly and willingly.

Perhaps the greatest beauty of the system is that it is not only flexible now but will remain so in the future. We shall shortly be introducing additional modules which will include a comprehensive filter unit, a stereo F.M. tuner and an even more powerful amplifier for very large systems. These and all other modules we introduce will be compatible with those shown here and may be added to your system at any time.

Project 60 modules have been carefully designed to fit into virtually every known type of plinth or cabinet and templates provided enable you to position them. Only holes have to be drilled into the wood of the plinth and any slight slips here will be covered completely by the aluminium front panel of the Stereo 60. The Project 60 manual gives all the instructions you can possibly want clearly and concisely.
Z-30
TWENTY WATT R.M.S. (40 WATT PEAK)
PPOWER AMPLIFIER

The Z-30 is a complete power amplifier of very advanced design employing 9 silicon epitaxial planar transistors. Total harmonic distortion is incredibly low being only 0.02% at full output and all lower outputs. As far as we know, no other high fidelity amplifier made can match this specification, no matter what the price. Thus you can be utterly certain that your Project 60 system will do full justice to your other equipment however good it may be. The Z-30 is unique in that it will operate perfectly, without adjustment, from any power supply from 8 to 35 volts. It also has sufficient gain to operate directly from a crystal pickup. So in addition to its use in a high fidelity system you can use a Z-30 to advantage in your car or a battery operated gramophone for your children, for example. These, and many other applications of the Z-30, are covered in the Project 60 manual.

SPECIFICATIONS
Power output—15 watts R.M.S. (30 watts peak) into 8 ohms using a 35 volt supply; 20 watts R.M.S. (40 watts peak) into 3 ohms using a 30 volt supply.
Output—Class AB.
Frequency response: 30 to 300,000 Hz ± 1dB.
Signal to noise ratio: better than 70:1dB unweighted.
Distortion: 0.02% total harmonic distortion at full output into 8 ohms and at all lower output levels.
Size: 3½ x 2½ x 6 inches.
Input sensitivity: 250mV into 100 Kohms.
Damping Factor: > 500.
Loudspeaker impedances 3 to 15 ohms.
Power requirements: 8 to 35 V d.c.

APPLICATIONS
High fidelity amplifier: car radio amplifier; record player fed direct from pickup; intercom; electronic music instruments; P.A.; laboratory work, etc. Full details of these and many other applications are given in the manual supplied with your Z-30.

STEREO SIXTY
PREAMPLIFIER AND CONTROL UNIT

The Stereo 60 is a stereo preamplifier and 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 and great attention has been paid to achieving a really high signal-to-noise ratio and excellent tracking between the two channels. Input selection is by means of push buttons and accurate equalisation is provided for all the usual inputs. The tone controls are also very carefully designed and tested.

SPECIFICATIONS
- Input sensitivities—Radio—up to 3mV; Magnetic Pickup—3mV Correct within ± 1dB on R.I.A.A. curve. Ceramic Pickup—up to 3mV; Auxiliary—up to 3mV.
- Output—1 volt.
- Signal-to-noise ratio—better than 70dB.
- Channel matching—within 1dB.
- Tone Controls—TREBLE +15 to −15dB at 10 KHz; BASS +15 to −15dB at 100 Hz.
- Power consumption 5mA.
- Power requirement—PZ 1 or PZ 6.
- Finish—brushed aluminum front panel with black knobs.
- Mounting—on cabinet front by spindle bushes and adjustable brackets.

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**NOMBREX TRANSISTORIZED Test Equipment**

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  - 24th
  - 29th
  - 30th
  - 31st

**STEREOHEADPHONES**


**23 A**

- **PRICE Sheet**
  - 10/50/500

**GRADINER FIRE DETECTOR UNIT**

- **PRICE Sheet**
  - 8" x 10"

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- Ideal for all transistor alignment. Built-in field strength meter 10mA. Complete. Ready to use. SWR 1 to 1.3

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- 8200 Gun Kit...
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(Burndant B.E.352) 50 watt model. Supplied Brand New complete with stainless steel tank 9 Conditional. 4 x 6 x 1 in. £60.

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EXTRACTOR/BLOWER FANS (Papst) 100 c.f.m. 4' x 4' x 2' in. 300 volt. 5 hp. (no motor) £15.00. Would be a profitable buy at 50/- or £240. A.C.

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PRECISION CAPACITANCE JIBS. Beautifully made with Motor Dielectric Weight and Capacity. Type 1. 18.50p/-

220p/- £10 ea. Type 2. 5.95/- 11.25d. ea.

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Same as 4-Station Intercom for two-way instant conversation from MASTER to SUB and SUB to MASTER. Ideal as Baby Alarm and Door Phone. Complete with 66ft. connecting wire. Battery 2/6. P. & P. 4/6.

**7-STATION INTERCOM**


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**NEW PRICES ON NEW COMPONENTS**

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- Dimensions (mm.): Body: 11W, 8 x 2 x 6.
- 11W, 10 x 4 x 9.
- Leds: 35
- 10% ranges: 10 Ohms to 10 Megohms (E12 Regard Series).
- 5% ranges: 4 Ohms to 1 Megohm (E24 Regard Series).

**Prices—per Ohmic Value**

<table>
<thead>
<tr>
<th>Value</th>
<th>Price</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>1W</td>
<td>10%</td>
<td>25</td>
</tr>
<tr>
<td>1W</td>
<td>5%</td>
<td>1/4</td>
</tr>
<tr>
<td>4W</td>
<td>5%</td>
<td>1/4</td>
</tr>
</tbody>
</table>

**CAPACITORS**
- Resistorised Polyester Film, Modular for P.C. mounting. Hard epoxy resin encapsulation. Radial leads.
- 10% tolerance, 100 Volt working.
- Prices—per Capacitance value (µF)

<table>
<thead>
<tr>
<th>Value</th>
<th>Price</th>
<th>Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
<td>0.002</td>
<td>1/4</td>
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<tr>
<td>0.005</td>
<td>0.01</td>
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<tr>
<td>0.02</td>
<td>0.05</td>
<td>1/4</td>
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</tbody>
</table>

**POTENTIOMETERS**
- Linear: 1K to 2M (1W at 40°C).
- Logarithmic: 5K to 2M (1W at 40°C).

**Prices—per Ohmic Value**

<table>
<thead>
<tr>
<th>Value</th>
<th>Price</th>
<th>Qty</th>
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<tr>
<td>18/8</td>
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<td>1/4</td>
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</table>

**GANGED STEREO POTENTIOMETERS**

- 3W at 70°C, Linear Spindle.
- 5K at 40°C, Logarithmic and Linear: 5k to 43M to 1M = 1M. 1M.

**SKELETON PRE-SET POTENTIOMETERS**

- High quality pre-sets suitable for printed circuit boards of 0.1m. P.C.M. 100 ohms to 5 Megohms (Linear only). Miniature: 0.1W at 70°C, ± 20% below 1M, ± 30% above 1M. Horizontal: 0.1W at 40°C. (4m. P.C.M.) or Vertical: 0.05W at 40°C. (8m. P.C.M.)

**New**

**Prices—per Ohmic Value**

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<tr>
<th>Value</th>
<th>Price</th>
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<td>15/8</td>
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**ELECTRICAL TEST GEAR**

- calibrated and ready to plug in

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**TELEPHONE AMPLIFIER**

**59/6**


Full price refunded if returned in 7 days.

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85/- post free

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Total diaplasion (in free air; Tue — 28°C) 100mV. Operating Factor 2mV/°C. Output Current Intensity: 100mA. Voltage 25V. Operating Temperature: from -40°C to +120°C.

Supplied complete with suitable lenses, full Technical Data and Application Sheets. Including Line of Sight Speech Link.

GALLIUM ARSENIDE LIGHT SOURCE — MGA 100
Filamentless, infra-red sources in a robust, abandoned cylindrical casing. With bean to kiloWatt optical alignment and heat sinking.

35/- post free

MAX RATINGS
Forward current 1mA max.; D.C. 500mA. Forward power 1mA max. D.C. 1W. Forward power dissipation for a 1mA D.C. dissipation is 1W. Reverse voltage max. 1V.

Supplied complete with suitable lenses, full Technical Data and Application Sheets. Including Line of Sight Speech Link.

PHOTOCONDUCTIVE CELLS

Cadmium Sulphide Cells (CdS)
Inelastic light sensitive devices which require only simple circuitry to work as light triggering units in a wide range of devices, such as; flashing or breakouts lights, exposure meters, brightness controls, automatic porch lights. Not polarity conscious — use with A.C. or D.C. Spectral response covers wide visible light range.

