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Tel: Portsmouth (0705) 62332 or 62180 Telex: 86114

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>SL402A</th>
<th>SL403A</th>
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<tbody>
<tr>
<td>Output power r.m.s.</td>
<td>2W</td>
<td>3W</td>
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<tr>
<td>Input impedance</td>
<td></td>
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<tr>
<td>Preamplifier</td>
<td>20 M Ω</td>
<td>20 M Ω</td>
</tr>
<tr>
<td>Main amplifier</td>
<td>100 M Ω</td>
<td>100 M Ω</td>
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<tr>
<td>Distortion</td>
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<tr>
<td>Preamplifier</td>
<td>0.1%</td>
<td>0.1%</td>
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<tr>
<td>Main amplifier</td>
<td>0.3%</td>
<td>0.3%</td>
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<tr>
<td>Frequency response</td>
<td></td>
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<tr>
<td>Lower—3dB point</td>
<td>20 Hz</td>
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<tr>
<td>Upper—3dB point</td>
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<td>30 kHz</td>
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<tr>
<td>Operating voltage</td>
<td></td>
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</tr>
<tr>
<td>Min. operating load</td>
<td>+14 V</td>
<td>+18 V</td>
</tr>
<tr>
<td></td>
<td>7.5 Ω</td>
<td>7.5 Ω</td>
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</table>

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3. High-power travelling-wave tubes
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<th>Product Type</th>
<th>Details</th>
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<tr>
<td>1. Magnetrons</td>
<td>X-band □ L-band □ S-band □ C-band □ mm. band</td>
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<tr>
<td>2. High power klystrons</td>
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<td>4. Hydrogen thyratrons</td>
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<td>5. Pulse tetrodes</td>
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<td>6. Low-power travelling-wave tubes</td>
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<td>7. Low power klystrons:</td>
<td>Receivers □ Transmitters □ Backward-wave oscillators</td>
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<tr>
<td>8. Duplexer devices</td>
<td>X-band □ L-band □ S-band □ C-band</td>
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<td>9. Voltage stabilisers</td>
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<tr>
<td>10. Storage tubes</td>
<td></td>
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</tbody>
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BROOKDEAL AMPLIFIERS: a limited guide to their unlimited uses.

Signal source | 450 | 451 | 431 | 432
--- | --- | --- | --- | ---
ac bridge (Hi-Z) | ✓ | ✓ | ✓ | ✓
ac bridge (Lo-Z) | ✓ | ✓ | ✓ | ✓
accelerometer (piezoelectric) | ✓ | ✓ | ✓ | ✓
accelerometer (moving coil) | ✓ | ✓ | ✓ | ✓
biological sensors | ✓ | ✓ | ✓ | ✓
CdS photocell | ✓ | ✓ | ✓ | ✓
condenser microphone | ✓ | ✓ | ✓ | ✓
Cu doped Ge photodetector | ✓ | ✓ | ✓ | ✓
electron multiplier | ✓ | ✓ | ✓ | ✓
Faraday cup | ✓ | ✓ | ✓ | ✓
Golay cell | ✓ | ✓ | ✓ | ✓
Hall-effect sample | ✓ | ✓ | ✓ | ✓
hydrophone | ✓ | ✓ | ✓ | ✓
hot carrier diode | ✓ | ✓ | ✓ | ✓
In Sb photocell (room temp) | ✓ | ✓ | ✓ | ✓
In Sb p-n photocell (cooled) | ✓ | ✓ | ✓ | ✓
inductive ratio divider | ✓ | ✓ | ✓ | ✓
ion detector | ✓ | ✓ | ✓ | ✓
magnetometer coils | ✓ | ✓ | ✓ | ✓
microwave point-contact diode | ✓ | ✓ | ✓ | ✓
moving coil microphone | ✓ | ✓ | ✓ | ✓
PbS photocell | ✓ | ✓ | ✓ | ✓
photodiode | ✓ | ✓ | ✓ | ✓
photomultiplier | ✓ | ✓ | ✓ | ✓
photovoltaic cell | ✓ | ✓ | ✓ | ✓
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plasma probes | ✓ | ✓ | ✓ | ✓
Pt wire detector | ✓ | ✓ | ✓ | ✓
resistance thermometer | ✓ | ✓ | ✓ | ✓
scintillation detector | ✓ | ✓ | ✓ | ✓
thermistor | ✓ | ✓ | ✓ | ✓
thermocouple | ✓ | ✓ | ✓ | ✓
thermopile | ✓ | ✓ | ✓ | ✓
vibrating capacitor | ✓ | ✓ | ✓ | ✓

This list includes present and envisaged applications of these amplifiers. For more information and specific applications assistance contact Geoffrey Gamble at 0344 23931/5.