MKY101-C
Epoxied sealed, 8 in. diam. x 4 in. thick. Resistance at 100 °C: 50 to 20,000 Ω. Maximum voltage 150 V.C. or D.C. Maximum current 150 mA.
10/6 post free

MKY 71
Glass sealed with M.S.S. bronze. Glass envelope 3/4 in. diam., overall length 7 in. Resistance at 100 °C: 50 to 150,000 Ω. Maximum voltage 150 V.C. or D.C. Maximum current 75 mA.
8/6 post free

PHOTOGENERATIVE CELLS

Selenium cells in which light energy is converted directly into electricity, measurable on microammeter or used with amplifier as light trigger for alarm and counting devices, luminous flueometers, exposure meters, colorimeters, etc. Spectral response covers visible light range.

Type 1: 13 x 1/2 in. Output 1 mA at 0.6 volts at 1,000 Lux
5/- post free

Type 2: 100 x 50 mm. Output 4 mA at 0.6 volt at 1,000 Lux
22/6 post free

REED SWITCH COILS & CAPSULES

Complete assembly of reed switches and operating coils that permit the design of an infinite variety of multi-switch circuits in an extremely small space. They eliminate the bulk and space contact disadvantage of electro-mechanical relays. Hermetically sealed contact isolation ensures long life reliability. Small enough to combine with solid-state components on printed circuit boards. Ideal for switching matrices, relay contactors, etc.

Type 1: (R/C8)
R/C6
R/C4
R/C2

2 Reed switches, contacts normally open. Size overall: 1 x 1 x 1 in.
6/- post free

4 Reed switches, contacts normally open. Size overall: 1 x 1 x 1 in.
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6 Reed switches, contacts normally open, 2 normally closed. Size overall: 1 x 1 x 1 in.
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Newly developed plastic light transmitting media by Oupouts, which can be used in both serious and inexpensive prototypes work. Ends can be ground flat, sanded, or dipped in special wax. Temperature range: +40° to +170°F. No loss of light through bending. 12 page Data and Applications booklet supplied with each order. Types available:

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VARIABLE VOLTAGE TRANSFORMERS

INPUT 230 v. A.C. 50/60

OUTPUT VARIABLE 0-260 v. A.C.

BRAKE NEW. Kenton's Prices in the country. All Types (and spares) from 1 to 50 amper from stock.

<table>
<thead>
<tr>
<th>Current (Amps)</th>
<th>Voltage (Volts)</th>
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<tbody>
<tr>
<td>0-10</td>
<td>0-260</td>
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<tr>
<td>0-20</td>
<td>0-260</td>
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<td>0-30</td>
<td>0-260</td>
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<td>0-50</td>
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50 AMPS

1 AMP.

OPEN TYPES

Designed for Panel Mounting.

Input 230 v. A.C. 50/60

Output variable.

260 v. 4.

5 amp. £3 10 0.

5 amp. £3 10 0.

1 amp. £1 10 0.

1/2 amp. £1 10 0.

1/2 AMP.

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1/2 AMP.
MINIATURE UNISELECTOR

UNISELECTOR SWITCHES NEW
4 BANK 25 WAY FULL WIPER
25 ohm coil, 24 v. D.C. operation.
6/23, #217.

6 BANK 25 WAY FULL WIPER
25 ohm coil, 24 v. D.C. operation.
6/23, #216 & 2/12.

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280 6-12 2 c/c incl. base 14½
170 12-24 4 c/c incl. base 15½
700 1-6 2 c/c incl. base 15½
800 1-24 4 c/c incl. base 15½
1000 1-25 4 c/c incl. base 16½
1250 6-20 2 c/c H.D. base 17½
9000 40-70 2½ c/c incl. base 10½

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Plughole round 5 ½ in. each. P. & P. incl.
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Complete with batteries and test prods. $7.50 Post paid.

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240 Amp. Multiplier for 3600 volt. Complete outfit in fitted case. $155 80, P. & P.

SANGAMO WESTON
Ex-W.O. Dual range voltmeter. 0-5 and 0-100 V. D.C. F.S.D. 1mA. in carrying case with test leads and 3½ in. D.C. F.S.D. 100 mA.

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Single "Dec" with each accessory and packaging.

S-Dec kit contains two "Dec"-operations, instruction book, all packed in attractive plastic box...

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Alloy panel to fit 11" Panel box to fit 6...Many other sizes in stock...

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400mW 10% tolerance...

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BPM-6 (20 Volts)...

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BPM-2-0.4 Volts at 23-5/3MA...

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Operate at 40kc/s...

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TMK METER KITS

**MODEL 200**

20,000 D.C. and 40,000 A.C. Multimeter. Features: 24 range selector switch with fine scale. 77387 make, full scale accuracy 5% over reading. DC and AC (5000 ohm scale). DC accuracy 7.5% over reading. For other applications of standards accuracy supplied. Compare in every detail with full specifications, circuitry and operating instructions.

**SPECIFICATION**

- **D.C. 0-25, 0-50, 250, 500, 1000 (0-700 ohms), 0-2500 ohms; 0-2.5V, 0-5V, 0-25V, 0-250V, 0-500V, 0-1000V, 0-5000V, 0-10K, 0-25K, 0-50K, 0-100K Ohms.**
- **Accuracy:** 0.1% to 1% over range.
- **Sampling:** 150 samples/sec.
- **Batt.:** 8-7=2 A.
- **Bulit-in buzzer:** 9 VDC.
- **Size:** 5x3 x 1.5 in.
- **Complete with test leads.**

**LASKY'S KIT PRICE 85/-**

Also available ready built and tested £12.10.0

**TMK 100K "LAB" SERIES MULTIMETER**

A highly accurate Multimeter using a 10 µA, 100 µm focal length. Fullscale reading is 1% of scale. Features: 10000 counts and incapsulated components. It is the only volatile less than 2 µA, full scale accuracy, and incapsulated components.

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Fully built and tested. 20,000 D.C. P.V. Multi-tester for the amateur or professional. Features: electronic circuitry and read grade ferrite for 1000 and 5000 D.C. ranges, A.C. range, 0-25V, 0-50V, 0-250V, 0-500V, 0-2500V. Complete with test leads. Size: 5x3 x 1.5 in. 2X4 battery. Complete with test leads.

**LASKY'S PRICE £6.19.6**

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- OA200 1/9d. - OA202 1/11d.

Build the NEW Mainline Audio Amplifier kits - UP TO 70 WATTS

The result of the combined resources of SGS and RCA, these quasi circuits set new standards in quality and performance. Each kit is complete with circuit diagram, all semiconductors, resistors, capacitors and printed circuit board.

- 12A £7. 0. 0.
- 25A £8. 5. 0.
- 40A £9. 0. 0.
- 70A £10.10. 0.

Any two will make an outstanding stereo equipment.

To: Mainline Electronics Limited, Thames Avenue, Windsor, Berkshire
I enclose 4/- Please send me your price list and guide
I am interested in ....... Amp Mainline Audio Amplifier Kits. Please send me full data
I am interested in receiving data on preamplifier & power supply kits

NAME __________________________ ADDRESS __________________________

(A member of the ECS Group of Companies)
SUPER-BARGAIN STOCK CLEARANCE SALE!!

Use form below for your order. CONDENSERS MUST BE ORDERED BY STOCK NUMBER ONLY.

If any sale item is 'sold-out' when order received we shall substitute items of equal value.

**ELECTROLYTIC CAPACITORS**

<table>
<thead>
<tr>
<th>Stock No.</th>
<th>Capacity</th>
<th>Voltage</th>
<th>Price</th>
<th>No. Required</th>
<th>£ s. d.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 uF</td>
<td>600</td>
<td>4</td>
<td>24</td>
<td>6.00</td>
</tr>
<tr>
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<td>13</td>
<td>1.50</td>
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</tbody>
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**RESISTORS. 5% EXCELLENT QUALITY. 7/6d. per 100 of any one value.**

Tick the values required.

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Price</th>
<th>No. Required</th>
<th>£ s. d.</th>
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<td>0.80</td>
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<td>91 ohms</td>
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<tr>
<td>220 ohms</td>
<td>3.3 k ohm</td>
<td>25 per 100</td>
<td>0.80</td>
</tr>
<tr>
<td>470 ohms</td>
<td>3.3 k ohm</td>
<td>25 per 100</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**SILVER MICA/CERAMIC/POLYSTYRENE CONDENSERS.**

Available in various values. Tick those required.