If the signal source you are working with isn't listed above, this doesn't mean to say that we can't supply the amplifier you need. It's just that space is limited here. However, in the range 1Hz to 1MHz, we can noise-match most signal sources. Send for full information.
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Some notes on Bridge Measurement by WAYNE KERR

Number 9
Four-Terminal Applications

In this issue we are illustrating the principal applications of four-terminal technique made available by the Transformer Ratio Arm Bridge.

The diagrams show six different measurement arrangements using four connection points to the bridge. The two upper terminals marked 'N' in the first diagram are the neutral connections, the two lower terminals representing connections to the bridge voltage and current transformers.

These diagrams are necessarily in summary form and, if further explanation is required, reference should be made to the first two issues of these notes.

Mutual Inductance, M, can be derived from bridge C reading:
\[ M = R^2 \times C. \]

Small capacitors (and all other types of component) can be measured at the end of long test leads. The effect of the neutral connections is to prevent the cable capacitances appearing in shunt with the component under test.

4-terminal connections minimise lead and contact resistance errors. Bridge measures A, ignoring B & C.

2-terminal connection for normal component measurements.

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- Slide-in cartridge carrier
- Calibrated pick-up arm bias compensation
- Calibrated fine stylus-force adjustment
- Automatic play of single records
- Styling of elegance and distinction

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And this is what independent opinion said about the SL95, the immediate predecessor of the SL95B:
"I have tested it for wow, flutter and rumble and found them too low to be measured with any confidence. In every way have tried to impede its working, I have failed. I greatly admire the cueing device and I would not dream of setting my own manual clumsiness against the delicacy with which the automatic mechanism puts down the stylus in the groove. This is near perfection." Ferry Wilson
Audio Record Review, August '68.


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Sixtieth year of publication

April 1970

Stabilized power supply unit
Digital remote control

This month's cover illustration shows an unusual view of a watchmaker's wheel adopted by Pye to aid the handling of components in the production of small receivers (see p.158).

IN OUR NEXT ISSUE
Simple high-quality pre-amplifier, having a high input impedance, suitable for radio and ceramic gramophone pickups.
Low-cost horn loudspeaker system

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Why we are excited about the C333 range

In these fast-moving days you might wonder why we're excited about a new capacitor range. Well, sales figures tell us that a lot of circuit designers are also enthusiastic about this—the latest Mullard range of miniature plate ceramic capacitors. Setmakers have already ordered them by the million. And, as for us, we were excited about this new range long before we even sold the first one. In case you are not already using these plate ceramic miniature capacitors, let us tell you (enthusiastically) something about them.

They're small. Well, of course. This is the mini age. Naturally, we designed them to fit a 2.45 mm. grid printed circuit board. But we also made them rectangular and thin (2.1 mm. max.). In fact they are no bigger than the winder on your wristwatch, so that they can pack very closely.

Wide range. This is something to be enthusiastic about. For the first time, circuit designers have available a wide range of low-cost, high stability, close tolerance miniatures to choose from—at low prices. The full range (at present) has 28 values in five sizes from 1.8pF to 330pF (the E6 range). With temperature coefficients between NP0 and N750 the stability of tuned circuits can be maintained over a wide temperature range—this is the C333 series.

High quality: low cost. These two conflicting objectives provided their own solution. In the first place we chose the most suitable materials for the performance and stability we required. Then we developed special, highly-automated processes to produce these tiny components within the rigid specifications we had laid down. These very efficient processes gave us the desired results; closely-controlled quality and low production costs.

Stability. This is essential for the applications for which these capacitors are intended. We developed materials which would not oxidise or peel in arduous conditions. And a special lacquer coating to protect them in conditions of high humidity. In brief, we designed in high stability and long life.

Tight tolerance. Again, the use of very stable materials and highly automated manufacturing and quality control equipment ensures that every capacitor is held within very close limits—essential for the components used in oscillator and filter stages. The tolerance on every capacitor is within 0.25pF or ±2%—whichever is greater.

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Mullard Limited, Consumer Electronics Division, Mullard House, Torrington Place, London, WC1
Technology versus Education

Technology is a means towards a better material standard of living. Education is a means towards a better quality of life. The two activities have quite different purposes. Yet they do overlap slightly at the edges, particularly in the field of vocational training. Technology needs and draws upon the resources of educated people: education depends to some extent on technology to provide subjects and stimuli for stretching the human mind.

Perhaps because of this overlap we seem to be getting into a muddle, with passions raised on all sides, about the function of some of our newer universities. The rumpus at Warwick University a few weeks ago, when students uncovered documents revealing an intimate liaison between university authorities and big business, is a case in point. The basis of the trouble seems to be that some students feel the universities are being exploited as outside R & D establishments by “the industrial-military complex”. They say that the university authorities have abandoned their independence in return for “industrial-military” gold (or even silver). The rejection of technology (more so than science) by boys at school may stem from some knowledge of this situation, coupled with an association of technology with destruction, and a consequent reluctance to be treated by “them” as “technology fodder”.