<table>
<thead>
<tr>
<th>Capacity (mm)</th>
<th>Voltage</th>
<th>Price</th>
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</thead>
<tbody>
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<td>100 pf</td>
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<tr>
<td>1,500 pf</td>
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<tr>
<td>2,700 pf</td>
<td>2,700</td>
<td>3.50</td>
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</tbody>
</table>

**COMPARE THESE PRICES!!**

**MULLARD POLYESTER CAPACITORS.**

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000 pf</td>
<td>6d.</td>
</tr>
<tr>
<td>1,500 pf</td>
<td>6d.</td>
</tr>
<tr>
<td>2,000 pf</td>
<td>6d.</td>
</tr>
<tr>
<td>2,500 pf</td>
<td>6d.</td>
</tr>
<tr>
<td>3,000 pf</td>
<td>6d.</td>
</tr>
</tbody>
</table>

**RECORDABLE TAPE GIVEAWAY!!**

ALL BRITISH MADE. BEST QUALITY. 6" x 600' 7/6d. 9" x 900' 9d.

These prices cannot be repeated. Order now. Don't forget to add your name and address! Please include suitable amount to cover post and packing. Minimum 2d.

G.F. MILWARD, DRAYTON BASSETT, near TAMWORTH, STAFFS. Phone: TAMWORTH 2321
**BETTER BARGAINS SERVICE FROM T.R.S.**

**Amplifier Kits**

Styled and tested by T.R.S., using quality components, including valves or transistors and excellent instructions. Backed by T.R.S. service.

**MULLARD**

Mono. Basic kit (requires pre-amp as below or passive controls £2 extra). Input: Sensitivity: 50 mV; Output: 24 W. £12.90. KIT: £10.18; BUILT: £13.06 (Carr. 60th, 7/8).

**MULLARD 3-VOLT PREAMP**

with switching for 3 inputs, bass/triple/volume 50,000 Hz. £16.80. KIT: £14.27; BUILT: £17.20 (Carr. 55th, 7/8).

**T.R.S. 10-15 STEREO AMPLIFIER**

Input sensitivity: 210 mV per ch. Response 20 kHz. £18.60 per ch. Complete kit £33.80. KIT: £29.40; BUILT: £34.20 (Carr. 55th, 7/8).

**THE NEW T.R.S.**

P.W. 12-12

T.R.S. have produced their own kit version of this extraordinarily good combined stereo amp and pre-amp. It conforms closely to France's Wireless's excellent but is styled for a flatter, more conventional cabinet which will be slightly smaller. Kit includes two-tone front panel and control knobs.

Inputs—Mag. P.U. (R.I.A.A.) 2.1 Ohm into 60 Kohms; Ceramic—Radio: Response—20Hz to 30KHz ± 6db. Output—12 watts per ch. R.M.S. into 15 ohms.

Power/Amp/Pre-Amp Kits available separately.

**VINAIRES—Latest U.C.I. Cabinets and Speaker units. Stained Dark Grays, Off-White, Tawny, Black, etc. 2/4 per ch. All dimensions of 6 in. cut. 2/4 per ch. Maximum width 48 in. Sold by Distributors—Refundable.

**BANDOCOUST—Speaker Cabinet Anti Vibrating pads used by leading Hi-Fi. Speaker makers. Mag. P.U. 2-3/4 per ch. 2-3/4 per yard £2 15s. BUILT: £5 10s. (Carr. 55th, 7/8).**

**TINNED COPPER WIRE**

3/0 ga. real prices.

6-gauge 5yd. £2 6s.; 4/0-gauge 3 yd. £4 6s.; 4/0-gauge 2 yd. £5 6s.; 3/0-gauge 1 yd. £6 6s.

**RESISTORS**—All standard sizes stocked.

6.8 ohms—10 ohms; 20 ohms; 30 ohms; 50 ohms; 100 ohms; 500 ohms; 1 Meg., 5 Meg., 10 Meg., 50 Meg., 100 Meg., 500 Meg., 1000 Meg.; 10,000 Meg. (Corr. 55th, 7/8).

**T.S.P.**—Adhesive copper wire. 5 ft. by 1/16 in. spool.

**PLUGS AND SOCKETS**

Phone plugs, 110 volt sockets, 11, twin; 110. DIN 5-pin plugs; 2-5-pin sockets, 11/2; 5-pin plugs; 2-5-pin sockets, 11/2.

**VOLUME CONTROLS**

Input: 1 in. long. Sensible Fampy make. Guaranteed 12 months. Log or Linear output.

**RESISTORS**—2 Meg., 6 Meg., 10 Meg., 30 Meg., 50 Meg., 100 Meg., 500 Meg., 1000 Meg., 5000 Meg.

**BASS & TREBLE CONTROLS**

Output: 10 ohms. (Carr. 55th, 7/8).

**SKELETON FUSES**

for Picleube use. 100 ohms-5 Meg. £3.60.
MARCONI TEST EQUIPMENT

VALENC VOLTMETER

**VALVE VOLTMETER** TYPE TK 16E

Measures AC 100mV to 100V, DC 10mV to 100V, multimeter extending range to 1.5kV. Automatic detection and centre-zero scale for DC. AC up to 1kV. 

IMPEDANCE BRIDGE TYPE TF 349

349 Measures AC 100mV to 100V, 1.5Hz, 10kHz, Ranges. -J, 510-100H. AC Bridge volts monitored and variable. Automatic detector sensitivity control. £10.95, Carriage £1.50. 

F.M. DEVELOPMENT METER TYPE TF 191F

Frequency range 4.5-520MHz. Deviation 1.5kHz. Specification and price on request. 

DISTORTION FACTOR METER TYPE ET 14E

Frequency range 25kHz to 500kHz. Input impedance 500k. Attenuation. 0-50dB continuously variable. Sensitivity lmV. £20.00. Carriage £3.00. 

PULSE GENERATOR TYPE TF 875P

Repetition frequency 500Hz to 250kHz. Duty cycle 0 to 100%. Time duration 0.1 to 100ms; built in 0.5 and 0.5sec delay circuits. £40.00. Carriage £5.00. 

CIRCUIT MAGNIFICATION METER TYPE TF 339P

Frequency range 50kHz to 500kHz. Magnification 10 to 5000. Tuning Capacitor: 40 to 450 pF with adjustable. Fully overhauled and calibrated. £70.00. Carriage £8.00. 

TF 889 VOLTOMETER, 100V

£71.10. Carriage £10.00. 

F.M. DEVIATION METER TF 934, 935, 936

VIDEO OSCILLATOR TF 885A & 885/A. £5.00 and £8.00 resp. Carriag £3.00. 

HEWLETT-PACKARD TEST EQUIPMENT

**MODEL 5248 ELECTRONIC COUNTER WITH MODEL 5258 PLUGS IN UNIT.** Basic counts. Measures frequencies from 10Hz to 10MHz and from 0 to 150VDC. Auto-panning position of decimal point. Eight plate regulation. Full self check faculty from built in frequency standards. Plug in unit extends frequency range of basic counter to 1000Hz. Full specification and price on request. 

**MODEL 40D VALVE MILLIVOLT.** Voltage range 1.5mV to 1000mV. In nine ranges. 10mV step. Input impedance: Greater than 50m. Full specification upon request. £13.00. 

SOLARTRON EQUIPMENT

**VF 232 VALVE VOLTMETER.** Voltage range 1.5mV to 1000V. In nine ranges. 10mV step. Input impedance: Greater than 50m. Full specification upon request. £13.00. 

**KELVIN & HUGHES PEN RECORDERS.** 

Boonton Signal Generator TS 47/S. £71.00. 

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CA 3012 wide band 1MHz amplifier. £9.50. 

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Ordinary postage 6d. per valve.

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SEND S.A.E. FOR LIST OF 6,000 TYPES

Wireless World, January 1970
Complete stereo system—£29 10s.

The new Duo general-purpose 2-way speaker system is beautifully finished in polished teak veneer, with matching vinyl grille. It is ideal for wall or shelf mounting either upright or horizontally.

**Type 1 SPECIFICATION**
- Impedance: 4 ohms.
- Sensitivities: 13 dB at 10 mV.
- Bass: built-in equaliser plus 5 dB at 15 KHz.
- Crossover: 1.5 kc.
- Treble: 20 KHz.
- Input: 10 watts.
- Output: 200 watts.
- Frequency response: 20 Hz to 20 KHz.
- Volume control range: 15 dB lift and cut.
- Power supply: 200-250 volts a.c.
- Power consumption: 12.5 watts.
- Size: 12" x 8" x 3".

**NEW COMPLETE HI-FI STEREO SYSTEM £39**
- comprising SP25 Garrard MkIII with diamond stereo cartridge. Viscount amplifier MkII. Two types 2 speaker system, plinth and cover.

**STEREO PRE-AMPLIFIER**
- Inputs: 2 phono, input switch for either mono or stereo input.
- Frequency response: 20 Hz to 20 KHz.
- Power supply: 200-250 volts a.c.
- Power consumption: 12.5 watts.
- Size: 12" x 8" x 3".
- Made in Britain.

**THE DORSET (6000mW Output)**
- £5.9
- Circuit: 286. FREE WITH PARTS MANS POWER PACK KIT: 3/6 extra.

**THE RELIANT MK.II**
- Solid State
- General Purpose Amplifier
- Input: 10 watts per channel.
- Output: 25 watts per channel.
- Sensitivity: 13 dB at 10 mV.
- Frequency response: 20 KHz.
- Volume control range: 15 dB lift and cut.
- Power supply: 200-250 volts a.c.
- Power consumption: 12.5 watts.
- Size: 12" x 8" x 3".

**THE VISCOUNT**
- Integrated High Fidelity Transistor Stereo Amplifier
- £14.50
- plus 7/6 d. & p.
- Specification:
  - Output: 10 watts per channel.
  - Sensitivity: 13 dB at 10 mV.
  - Frequency response: 20 KHz.
  - Volume control range: 15 dB lift and cut.
  - Power supply: 200-250 volts a.c.
  - Power consumption: 12.5 watts.
  - Size: 12" x 8" x 3".

**SPECIAL OFFER**
- Complete stereo systems comprising BALFOUR 4 speed auto changer with stereo head 2 DUO speaker systems size 12 x 6 x 3.
- Pitchless clones with and the DUETTO stereo amplifier.
- All above items.

£20 plus 20/- p. & p.
BAILEY PRE-AMPLIFIER

High quality pre-amplifier circuit described by C. A. Bailey in the December, 1966, "Wireless World." This is a low distortion circuit of great versatility with a maximum output of 2 volts making it suitable for driving Bailey 50W and 30W Amplifiers. Lindley Hood Class A Amplifier and many others. All normal pre-amplifier facilities and controls are incorporated. A new Printed Circuit Board containing these modifications. Bailey 30W Amplifier is fully transistorised, using edge connector mounting, roller fender finished and silk screened component locations. This board is available in S.B.B. material or Elcyray. Bailey 50W Amplifier Kit for the units containing gain graded BC 108 transistors, polyester capacitors and metal oxide resistors where specified.

BAILEY 30W AMPLIFIER

All parts are now available for the 60-6t single supply all version of this unit. With a lot of parts for a new Printed Circuit Board intended for edge connector mounting. This has the component locations marked and is in roll form for ease of assembly. Size is also smaller at 44l, by 24l. Price in S.B.B. material is 46d for the unit in Fibrelyte. BAILEY 50W AMPLIFIER

All parts in stock for this Amplifier including specially designed Printed Circuit Boards for pre-amp and power amp. Main Transistor for mono or stereo with biphase wound secondary and special 28V primary for use with CZA Thermostat, 35d, post 1.


Reprint of "Wireless World" ziracle, 5d post free.

DINSdale 10W AMPLIFIER

All parts still available for this design. Reprint of parts sheet 1.

LINSLEY HOOD CLASS A AMPLIFIER

Parts now available for this unit including special mait black anodised Metalwork and all power supply components.

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Dual-in-line 16-lead flat package with heat sink strip. Maximum audio output 3.5 V into 7.5 RF load. Circuit consists of a pre-amplifier followed by a main amplifier. Input impedance 50k at 1% with increasing to 6.5% at full output. Frequency response 20 to 30000k. Output voltage 1.26. Rubicon evergrowing cut-out. Price, complete with application card 49/-

SILICON MATCHED DIODE PAIRS

Wide range of silicon diodes in TO5 epoxy case. Separate anode leads and joint cahde. Diodes are statically and dynamically balanced. Max. reverse voltage 20V. Max. dissipation 50mW. Suitable for TV horizontal phase discriminators and similar applications. Price 9/- each. Countable discounts for quantities.

MULTIMETERS TYPE 108-17

6-range precision galvanometer, 3,000 p.p. DC/AC, Volt 2.5-10-20-300-600-2000V, A.C. Value; 10-30-100-250-300-600 V. D.C. current 0.1-1-5-10-25-50mA. Resistance 1000-250000 ohms. Power output calibration for 560 ohms line. 60%-5% sensitivity 1%-2%, Weight 3/4 lb. Dimensions: 11in. x 4in. ± 2in. Weight 12/4lb

TYPE MF16

D.C. Voltage range 0-6-2-12-24-250V, A.C. Voltage range 10-60-300-600V. D.C. current range 0-10-6-2-1-A, A.C. current range 0-10-6-2-1-A. Resistance range 1000-250000 ohms. The meter is also calibrated for input resistance and output current measurements. Sensitivity 1%-2% accuracy ±2.5% for D.C. and ±4% for A.C. measurements. Dimensions: 11in. x 4in. ± 2in. Price £6.5/-

When ordering by post please add 2/6 in £ for handling and postage.

No C.O.D. orders accepted

All mail orders must be sent to head office and not to retail shop.

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Retail branch (personal callers only)
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A.R.B. Approved for inspection and release of electronic valves, tubes, transformers, etc.

We want to buy:
723A/B; 2K25; 4CS5—50%—paid subject to test. Please offer us your special valves and tubes surplus to requirements.

Our new 1970 catalogue is now ready. Please send quartto S.A.E. for your free copy

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COMMUNICATIONS ENGINEER

British Petroleum has a vacancy for a Communications Engineer for Das Island in the Arabian Gulf. This is a bachelor posting only, but with generous home leave allowances. The successful candidate will be required to work on the installation, maintenance and supervision of an offshore oil producing, modern telecommunications, telemetry and control network.

Candidates should possess a minimum of HNC or equivalent and have several years experience in telecommunications/electronics.


Radio Operators
Your chance of a shore job with good pay from the start!

If you hold 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, the Post Office can now offer you a starting salary of £917-£1149 or, after 1st January, 1970, £965-£1215 (depending on your age). Annual rises will take you to £1650 and there are good prospects of promotion to more responsible and better paid posts.

If you are over 21, write for more details to:

ELECTRONIC SYSTEMS SERVICE ENGINEERS

THE JOB
Systems Service Engineering on Advanced Training Aids for Aircraft, Radar Networks, Nuclear Reactors and Submarines.

THE MAN
Electronic Engineer preferably with O.N.C. or H.N.C. having had practical experience of electronic devices with a keen desire to learn new techniques and applications.

THE AWARDS
Salary offered will be up to £1,700. High job interest. Opportunity to work on complex systems incorporating digital and analogue computers, associated peripherals, colour television systems and servo systems, as a member of a team. Opportunity to fly and operate simulated aircraft and other equipment. High quality training will also be given.

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Our terms and conditions of employment are good and include contributory pension scheme, free life assurance, etc. We are not merely offering posts which will afford candidates opportunities of attaining a good job. Selected candidates will be offered long-term careers. Opportunities for travel at home and overseas.

There are vacancies at both Aylesbury and Crawley locations. Applications should be made in the first place to

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REDIFON LIMITED
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RACAL INSTRUMENTS LIMITED
AIRMEC DIVISION
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REQUIRE
TEST ENGINEERS

To work on a wide range of analogue and digital measuring instruments employing the latest techniques.

Entrants may be graded as Test Engineers Grade I, Grade II or Project Leaders according to qualifications and experience.

Salaries up to £1,600 per annum.

These positions offer permanent and progressive employment in a seaside area of great natural beauty. Both private and local authority housing will be available.

Apply:
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Racal Instruments Limited,
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Or telephone Mr. G. Hatt, Chief of Test.
Seaton 1100/1.

SENIOR ELECTRONICS INSPECTOR

Due to expansion a vacancy for inspector has been created. Applicant will preferably have several years of inspection experience and be familiar with defence specifications and B.S. 9,000 procedure. A knowledge of high precision electrical and coaxial connectors would be advantageous, but a sound basic knowledge of electronic equipment may in itself be sufficient.

Attractive conditions of employment and commencing salary would be offered with good prospects of promotion for the right man.

Please apply in writing to:
Technical Manager,
PRECISION CONNECTORS LIMITED,
56-58 GREEN STREET,
FOREST GATE,
LONDON, E.7.
Tel: 01-552 3405

A member of the Delta Metal Group of Companies.
Government of UGANDA
REQUIRES
BROADCASTING ENGINEERS

To serve on contract for one tour of 21-27 months in the first instance. Salary according to experience in scale Uganda Shs 21,120-27,780 (£Sg. 1,232-1,620) a year, plus an Inducement Allowance, normally tax free, of £Sg. 778-886 a year, paid direct into a Uganda bank account nominated by the officer. Gratuity 25% of total emoluments drawn. Liberal paid leave. Accommodation provided at reasonable rental. Outfit and education allowances. Free passages. Contributory pension scheme available in certain circumstances.

Candidates must possess the City and Guilds Final Certificate in Telecommunications (with Radio) or an equivalent qualification and have wide practical experience of technical broadcasting equipment including transmitting and studio control equipment.

The officer will be required to undertake senior operational duties including the maintenance of broadcasting equipment in transmitting stations and studios; outside broadcasts and recordings in remote districts; and to give assistance with the training of junior engineering staff.