In electronics, of course, we know that there has long been a close collaboration between industrial firms and certain university departments. At Warwick itself, for example, the School of Engineering Science does research in microwave integrated circuits partly supported by G.E.C.-A.E.I. and Racal (and employees of these firms work in the School). The Wayne Kerr Company has endowed a chair of measurement science at Surrey University. For some years the computer department of Ferranti was almost indistinguishable (in staff and activities) from a section of Manchester University’s department of electrical engineering. Mullard Southampton run an M.Sc. “bridging” course in partnership with Southampton University. Brookdeal Electronics sponsor work in the physics department of Reading University and the company’s research director is a senior lecturer at the university. . . . And so on. This is all quite openly done—in fact great pride is taken in it—and whether or not it is considered sinister depends on which side of the artificial Arts-Sciences barrier one has been forced to stand. (A barrier, incidentally, which the Open University has knocked down.)

There is perhaps one small thing we can do about the emotional muddle. We may not be able to get rid of hypocrisy, snobbery and prejudices about education but we can decide to be honest about the verbal descriptions applied to things. If some of the newer establishments are not real universities (note, we are not making assertions about this) then nobody is going to be hoodwinked by the mere fact that they have been called universities. If they are really institutes of higher technology with a few Arts courses tacked on to keep the critics quiet, let them be honest in the way they describe themselves. (The Massachusetts Institute of Technology and, more recently, the Cranfield Institute of Technology are, presumably, proud of their titles.)

Ultimately, education, including all universities, must get its money from industry. But, for the good of the spiritual side of us, it is questionable whether this money should be transferred so directly that the philistines—and there are plenty—can insist “he who pays the piper can call the tune”. Lord Radcliffe, the chancellor of Warwick University, has said as much himself.
Stabilized Power Supply

A versatile unit which will provide a variable stabilized output voltage with adjustable current limiting or a variable constant current with adjustable voltage limiting

by A. J. Ewins

The stabilized power supply to be described provides not only a fully variable, stable voltage output from 0 to 30 V at a continuous current rating of 1 A, but also a fully variable range of constant currents from 1 mA to 1 A at a maximum voltage of 45 V. In the voltage stabilized mode the constant current network provides current limiting over the range of currents. In the constant current mode the stabilized voltage network provides voltage limiting from 0 to 30 V.

The power supply departs from convention in that the entire electronic circuitry, except the series regulator transistor, is powered by a separate voltage supply. As a result of this, no transistor, except the series regulator, need have a maximum \( V_e \) rating greater than 20 V or a maximum power dissipation greater than 180 mW. This enables the constructor to select the transistors needed for the electronic stabilizing circuitry from the ever growing range of cheap, plastic encapsulated, silicon planar devices.

Although the maximum stabilized voltage provided by the power supply is only 30 V, it can easily be modified to provide an output voltage greater than this; the maximum value being dependant mainly on the \( V_e \) rating of the series regulator transistor used. (The 2N3055 has a \( V_e \) of 100 V max.) However, it is likely that the maximum current drawn from the supply would have to be reduced since a power dissipation of 100 watts (within the capabilities of the 2N3055) would call for an excessively large heat sink.

Circuit Description

Before proceeding to a description of the circuit it will prove useful to show how the power supply departs from convention. Fig. 1 shows a fairly conventional stabilized power supply circuit. The output voltage, \( V_o \) is given by: \( V_o = (R_v/R_k) \cdot V_r \) and is directly proportional to \( R_v \). To \( V_r \) and \( R_k \) are kept constant. Keeping \( R_k \) constant has the advantage that the sensing current, \( I_s \), drawn by the potential divider, \( R_v \) and \( R_k \), remains constant for all output voltages. Thus the current through the zener reference diode remains constant also, helping greatly towards the stability of the reference voltage. Looking now at Fig. 2 it will be seen that the circuit is similar to that of Fig. 1 in principle, however, the difference amplifier and the first two transistors of the series regulator triplet, \( Tr_2 \) and \( Tr_3 \), are now powered by a separate voltage supply. The reference voltage is now a positive one since, due to the rearrangement of the circuit, a negative output voltage (with respect to the zero voltage line) is being regulated.

With this rearrangement of the circuit \( Tr_2 \) and \( Tr_3 \) do not have to withstand the full unregulated power supply voltage when supplying an output voltage of zero volts, with a consequent reduction in the maximum power dissipation required of \( Tr_2 \). If the series regulator, \( Tr_1 \), has a current gain of 30 at a collector current of 1 A, then \( Tr_2 \) must be capable of supplying 33 mA for a maximum output current of 1 A. In Fig. 1, \( Tr_2 \) would have had to have supplied this current at a maximum \( V_o \) of about 35 V with a consequent maximum dissipation, when the output from the power supply is 0 V at 1 A, of \( 35 \times 33 = 115 \) W. In Fig. 2 the dissipation of \( Tr_2 \) under similar conditions is:

\[
33(V_r - V_{01} - 33 \cdot R_s)
\]

With \( V_r = 13 \) V (under load conditions), \( R_s = 270 \) \( \Omega \) and \( V_{01} \) of the order of 0.6 V the dissipation in \( Tr_2 \) is about 133 mW. However, in Fig. 2, the dissipation of \( Tr_2 \) is a maximum when its collector current equals \( (V_r - V_{01})/2R \), which, in the above example, equals 23 mA. Thus maximum dissipation in \( Tr_2 \) is 142 mW.