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 MzK/690995/WF.

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TECHNICIAN
required for
ELECTRONICS WORKSHOP

Candidates should have a minimum of two years' experience of construction and/or servicing of electronic equipment using transistors and integrated circuits, and some knowledge of digital and pulse techniques. Qualifications to City and Guilds technicians level. Opportunities for day release. Salary according to age, qualifications and experience.

Apply to the Administrative Secretary, Medical Research Council's Laboratory of Molecular Biology, Hills Road, Cambridge.

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NORTH-EAST ESSEX
TECHNICAL COLLEGE
Sheepen Road, Colchester
DEPARTMENT OF ELECTRICAL ENGINEERING

LECTURER GRADE II
is required to teach TELECOMMUNICATION SUBJECTS up to first degree standard. Applicants must have a University degree in Electrical Engineering or Physics with suitable teaching and/or industrial experience. Salary: Lecturer Grade II — £1,827-£2,417 p.a. Assistance with removal expenses may be considered.

Application forms are available from the Principal at the College, to whom they should be returned within fourteen days of the appearance of this advertisement. Please state ref. WW.

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Rank Strand Electric Limited, who are leaders in their field of theatre and television studio equipment, require two

electronics commissioning engineers

around £1,500 p.a.

To test and commission sophisticated lighting control systems into theatres and television studios at home and abroad.

Based with the Research and Development Unit at Brentford, Middlesex, they will initially complete a three-month training course before commencing operations in the field.

Applicants must have sound knowledge and experience of electronics. Ability to communicate effectively with customers important. Knowledge of theatre and television an advantage.

Must be willing to travel extensively and work irregular hours.

Please apply for application form: The Personnel Office, Rank Strand Electric Limited, 29 King Street, Covent Garden, London, W.C.2. 01-4444 ext. 147/148

The Rank Organisation
The man with the gong — a man of many skills
Become a RADIO TECHNICIAN

and work at the nerve centres of civil aviation

The National Air Traffic Control Service of the Board of Trade needs Radio Technicians to install and maintain the very latest electronic aids at Civil Airports, Air Traffic Control Centres, Radar Stations and specialist establishments. Vacancies exist in various parts of the United Kingdom.

This is responsible demanding work (for which you will get familiarisation training) involving communications, computers, radar and data extraction, automatic landing systems, and closed-circuit television. It offers excellent prospects with ample opportunities to study for higher qualifications in this fast-expanding field. If you are 19 or over, with at least one year’s practical experience in telecommunications, fill in the coupon now. Preference will be given to those having ONC or qualifications in Telecommunications.

Salary: £985 (at 19) to £1,295 (at 25 or over); scale maximum £1,500 (higher rates at Heathrow). Some posts attract shift-duty payments. The annual leave allowance is good and there is a non-contributory pension scheme for established staff.

Complete this coupon for full details and application form:

Name: 
Address: 

Not applicable to residents outside the United Kingdom.

NATCS National Air Traffic Control Service

INTERTEL COLOUR TELEVISION
requires ENGINEERS
in their Vision and Video Tape Departments to be based at their Dean Street, London, Studio. Applicants should have a good working knowledge of Colour Television Practice.

Applications to:
CHIEF ENGINEER
INTERTEL COLOUR TELEVISION
WYCOMBE ROAD, WEMBLEY
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computer engineering

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/£1,250 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
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Plan your future with NCR
Government of Zambia

REQUIRES

MAINTENANCE ENGINEER

for the Zambia Broadcasting Services, Ministry of Information, Broadcasting and Tourism, on contract for one tour of 36 months in the first instance. Commencing salary Kwacha 3,408 (£Stg. 1988) rising to Kwacha 3,516 (£Stg. 2051) a year, plus an Inducement allowance of Kwacha 1002-1034 (£Stg. 585-£Stg. 603). A Direct Payment of £291 is also payable direct to the officer's bank in the U.K. Salaries are supplement to CONTROLLERS with effect from 1st January 1970. Gratuity 25% of total salary drawn. Both Gratuity and Direct Payment are normally TAX FREE. Free passages. Accommodation at moderate rental. Education allowances. Liberal leave on full salary or terminal payment in lieu. Contributory pension scheme available in certain circumstances.

Candidates, between 25-55, must have passed City and Guilds final certificate in Telecommunications or equivalent and should have had at least eight years experience with a broadcasting organisation, with particular experience in the installation of recording equipment and studio control equipment.

The officer will be required to maintain and service audio-visual aid equipment and install and operate public address/ recording film projection equipment when and where required. He will be required to supervise workshops and staff in the absence of the Senior Maintenance Engineer.

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 number MzZ/691029/WF.

EXETER AND MID-DEVON HOSPITALS
MANAGEMENT COMMITTEE
GROUP WORKS DEPARTMENT

Technician—Medical Physics
Grade II,

for maintenance of dialysis machines and electronic equipment.
Salary £1,313 x (6) = £1,671.
Qualifications required—H.N.C. or H.N.D. in Electrical Engineering or equivalent.

Applications together with names of three referees to reach the Group Engineer,
26 Queen Street, Exeter, Devon, within 10 days.

COMPUTER STAFF

Vacancies exist in our Computer Services Dept. for EQUIPMENT CONTROLLERS to be responsible for the installation and performance monitoring of three IBM360/50 Computers used for real-time data processing. Applicants should have some knowledge of digital computers and may at present be employed as commissioning engineers or in a similar post. Knowledge of teleprocessing, Data services and computer terminal equipment would be an advantage though it is not essential as full training will be given.
Salary up to £2000 according to experience and ability. Assistance with house purchase is available.

Please apply in writing giving full particulars to:

GEC–Marconi Electronics

Technicians and Engineers for St. Albans and Luton
qualified or not!

Vacancies in all grades

- VACANCIES exist for work on testing and calibrating valve and solid-state electronic measuring equipments embracing all frequencies up to u.h.f. in Production, Service and Calibration departments.
- APPLICATIONS are invited from people of all ages with experience or formal training in electronics and from ex-Armed Services technicians.
- SALARIES up to £1,600 negotiable and backed by valuable fringe benefits.
- RE-LOCATION EXPENSES available in many instances.
- CONDITIONS excellent: free life assurance, pension schemes, canteen, social club.
- 37½-hour, 5-day, office-hours week.
- WRITE or phone Personnel Department stating age, details of previous employment, training, qualifications. Approximate salary required.

Marconi Instruments Limited
Longacres, St. Albans, Herts. Tel: St. Albans 59292
Luton Airport, Luton, Beds. Tel: Luton 31441

A GEC-Marconi Electronics Company
Product
Test
Technicians

Career Opportunities with IBM Manufacturing

We need high calibre men to fill vacancies created by promotion and programme expansion.

The job
Is to commission the latest IBM products and systems in production at the Scottish plant, near Greenock, and requires an intimate knowledge of the equipment under test, which can include computers, punched card and tape peripherals, magnetic disk and tape storage, high and low speed printers, visual display units, multiplexors, Tele-processing and optical character recognition equipment. The products have to be tested thoroughly, and all faults traced and rectified. The work is interesting and absorbing, and the prospects for the right man are good.

Training
Will be a mixture of formal and "on the job" instruction. We will teach you all you need to know about IBM equipment - providing your basic knowledge is to the required level.

Pay and conditions
Starting salaries will be excellent.

Benefits include a non-contributory pension, immediate free life assurance and full sickness pay for up to 26 weeks in any 12 months. The 254,000 square feet plant is modern and situated in a pleasant rural valley. There is a subsidised restaurant.

Working conditions are excellent and there are good recreational facilities in the area. IBM will assist with removal expenses where applicable.

The man
Will be at least 18 and probably less than 30 and have a strong electronic background, with experience in, for example, the testing of electronic products, maintenance of radio, radar or TV or similar work in the armed forces.

He will probably have, or be near to attaining, a qualification such as HNC, ONC, first class PMG, final RTEB, or final City and Guilds (Course Nos. 47, 48, 49, 57, 390). A knowledge of transistor circuitry and the use of oscilloscopes will be a distinct advantage.

If you have what we need, and are keen to join a vigorous, expanding and up-to-the-minute industry, please write, giving details of your age, experience and qualifications, and quoting ref. No. PTa/WW/169 to: Manager, Personnel Selection, IBM United Kingdom Limited, P.O. Box 30, Spango Valley, Greenock.

University of London
Audio-Visual Centre
requires
TELEVISION ENGINEERS
and JUNIOR TELEVISION ENGINEERS

to work on maintenance and operational duties with its studio and mobile equipment, under the supervision of the Chief Engineer, R. H. Bradley, MBE.

Applicants for the post of Television Engineer should have technical experience in broadcast or educational television. A broad knowledge of other audio-visual equipment would be an advantage.