The addition of a number of components in Fig. 3 limits the output current in the event of a short circuit or similar overload. When the output current is less than the value of the limiting current, the current flowing into the base of \( Tr_3 \) is controlled by the "voltage" difference amplifier, thus maintaining a stable output voltage. When the current flowing through \( R_s \) (which is equal to the output current, \( I_o \), plus \( I_s \) and \( I_D \) ) is such that the voltage developed across \( R_s \) is equal to \( V_{01} [R_s/(R_s + R_k)] \) the "current" difference amplifier takes

---

Fig. 1. A conventional stabilized power supply.

Fig. 2. Using a separate supply line for the stabilizer circuitry.
over control of the current flowing into the base of $Tr_3$ with the result that the output voltage is adjusted to maintain a constant current through $R_c$.

The output current is thus limited to a value given by:

$$I_{o} = \frac{V_2}{R_c} \left[ \frac{1}{R_3/R_4} \right]$$

now $\left[ \frac{V_2}{R_3/R_4} \right]$ is equal to the emitter current of $Tr_3(I_{e3})$ and

$$I_{e3} = (\beta_1 + 1)I_1$$

where $\beta_1$ is the current gain of $Tr_1$. Therefore:

$$I_{o} = I_{e3}/(\beta_1 + 1)$$

and

$$I_c = \left[ \frac{I_1}{(\beta_1 + 1)} \right] \left[ \frac{V_2}{R_3/(R_4 + R_2)} \right]$$

Thus, provided that $\beta_1$ is very much greater than 1 and does not vary greatly with the voltage drop across $Tr_1$, and $I_1$ is very much less than $I_c$, then $I_c$ is approximately limited to a value:

$$V_{e3}/R_c \left[ \frac{1}{R_3/(R_4 + R_2)} \right]$$

In order that a range of constant currents may be provided the circuit of Fig. 3 must be rearranged in such a way that the voltage developed across $R_c$ is directly proportional to $I_c$. Fig. 4 shows such a rearrangement. Whereas, in Fig. 3, $R_c$ was effectively in the emitter line of $Tr_3$, it is now effectively in the collector line of $Tr_3$. The currents $I_{e1}$ and $I_c$ do not now flow through $R_c$ and the constant output current, $I_o$, is given exactly by the expression:

$$I_o = \frac{V_2}{R_c} \left[ \frac{1}{R_3/(R_4 + R_2)} \right]$$

In this circuit, should the constant current fall below the value:

$$\left( \frac{V_2}{R_c} \right) \left[ \frac{1}{R_3/(R_4 + R_2)} \right]$$

the “current” difference amplifier will lose control of $Tr_3$ base current to the “voltage” difference amplifier. In this event, the output voltage will be adjusted to a value equal to:

$$R_c \cdot \left[ \frac{V_2}{R_c} \right] - I_c R_c$$

and when the output is open circuited ($I_c$ becoming zero) will be limited to a value $R_c \cdot \left[ \frac{V_2}{R_c} \right]$.

Fig. 5 is a combination of Figs 3 and 4 and includes the addition of switch $S_1$ called the “mode” switch. With the mode switch in
position 1 the output voltage is stabilized and the output current limited.

\[ V_o = R_o \left( V_{ref} / R_s \right) \]

\[ I_o = (V_{ref} / R_s) \cdot R_s \cdot (R_1 + R_2) \cdot \left( \beta / \beta + 1 \right) - I_o \]

where

\[ I_o = (V_{ref} + V_{in}) / (R_1 + R_2) \]

and

\[ V_o = R_o \cdot I_o \]

With the mode switch in position 2 the output current is kept constant and the output voltage limited.

\[ I_o = (V_{ref} / R_s) \cdot R_s \cdot (R_1 + R_2) \]

\[ V_o = R_o \cdot (V_{ref} / R_s) - I_o \cdot R_o \]

where

\[ I_o = (V_{ref} / R_s) \cdot R_s \]

\[ V_o = R_o \cdot I_o \]

Fig. 6 shows the electronic stabilizing circuitry of the power supply, as illustrated in simplified form in Fig. 5. The principle of operation is precisely as previously described, but with a considerable amount of circuit sophistication to improve the performance. The transistor pair, Tr5 and Tr6, is the voltage difference amplifier and the transistor pair Tr8 and Tr9 is the current difference amplifier. The common collector load of Tr8 and Tr9 is made to appear very high by employing a constant current source, provided by Tr7, instead of the usual resistor. Similarly, the emitter load of the current difference amplifier is replaced by a constant current source, provided by Tr9. When switching from the voltage stabilizing mode to the constant current mode the emitter voltages of Tr8 and Tr9 vary from +0.4 V to -1.6 V, a change of 2 V. As it is desirable to keep the emitter current at the same value in either mode (for balanced operation of Tr8 and Tr9), this could have been achieved by switching in alternate values of emitter resistor. However, providing a constant current source was considered the better (if not cheaper) solution.

The two major reference voltages, V1, and V2, are provided by the zener diodes, ZD1 and ZD2. The currents through these two zener diodes are kept constant because the collector currents of Tr1 and Tr5 are constant by design as are the currents flowing away from the diodes. The additional zener diodes used in the reference voltage circuits, ZD1 and ZD2, provide stable voltages to the bases of the transistors Tr7 and Tr10, which, together with their respective emitter resistors, R11 and R17, determine the values of the constant currents provided to the collectors of Tr7 and Tr10 and the emitters of Tr8 and Tr9, as previously described.

The preset resistors, Rp1, Rp2, and Rp3, allow for accurate setting of the voltage, current limiting and constant current ranges.

The silicon diodes, D1, and D2, prevent the voltage on the base of Tr8 from swinging beyond ±0.6 V safeguarding the transistor from possible surges in the output voltage. C8 reduces the value of R6 to alternating signals increasing the loop gain of the amplifier and thus reducing the ripple content of the power supply. The capacitors, C15, and C16, reduce the loop gain of the amplifier at high frequencies, preventing instability. As a result the output impedance of the power supply rises from about 0.01 Ω at 1 kHz to 0.03 Ω at 20 kHz.

It was found necessary to include the resistors R1 and R2 because it was discovered that the two reference voltage circuits were not self-starting. Should trouble of this nature still be encountered, a more positive solution is to connect a resistor between the zero voltage line and the negative end of ZD1 (or the zero voltage line and the positive end of ZD2) dispensing with R1 and R2. The value of the resistor should be such that the current flowing through it is of the order of 1 mA. This will, naturally, degrade the performance of the reference voltage circuit, but not very seriously.

An additional feature of the power supply is the provision of a current or voltage overload indicator. The circuit of the indicator is shown in Fig. 7. In the voltage stabilized mode, with no current limiting, the collector voltage of Tr8 is a little above zero volts with the result that lamp L1 will be normally lit. When current limiting takes place the collector voltage of Tr8 rises to about 3 V, which is sufficient to turn lamp L1 off and lamp L2 on, indicating a current overload. In the constant current mode the operation of the indi-

(Above) Fig. 6. The circuit of the power supply unit.

Fig. 7. Overload indicator circuit.
The d.c. supply circuits.

To junction of Tr3 emitter & C8

Fig. 9. (a) Construction of \( R_v \). (b) Construction of \( R_c \).

The capacitor circuit is reversed. \( L_1 \) is normally on, indicating a constant current output, and goes off, \( L_2 \) coming on, when the output current falls below the "constant" value, indicating voltage limiting. Thus, together with the position of the mode switch, the lamps \( L_1 \) and \( L_2 \) provide an indication of the operating conditions of the power supply. The voltage supply for the circuit of Fig. 7 is taken directly from the two 13.5 volt a.c. tappings on the mains transformer.

Fig. 8 shows the circuit diagram of the two voltage supplies. A word of explanation is necessary about the OFF/ON-Voltage Select switch, \( S_2 \). The two wafer banks, \( S_{2(a)} \) and \( S_{2(b)} \) (see Fig. 9(a)) are self-explanatory, save the \( S_{2(a)} \) should be a break-before-make wafer and \( S_{2(b)} \) a make-before-break wafer. \( S_{2(c)} \) and \( S_{2(d)} \) are two halves of a mains ON/OFF switch operated by the 6-way rotary switch. The two halves are open in position 1 and closed in positions 2 to 6. The OFF/ON-Voltage Select switch provides the following functions:

1. All supplies off.
2. Stabilizer circuitry on—unregulated voltage supply off.
3. All supplies on—unregulated voltage output 17 V max. —0 to 11.25 V stabilized output available.
4. Ditto Position 3 except that unregulated voltage output 31 V max.—stabilized voltage output 10 to 21.05 V.
5. Ditto Position 3 except that unregulated voltage output 45 V max.—stabilized voltage output 20 to 31.25 V.
6. Unregulated output voltage of 45 V available at output terminals.