Applicants for the Junior posts should be 18-20 years old, with a basic knowledge of electronic equipment and some experience in its use. Formal technical or educational qualifications would be an advantage.

Salaries:

TV Engineer. Starting at £1600-£2000 according to qualifications and experience. University Pension Scheme. Junior TV Engineer. Starting salary £800-£1000 according to qualifications.

Applications to the Director:
University of London Audio-Visual Centre
11 Bedford Square, London, WC1
EAST AFRICAN COMMUNITY

Meteorological Department

requires

Sectional Engineer Grade II (Telecomms.)


Candidates, up to age 45, must possess O.N.C. or City and Guilds Final Certificate (Telecomms) plus 7 years relevant experience in telecomms, engineering. Equivalent experience in one of the armed services is acceptable. Candidates must have a good theoretical and practical knowledge of FSK, ISB and SSB receivers and transmitters and of Mufax and facsimile transmitters and recorders. A good working knowledge of radar systems is essential.

The officer will be responsible to the Chief Sectional Engineer for the operation and maintenance of the Department’s radio telecommunications, radio-sounding and radar equipment. He will be liable for service anywhere in East Africa but will probably be stationed at Entebbe, Dar es Salaam or Nairobi.

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 number MzK/690413/WF

TECHNICIAN


Apply: B. RHODES & SON LTD., Danes Road, Off Crow Lane, Romford, Essex.

Telephone Romford 62333/4/5.

ELECTRONICS TECHNICIANS

SENIOR TECHNICIAN prototype wireman required for research contract. TECHNICIAN for interesting project and development work in research and teaching laboratories. Day release available.

Incremental salary ranges £868-£1252, £1151-£1486 depending on age, experience and qualifications. 37½ hour week, good working conditions and holidays.

Apply in writing to Mr. E. Thompson, Royal School of Mines, Mining & Mineral Technology Department, Prince Consort Road, London SW7

Electronics Engineer

Professional Audio, Video and Instrumentation Equipment.

3M Company, one of the world’s foremost names in magnetic recording, is expanding distribution of its "Mincom" range of equipment in the audio, video and instrumentation fields in the United Kingdom.

An interesting opportunity is available for a young man aged 23-26 to join us as an Electronics Engineer. He must possess a good electronics background, possibly obtained in the radio communications field. Ideally he should be qualified to C & G or ONC/HNC standard but lesser qualifications may be acceptable in the case of an applicant with exceptional practical experience.

The position will be London based but ultimately the successful applicant will be required to undertake some travelling working on his own initiative on field assignments. This is a progressive position in a fast growing field. The starting salary will be attractive and there are first class employee benefits. Please write in confidence with concise details, age, qualifications and experience to:

Mr. D. J. Stuckey (Ref. MT)
3M Company Ltd.,
3M House,
Wigmore Street,
London W1A IET.
APPOINTMENTS

TECHNICAL AUTHORS

We are one of the World’s leading manufacturers of Flight Simulators which incorporate both analogue and digital computers. We require Technical Authors with a sound knowledge of electronics who preferably have some knowledge of basic digital computer operation. Authors will produce operating and maintenance manuals, and must be able to write literature in a clear and concise style. Formal qualifications are desirable, but not essential. There will be ample opportunity to employ a measure of creative expression. Simulation is based on novel applications of known techniques. This work is certainly not of a monotonous nature.

INSTRUCTORS

are required to lecture to customers and engineers on digital and analogue computing techniques at basic, intermediate and advanced levels. Students are required to maintain and programme highly sophisticated flight simulators. Applicants should preferably be qualified to at least H.N.C. level or equivalent. Preference will be given to those with practical analogue or digital computing experience, but applications from men with several years’ industrial experience and/or who have a flair for and a genuine interest in lecturing will certainly be welcome. Training in the Company’s advanced computing techniques will be given.

This Company offers good working conditions, welfare benefits. There is a contributory pension scheme coupled with free life assurance.

Apply to: H. C. Hall, Personnel Manager,
REDIFON LIMITED
Flight Simulator Division,
Gatwick Road, Crawley, Sussex
Telephone: Crawley 28811

ST. JOHN’S COLLEGE OF EDUCATION - YORK

Dept. of Closed Circuit Television

Applications are invited for the post of SENIOR TECHNICIAN, to join a team making television programmes for this and five associated colleges.

Duties will include the maintenance of cameras and videotape recording equipment. Opportunities for operational and production work will occur. A mobile recording van is in regular use and ability to drive would be an advantage.

Salary: Local Government Scales: Technical Grade 6 (at present £1,540-£1,775): the post is superannuated and good holidays are given.

Applications (no special form), should be made in writing to the Principal, stating qualifications, experience and the names of two referees. Closing date 31st December, 1969.

SOUTH AFRICA

FULLY QUALIFIED RADIO & TELEVISION TECHNICIAN

Applicants should be capable of supervising a workshop from which the installation and repairs to all types of radios and television are undertaken.

Applications with full details of experience etc., should be sent in the first instance to Mr. E. B. UNWIN.

NEL & UNWIN (PTY) LTD.
P.O. BOX 199, KROONSTAD
SOUTH AFRICA
CONTINUOUS EXPANSION

Standard Telephones & Cables, Microwave and Line Division based at Basildon are growing fast. In order to keep pace with this consistent growth rate we require the following:

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.

TECHNICIAN
required in APPLIED ACOUSTICS RESEARCH LABORATORIES situated near Fulham Broadway, S.W.6. Valued work, but a knowledge of electronic construction and design an advantage. Day release facilities for further study.

Salary: £80/£102 p.a., depending upon age, experience and qualifications.

Application forms and further information from the Superintendent of Laboratories (T.A.), Department of Physics and Electronics, Chelsea College, Manor Road, London, S.W.3.

EAST SUFFOLK COUNTY COUNCIL
Lowestoft College of Further Education
Principal A. E. Boddy, B.Sc. (Econ.), F.R.G.S.

LECTURER GRADE 1
required for City and Guilds Radio and Television Servicing Mechanics' and Technicians' Courses, including colour television.

Applicants should have appropriate technical qualifications, together with suitable Industrial and Teaching experience. Ability to offer teaching in similar courses would be an advantage.

The appointment is vacant as from the 1st April, 1970, but an earlier commencing date may be negotiated.

Salary in accordance with the Burnham Scale for Lecturers Grade 1, £1,110 to £1,955, plus increments for approved qualifications and experience. Starting point within the scale determined by previous Industrial and Teaching experience.

Applications should be sent as soon as possible to
The Principal of the College, an application forms available from the Secretary, Lowestoft College of Further Education, St. Peter's Street, Lowestoft, Suffolk.

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.

SENIOR LABORATORY TECHNICIAN

A SENIOR ASSISTANT with a good understanding of electronics is needed to join a small team providing physics support to the Isotope Production Unit at Harwell. The team is mainly concerned with making accurate measurements of a wide variety of radiation sources and with the development and maintenance of the necessary measurement system. The post is tenable at Harwell.

QUALIFICATIONS & EXPERIENCE:—
The minimum age for appointment is 27 and the minimum qualifications necessary are four 'O' levels including English Language and Mathematics or a Science subject. Electronics experience is essential and experience in the measurement of radiation sources would be advantageous.

SALARY: £1,350 rising to £1,755
APPLY TO: The Personnel Officer

THE RADIOCHEMICAL CENTRE
Amersham
Bucks

www.americanradiohistory.com
SKILLED IN ELECTRONIC ENGINEERING?

Help keep aircraft on the straight and narrow

Air traffic has become so congested that complex electronic techniques are used as an aid in controlling aircraft both on airways and on airport approaches. As a Telecommunications Technical Officer III in the National Air Traffic Control Service of the Board of Trade, your job would be to install and maintain various radio navigational and landing aids at civil airports, and communications and computer systems at radar stations and signals centres.

Because you handle such advanced equipment, you will receive thorough training. Study for higher qualifications is encouraged, and this could range from short courses with financial assistance to full-time study at a university or technical college.

Pay: (London rates — a little less elsewhere) £1,350 starting salary at 23, £1,625 at age 28 or over on entry, rising to £1,810. Within three years you could be upgraded, and on a scale rising to £2,050. A few years after that, you could be on the salary bracket going up to £2,375, and there are several higher grades still.

Qualifications: O.N.C. in Engineering, including a pass in Electrical Engineering; or equivalent standard of technical education.

Send for full details and an application form (which must be returned completed by January 2nd, 1970) to: Civil Service Commission, 23 Savile Row, London, W1X 2AA. Please quote S/207/.

HENRY'S RADIO LTD.
303 EDGWARE ROAD, LONDON, W.2
HAVE THE FOLLOWING VACANCIES IN THEIR ORGANISATION

SALES ASSISTANTS
Young men with good general knowledge of electronic components required for our retail sales dept. Please telephone 723-7105/Ext. 1.