The inclusion of position 2 can be better understood by considering what happens when the power supply is switched off. If the power supply is operating with the OFF/ON-Voltage Select switch in position 3, the output voltage will be determined by the position of the four toggle switches and the variable control. On switching to position 2, the unregulated voltage supply is switched off and—depending on the stabilized output voltage set, the size of the external load and the reservoir capacitor, \( C_0 \)—the voltage provided by the unregulated supply will stay above the value of the stabilized output voltage for a short time. However, the stabilizing circuitry is still on so that the stable output voltage, \( V' \), will be maintained until the voltage across \( C_0 \) falls below a value a few volts greater than \( V' \). If the stabilizing circuitry was switched off at the same time as the unregulated supply, it would be quite possible for the voltage at the output terminals to rise, for a short time, above the value \( V' \). As an extra precaution, \( S_{2(d)} \) is included in the negative line of the unregulated supply making it impossible for an output voltage to appear at the terminals when the OFF/ON-Voltage Select switch is finally turned to position 1. Including position 2 also ensures that the stabilizing circuitry is operating before the unregulated supply is switched on, again preventing a possible surge in the output voltage should the stabilizing circuitry fail to control the output level immediately.

Fig. 9(a) shows the construction of \( R_v \) as used in the prototype power supply. The sensing current, \( I_s \), flowing in the voltage feedback line was designed to be 5 mA. Thus the resistance of \( R_s \) is 200 Q/V.

Fig. 9(b) shows the construction of \( R_c \). For current limiting and the constant current supply, the voltage across \( R_c \) is stabilized at 1 V.

**Specification**

- **Voltage ranges**: 0 to 30 V in switched steps of 1 V, plus 0 to 1.25 V fully variable.
- **Current ranges**: 1 mA to 1 A in switched steps of 1 mA, plus 1 to 2 mA fully variable.
- **Voltage limiting**: Operative on stabilized current output; limits voltage across the external load from 0 to 30 V.
- **Current limiting**: Operative on stabilized voltage output; limits output current from 1 mA to 1 A.
- **Setting accuracy**: 10% mains variation—less than 0.1% on all voltage and current ranges.
- **Stability**: Voltage output—no load to full load—less than 0.1%.
- **Temperature variation**: Dependent upon temperature coefficient of zener diodes.
- **Output Impedance**: (Voltage stabilized mode) no current limiting 0.01 Ω at 1 kHz to 0.03 Ω at 20 kHz.
- **Voltage ripple**: (Voltage stabilized mode) 2 mV peak-to-peak on full load.
(it is, in fact, a little higher than this when current limiting because the current flowing through the external load is fractionally lower than that through $R_L$). The limiting and constant current values are thus determined by dividing 1 V by $R_L$. Thus $I_L$ and $I_e$ equal $1/R_L$. Switching the ten individual values of $R_L$ in and out provides a range of currents from 1 mA to 1 A. An additional fully variable range from 1 mA to 2 mA is provided by a wire-wound variable resistor connected in series with a fixed one of the same value.

The methods of constructing $R_L$ and $R_e$ have already been discussed but a word about the components may prove useful. $1\%$ high-stability, carbon resistors of 1 watt rating were used for all the standard values of resistance. The "odd" valued resistors were $1\%$ wire-wound, 1 watt types, available, to order, from the Planet Instrument Co., 25(E) Dominion Avenue, Leeds, 7.

The mains transformer used was a Douglas, type MT.3AT with rewound secondaries. The original secondary, 0-30 V, multi-tapped and rated at 2 A was removed, carefully noting the number of turns per volt. One secondary, providing 0-12-22-32 V at 1 A, was wound using 19 s.w.g. enamelled copper wire; the other secondary was wound using 33 s.w.g. enamelled copper wire to provide 13-5-0-12-15-20 V at 50 mA.

The two transistor pairs, $T_1$ and $T_4$, and $T_5$ and $T_6$, of the "voltage" and "current" difference amplifiers were mounted in individual heat-sinks, constructed from $\frac{1}{2} \times 1\frac{1}{2}$" brass bar, to improve the long-term stability of the power supply.

The series regulator transistor, $T_3$, was mounted on a large, finned heat-sink attached, on the inside, to the back of the power supply cabinet.

### Components List

#### Resistors

The prefix $R$ and the suffix $\Omega$ has been omitted from components in the list below for clarity.

<table>
<thead>
<tr>
<th>Value</th>
<th>Resistance (Ω)</th>
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<td>6-1 k</td>
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<td>10-1 k</td>
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<td>26-6 k</td>
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<tr>
<td>29-2</td>
<td>2-2 k</td>
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All 0.25 W, 5\% carbon except where shown

<table>
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<td>3-50</td>
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</table>

#### Capacitors

The prefix $C$ has been omitted in the list below

<table>
<thead>
<tr>
<th>Value</th>
<th>Capacitance (μF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-25</td>
<td>12 V working electrolytic</td>
</tr>
<tr>
<td>2-25</td>
<td>12 V working electrolytic</td>
</tr>
<tr>
<td>3-0.001</td>
<td>0.5 µF disc ceramic</td>
</tr>
<tr>
<td>4-0.001</td>
<td>0.5 µF disc ceramic</td>
</tr>
<tr>
<td>5-8</td>
<td>25 V working electrolytic</td>
</tr>
<tr>
<td>6-8</td>
<td>25 V working electrolytic</td>
</tr>
<tr>
<td>7-50</td>
<td>50 V working electrolytic</td>
</tr>
<tr>
<td>8-25</td>
<td>12 V working electrolytic</td>
</tr>
<tr>
<td>9-0.1</td>
<td>250 V working polyester</td>
</tr>
<tr>
<td>10-2,000</td>
<td>2,000 µF, 50 V working electrolytic</td>
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<tr>
<td>11-500</td>
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<td>12-500</td>
<td>25 V working electrolytic</td>
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<tr>
<td>13-100</td>
<td>25 V working electrolytic</td>
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#### Semiconductors

The prefix $T$ has been omitted in the list below

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<tr>
<th>Value</th>
<th>Type</th>
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<tbody>
<tr>
<td>1-2N4289</td>
<td>10-BC 168</td>
</tr>
<tr>
<td>2-BC 168</td>
<td>11-BC 168</td>
</tr>
<tr>
<td>3-2N4289</td>
<td>12-BC 168</td>
</tr>
<tr>
<td>4-BC 168</td>
<td>13-2N3055</td>
</tr>
<tr>
<td>5,6-BC 109*</td>
<td>14-BC 168</td>
</tr>
<tr>
<td>7-2N4289</td>
<td>15-BC 168</td>
</tr>
<tr>
<td>8,9-BC 109*</td>
<td>16-BC 168</td>
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</table>

*matched pairs

† must have a minimum gain of 30 at 1A

The prefix $ZD$ has been omitted in the list below

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<thead>
<tr>
<th>Value</th>
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<tr>
<td>1-4-3 V, ZB4-3</td>
<td>3-6-2 V, ZB6-2</td>
</tr>
<tr>
<td>2-6-2 V, ZB6-2</td>
<td>4-4-7 V, ZB4-7</td>
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</table>

All 250 mW. S.T.C. type numbers shown

The prefix $D$ has been omitted in the list below

<table>
<thead>
<tr>
<th>Value</th>
<th>Type</th>
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<tbody>
<tr>
<td>1,2-</td>
<td>any silicon diode</td>
</tr>
<tr>
<td>3 to 6 any diode rated at 1 A, 100 p.i.v.</td>
<td></td>
</tr>
<tr>
<td>7 to 12-</td>
<td>any diode rated at 100 mA, 40 p.i.v.</td>
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### H.F. Predictions—April

#### Mains Transformer: secondaries

<table>
<thead>
<tr>
<th>Value</th>
<th>Voltage (V)</th>
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</thead>
<tbody>
<tr>
<td>0-12-22-32 V at 1 A</td>
<td></td>
</tr>
<tr>
<td>13-5-0-13-5 V at 50 mA</td>
<td></td>
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</tbody>
</table>

#### 6-pole, 6-way rotary switch plus mains ON/OFF switch (see text)

#### 3-pole, 3-way rotary switch

Cabinet type: Y. G. W. Smith and Co. Ltd.
Resistors and toggle switches for constructing $R_L$ and $R_e$ (see text)
Two 6 V, 40 mA bulbs
Plugs, sockets, Veroboard, heatsink (4" x 4" x 1")

The predictions are based on an ionospheric index of 96, the corresponding sunspot number being 83. These are slightly lower than the observed values for 1968 and 1969.

The trans-equatorial paths have their highest MUFs during equinox months and conditions should be good above 20MHz. Evening fading is relatively independent of season and cycle on the South African route but is worse during this period on others. The Far East will have weak unstable signals from midnight to 09.00 G.M.T. and North America will be liable to several days of weak signals from 06.00 to 16.00 G.M.T. The MUFs shown apply to both directions of the route while LUFs are for reception in the U.K. only.
Describing how long-distance propagation can be improved by exploiting the natural terrain

By L. A. Moxon,* B.Sc., M.I.E.E.

Since first hearing transatlantic morse signals in the early years of short-wave radio, the author has been fascinated by communication over long distances using low-power. This interest has been maintained by the frequent emergence of new and intriguing problems. In particular, by the discovery, when resuming amateur activities after the war from a new location, that communication was easy with Australia but almost impossible with anywhere else. Further, when Australian signals were at their best South Americans were usually weak or absent, clearly inconsistent with the usual theory of long-distance propagation by means of multiple earth-ionosphere reflections.

These mysteries were resolved by a process which stressed not only the importance of low-angle radiation, but also the need for more information on what constitutes a "low angle". A study of two medium-length east-west paths has concluded that for these paths angles as low as 1 deg. are desirable, but for the most part quantitative data is in short supply.