SALES ASSISTANTS
Young man with a good general knowledge of HIGH FIDELITY EQUIPMENT required for our Hi-Fi SALES DEPT. Please contact M.R. STEVENS, Telephone 723-6493. Ext. 2165.

An immediate vacancy occurs at THE WIRELESS COLLEGE, COLWYN BAY, NORTH WALES for an additional instructor to assist in preparing students for the G.C.E. 'O' and "A" level examination. The primary responsibility will be to conduct the practical instruction in modern wireless radio engineering. Applications must have a H.N.C. Certificate and should have a sound technical knowledge. Recent or current experience in a similar capacity is desirable but not essential. In view of the rapid increase in the number of students, a rise in the first instance to the Principal, is envisaged.

SPECIAL OPPORTUNITY
Small company in medical electronics development (Richmond, Surrey) offers starting salary £1,300 to keen man suitable early directorship. Founder approaching retirement, must be self-contained flat available. Phone 01-940 0865 evenings.

SITUATIONS VACANT

If you are interested in P.Y. or E.T. technical work, you will receive experience in the Retail Radio Trade, an excellent opportunity awaits you. Apply, 247 Queen's Row, London, W.1. Tel. 397-1617.


CHIEF ELECTRONIC TECHNICIAN required to supervise Electronic Workshops and maintenance electronic equipment for use in the teaching and research laboratories of the Departments of Electronics and Physics. Salary £1,510—£1,703 p.a. according to age and experience. Further information and application form from the Laboratory Superintendent, Laboratories Department of Physics and Electronics, Chelsea Arts Centre, Manresa Road, London, S.W.3.

COLOUR TELEVISION: Multi-National Advertising Agency requires a Technical Assistant in Tokyo to operate and maintain colour television film camera equipment. Candidates should have experience of the ages 22 and 30 and should have "C" and "Q" Television or equivalent, and preferably experience on this type of equipment. Salary is negotiable. Write to Mr. R. Martin, J. Walker Thompson Co Ltd., 46 Berkeley Square, W1 6AD.

ELECTRONIC TECHNICIAN required to assist in the development, construction and installation of electronic instruments used in biochemistry research. Candidates should possess O.N.C. or equivalent and be able to construct and test equipment from wiring diagrams. Salary according to age and experience in the range of £1,025 to £1,295 per annum. Supplementary payments for certain qualifications. Good conditions of service. Applications in writing to: Mr. R. Martin, J. Walker-Thompson Co Ltd., 46 Berkeley Square, W1 6AD. Telephone 962-2422.

ELECTRONIC TEST ENGINEERS required for work on a new range of Digital Measuring Equipment using Billing, Transistors and Microprocessors. Fully qualified applicants preferred, although proven experience in electronics would be considered. Preference will be given to those offering the services. Please apply to: The Personnel Manager, Venner Limited, Kingston By-Pass, New Malden, Surrey. Telephone: 01-942 2462.

J.P.C. research and development. ELECTRONIC ENGINEERS AND TECHNICIANS. Advanced optical/electronic and microprocessor technology are now being used to develop new and improved systems for publication are being developed in the Information Science and Technology. Chief's Laboratory there are several immediate opportunities for: QUALIFIED ELECTRONIC ENGINEERS to join a team working on the design and development of systems using computer, CRT, TV, and optical techniques. Expert knowledge in at least one of these is essential. Salaries within the Development Offer scale ranging from £1,900 to £3,500. LABORATORY TECHNICIANS for layout, construction and testing of prototype electronic apparatus. Salary scale up to £1,675. Write for applications form to the Director of R & D, J.P.C. Laboratories, Wood Lane, Hemel Hempstead, Herts.

Turnover doubled since 1962—now growing faster in the
decimalization rush. Burroughs dominate the U.K. market in
the new terminal computers and accounting machines. A
wide variety of machines, an expanding market and a policy
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the computer field or into the supervisory grades and
beyond. Join the Burroughs boom—and grow with us.

If you are between 20 and 30, with an electronics qualifica-
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a job for you with us. With Burroughs, you can find the free-
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skills—the largest third-generation systems in the World
—these are the exciting prospects at Burroughs. In return,
we're offering you 3 weeks' paid holiday, free life assurance
and a contributory pension scheme.

Take a big step now into one of today's development indus-
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Burroughs Machines Limited (2),
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ADDRESS:...........................................

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**UNIVERSITY OF ESSEX**
**DEPARTMENT OF PHYSICS**
**SENIOR TECHNICIAN**

required for maintenance of electronic
equipment, supervision of equipment
in a teaching laboratory and assistance
to research groups. Candidates should
preferably have H.N.C. or equivalent
qualification in electronics and ex-
perience with modern electronic cir-

cuitry and equipment. Salary range
£1,056-£1,311 with additional allow-
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Applications to the Registrar,
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Colchester, Essex.

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We are planning a considerable expansion of our activities and have
the following vacancies:

I. **A SENIOR ENGINEER**

to have control of all aspects of systems design, planning, estimating,
installation and commissioning.

II. **ENGINEERS**
capable of undertaking either:
(a) System planning and estimating.
(b) control of installation work.
or (c) test and commissioning duties.

Candidates for these appointments must have a good background of
practical experience in this field of work, and an up-to-date knowledge
of techniques and equipment.

Applications, which will be treated in strict confidence, should be
sent to:

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The General Manager,
Special Services Division,
British Relay House,
41, Streatham High Road, S.W.16
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Television Service Management

Applications are invited for vacancies in the North East Region from mature T.V. Service Managers who are experienced in the operation of a large scale rental service organisation.

Applicants must be technically competent and have a strong flair for the solution of organisational, administrative and personnel problems.

An attractive salary will be offered and a car provided.

Applications please to:
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FACULTY OF APPLIED SCIENCE

Applications invited for the following post, duties to commence as soon as possible—

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(Grade T.3)—Ref. No. T698/46/2

to take charge of Nuclear Physics/Radiochemistry Laboratory.

Applicants should be over 28 and have qualifications to at least O.N.C. or C. & G. Ordinary Technician standard and previous laboratory experience. 38-hour, 5-day week with generous holiday and sick pay schemes. Opportunities for evening work with additional pay. Permanent posts with superannuation under Local Government conditions of service.

Salary Scale: £390—£1,095. Starting salary dependent upon age, qualifications and experience. An additional £50 or £30 per annum will be paid for appropriate National Certificate and C. & G. qualifications.

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APPOINTMENTS

Radio School in Panama

Radio Technician

Required to operate radio school in Santiago de Veraguas. The school provides an elementary adult education programme and is now unable to function for lack of a technician to take charge. Challenging opportunity to fill a vital need in the development of rural areas. Volunteer terms: board, clothing, personnel, fares, allowances. Write CHER/OV 36 King Street, London, W.C.2.

Edison Ltd. require a fully experienced Telecomunications Test Engineers and Electronics Inspectors.

Good remuneration for experienced technologists. Salaries £1,350-£1,735 p.a. Write giving full details to—The Personnel Manager, Edison Ltd., Bromhill Road, Wandsworth, S.W.18.

Senior Electronics Technicians are required by the Department of Applied Psychology to support the development of Instrumentation for research work. Opportunities are available for enterprising technicians to gain experience in any of the following fields: Electro-physiological recording, magnetic tape systems, analogues and digital computing, digital electronics and building special peripherals to the departmental on-line PDP 9 computer. Experience and interest in building or maintaining equipment will be an advantage. Salary on the scale £1,026 to £1,280 per annum, with supplementary pension of £60 per annum if approved qualifications held. Five day week. Pension scheme. Applications from the Staff Officer, The University of Aston in Birmingham, Gosta Green, Birmingham, B59 2TT quoting reference L/116 W.

University of Sheffield—Chief Technician

required in Department of Chemistry to take charge of Electronics Workshop, concerned with development and construction of new electronic equipment for research and teaching, and maintenance and repair of wide range of electronic equipment. Experience necessary, qualifications preferable. Salary £1,150-£1,576 p.a. Write, stating qualifications and experience, to the Bursar (Ref: B.639), The University, Sheffield S7 1TF.

University of Aston—Chief Technician

Applications are invited for the post of Chief Technician in the Department of Applied Psychology. Further particulars to the Senior Administrative Officer, Department of Applied Psychology, Aston University, Birmingham B59 2TT quoting reference L/116 W.

We have vacancies for four experienced Test Engineers in our Production Test Department. Applicants are preferred who have experience of Pye Pinpoint and Testing of Mobile VHF and UHF Mobile Radios. Excellent opportunities for promotion due to Expansion Programme. Please apply to Personnel Manager, Pye Telecommunications Ltd., Cambridge Works, Hag Road, Cambridgeshire. Tel. Cambridge 31211. Ext. 327.

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A 88 mains transformers, £2.10.0; 12/24V carbon pile voltage regulator units, 36: 40 amp, 4-watt terminal blocks, 1/2; Rotax electronic relay, silicon, 50V, 1A dc. outbut 15/8, 3 phase, 400 Hz, 1,4 amps—£1.15.0; 100 amp. terminals, insulated leads, 8/6, 12/6 rubber and packing extra. Also, f10 voltage regulators and rectifiers in stock. Western Electronic Man Co., 2683 Garth Road, St. Paul's Lane, Sheffield S7 1TF.

Brand New L.E.D. L14/16 volt, 0-5, 1, 5, 10, 15, 25, 30, 40, 50, 100, 150, 200, 250, 300, 350, 450 megohm Resistors, 1 watt 5% B.E. Series 10 ohms to 1 meg ohm, 1/4 watt, 50%, 0.1%, 5% B.E. Series 106, 10 meg ohm. The C. R. Supply Co., 12 Chesterfield Rd., Sheffield 9. 2764.

Build it in a DEWBOW quality plastic cabinet, 2 in. x 2 in. x any length. D.W.K. Ltd., (W), Ringwood Rd. FERNSHILL, Dorset. S.A.E. for details. Write now—Right now.

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Purchased January 1968 and built by Ampex. The unit includes 3 Vidicon Cameras and full sound and communication facilities. There is also a built-in scan V.T.R. unit and an audio tape recorder on board, both built by Ampex. Offers should be made to Television Facilities, Queens Hall, Leeds 1. Finance available.

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Ferranti, AF3, AF6, BI, OP, OPM1(3), OP6S, OP4S, OPM1, OPM5, OPM6, OPM7, X, £5 a.m.o. CARRINGHAM PAID. —Norwich, Hay Hill, Hay Road, Norwich. 2767.

For Sale by Tender

170,000 Valves

The Commissioners of Customs and Excise are offering for sale by competitive tender approx. 170,000 valves in lots of approx. 1,000.

For further particulars, apply to:

The Officer, Customs and Excise, Queen's Warehouse, Custom House, Lower Thames St., London, E.C.3, before January 2nd, 1970.

ELECTRONIC TECHNICIANS

Ampex Quality Control Department now has vacancies for technicians to be responsible for fault finding and testing a wide range of Professional Audio and C.C.T.V. Magnetic Recording Equipment.

Experience gained in the electronic industry, radio or television servicing would be an advantage or a qualification of O.N.C. standard.

Excellent salaries, three weeks annual holiday, canteen, life assurance, pension and sickness benefit schemes in operation.

Please write or telephone the Personnel Officer, Ampex Electronics Limited, Acre Road, Reading, Berkshire.

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Wish experience of valve and transistor audio equipments, wanted to join our senior staff. 40 hour week. Salary £1,200 per annum.

ASSOCIATED ELECTRONIC ENGINEERS LTD., Dalston Gardens, Stanmore, Middlesex.

Tel.: 01-204 2125

Bath University of Technology

A TECHNICIAN

is required in the School of Mathematics to assist mainly in servicing and developing ANALOGUE AND DIGITAL COMPUTING devices.

Candidates should have experience in electronics, should possess a basic qualification and be competent in elementary workshop skills.

Salary in the range of £773—£1,077 per annum, according to age, experience and qualifications.

Further details and application form from Registrar (S), The University, Bath, BA2 7AY, quoting ref. 69/83.

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Working Foreman

for small shop producing transformers, 20vA-10KvA. Must be fully experienced, all stages of production. Commencing salary about £1,200.

Also Young Assistant with testing experience

S.S. Electronics Limited, Severalls Avenue, Chesham, Bucks.

Phone: Chesham 4774

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Specialist training courses lasting approximately nine months, according to the trainee’s progress, are held at intervals. Applications are now invited for the course starting in September 1970.

During training a salary will be paid on the following scale:

<table>
<thead>
<tr>
<th>Age</th>
<th>Salary per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>£800</td>
</tr>
<tr>
<td>22</td>
<td>£855</td>
</tr>
<tr>
<td>23</td>
<td>£880</td>
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<tr>
<td>24</td>
<td>£925</td>
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<tr>
<td>25</td>
<td>£965</td>
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Free accommodation will be provided at the Training School.

After successful completion of the course, operators will be paid on the Grade 1 scale:

<table>
<thead>
<tr>
<th>Age</th>
<th>Salary per annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>£965</td>
</tr>
<tr>
<td>22</td>
<td>£1025</td>
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<tr>
<td>23</td>
<td>£1086</td>
</tr>
<tr>
<td>24</td>
<td>£1145</td>
</tr>
<tr>
<td>25 (highest age point)</td>
<td>£1215</td>
</tr>
</tbody>
</table>

then by six annual increases to a maximum of £1,650 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must normally be under 30 years of age at start of training course and must have at least two years operating experience. Preference given to those who also have GCE or PMG qualifications.

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Recruitment Officer, Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Gloucs., GL52 5AJ.

Telephone No. Cheltenham 21491 Ext. 2270.

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This private College provides efficient theoretical and practical training in the above subjects. One-year day courses are available for beginners and shortened courses for men who have had previous training.

Write for details to: The Secretary, London Electronics College, 20 Penywern Road, Earl's Court, London, S.W.5. Tel.: 01-378 8721.

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Tel.: 01-204 2125

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AYR

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Qualifications: a degree, H.N.C., N.H.C., Grad. I.E.E.E. or equivalent in electronics engineering, applied science or applied physics.

Salary: A.E.O. up to £1,208 in a scale to £1,454; E.O. in a scale from £1,190 to £2,006.

Further particulars may be obtained from the Secretary of the Institute, to whom applications, with the names of two referees, should be submitted by 17th January, 1970.

WE OFFER A YOUNG ENGINEER

the opportunity of working in an up-to-date tape recorder 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 free local transport.

If you are interested, please write giving brief details about your qualifications and experience to:

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Draughts,
Aldermaston Court. Aldermaston, In-
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Grants available.
(Dept.
for details of modern
Guide-
City & Guilds,
in
W.W.
Loughborough.
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for small
S.E.13.
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quotation
Wireless
Phone Hoddesdon
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VALVE
SCRAP R.F.
BECOME
LEAK
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lion will bring
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College of
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estimating.

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Wireless
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monitors,
E.11.

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televisions, tape recorders, radio-
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West Bromwich, Staffs. Tel. Wens. 1016. (7)
Wireless World.

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VALVE cartons by return at keen prices; send 1/-
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Parts acceptable.—S.B., 167 South Avenue, Southend-
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don, E.11, Lep. 4666. (63)
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or earlier model). Details please to Mr. C.
Moffat, C.E., PHILPOTT'S METALWORKS, Hoddesdon, Herts.
Phons Hodgeston 4692. (2772)
WANTED, televisions, tape recorders, radio-
new valves, transformers, etc.—Brian Willetta, 31
St.
West Bromwich, Staffs. Tel. Wens. 1016. (7)
Wireless World.

CAPACITY AVAILABLE
ARTRONICS, Ltd., for cell winding, assembly and
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istor/con-
- uilt sheet metal work.—J. Waldercut, Rd., Lon-
don, S.E.11, Tel. 61-412 1704. (3)

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METALWORK, all types cabinets, chassis, radio,
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KINGSWINFORD, Education Committee,
College of Technology. Principal: R. Jones, M.Sc.
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FILL-TIME courses for P.M.I. certificates and the
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W. Moffat Road, Thornton Heath.
Survey, C.H. 339. (26)
REQUIRED 1937 Jones Radio Handbook. Lither-
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Knowledge of French for use in measurement apparatus.
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Housing facilities.
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GIANT PANELS 51/2 x 4 min. 30 transistors 9 x 60. Inductor, resistors, capacitors etc. 3 for 41/ - p. & p. + 5/ p. & p.

As above only 21 transistors, 70 diodes. min. 1105W resistors, 3 for 25/ - p. & p. 21/2.

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Mullard Type TAY233 A.F. Amplifier 8/8
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Mullard Type TAY310 Record/Playback Pre-Amplifier 5/8
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These prices are based on the above spec. for each type of transistor. The specification may be altered at the discretion of the manufacturer.

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Although Bantex is best known for glass-fibre aerials with a unique process for high strength, designs for metallic aerials have also been developed.

The photograph shows two boats of the Ford team in the 1969 Round Britain Power Boat Race. Both used Bantex aerials.

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Telephone 727 3432/3
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The photograph shows two boats of the Ford team in the 1969 Round Britain Power Boat Race. Both used Bantex aerials.

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<td>Triple 3-input gate</td>
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<td>ST 946</td>
<td>Quad 2-input gate</td>
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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
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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
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