Recent speculation1 has suggested dramatic possibilities from the use of very low angles of radiation, perhaps even less than 1 deg., and it was with somewhat similar ideas in mind that a low-power (1W output), transistor s.s.b. transceiver was designed and built, light enough to be carried complete with aerial system up steep mountainsides.

*Amateur station G6XN

Fig. 1 When a horizontal aerial is erected at a height h over level ground, its image B is an antiphase. The direct and reflected waves are in phase at a distant point when BC = h/2, i.e. when 2h sin $\theta = \sqrt{2}$ where $\theta$ is the angle of radiation.

It was hoped in this way to achieve efficient radiation at the desirable low angles whatever these might be, by exploiting natural ground features. An earlier exercise, complementary to this, was aimed at maximising the low angle radiation obtainable from a flat site with limited aerial heights, accepting the inevitable low efficiency and consequent need for relatively high power to produce a given signal level.

On the basis of these experiments, and such information as can be found in the literature, solutions have been sought to the following problems:

(a) How to select the best site for an h.f. aerial, for communicating with low power over distances of 3,000 miles or more.

(b) How to make the best use of a given site.

The discussion which follows does not necessarily apply to commercial h.f. circuits for which 24-hour availability is likely to be more important than good results over shorter periods.

Avoidance of cancellation

The difficulty of achieving low angles of radiation arises from cancellation of the direct signals by the ground-reflected wave as shown by Fig. 1. This can, in principle, be prevented by one or more of the following procedures:

(a) Using a high mast so that the path difference for the two rays is $\sqrt{2}$, which then add in phase giving 6dB gain relative to free-space propagation. For 14 MHz and a radiation angle of 1 deg. this requires a mast height of 1,000ft, which is unlikely to be popular with the neighbours.

(b) Using a steep ground slope, as in Fig. 2. If the slope is 45 deg. a height of only 25ft is required at 14MHz to bring the direct and reflected waves into phase. This height is not critical and only 3dB is lost by dropping the height to 12ft 6in. or raising it to 3ft 6in. Moreover, there is the advantage of a single broad lobe in the vertical plane, whereas a large height as in Fig. 1 produces an interference-pattern with lobes and nulls alternating at 1 deg. intervals. The best angle of radiation is not necessarily always the lowest, and the optimum may well coincide with a null. So far all this is well known, but most references overlook the fact that the slope has to end somewhere. As first pointed out by Norton and Omberg this has important consequences, of which more later.

(c) With vertical polarization and perfectly-conducting ground, the phase of the reflection coefficient is reversed and efficient low-angle propagation is achieved independently of aerial height. This can be approximated by laying down a conductive earth-mat of sufficient extent. A beam aerial designed on this principle has been found to operate under radio conditions which render conventional equipment useless. The installation uses an earth mat 1,800ft long and 832ft wide, containing 25 miles of copper wire. Such a system is obviously beyond amateur resources, but sea-water is sometimes available and is a good-enough conductor to act as a useful (though not ideal) substitute.

(d) With vertical polarization and imperfect ground there is a "pseudo-Brewster angle", below which the phase of the reflection coefficient is reversed, so that for low angles and moderate or large aerial heights there is little to choose between vertical and horizontal polarization. In the vertical case, however, the reflection coefficient is less than unity so that cancellation is imperfect and some low angle radiation takes place, however, low the aerial. This principle has been exploited to produce a very effective, cheap and easily-erected beam for 7MHz, as described later.

Fig. 2 With the aerial at a height h above ground sloping at an angle $\alpha$, the direct and reflected waves are in phase when $2h \sin (n + \theta) = \sqrt{2}$. For small values of $\theta$ this becomes $2h \sin \alpha \approx \sqrt{2}$. This diagram is identical with Fig. 1 except for rotation through the angle $\theta$, and the increased ground angle.
Fresnel zones

Figs. 1 and 2 are oversimplified to the extent that reflection takes place not from a point but from a Fresnel zone which is defined by the fact that reflections from all parts of it tend to add in-phase.

Formulae for the sizes and required degrees of flatness of these zones are to be found in the literature. The size of the zone for the previous example based on Fig. 1 is very large, the near edge being at 2½ miles range, and the far edge (ignoring earth curvature) at 85 miles. As the height is reduced and the angle of maximum radiation relative to the ground increases, the corresponding Fresnel zone contracts with the far edge moving in roughly as the inverse square of the angle.

For the example based on Fig. 2 the "near edge" is 25ft behind the aerial and the far edge only 175ft down the slope. The shape is elliptical, its effective width being roughly 5 times the aerial height, and the ground need not be particularly flat. Obstacles with dimensions up to about a quarter of the aerial height are acceptable. Very long distances to the far edge (as in the first example) are reduced somewhat when due allowance is made for earth curvature.

Double reflections

Discussion so far has been concerned with situations which may seem ridiculous, since amateur resources have been implied and angles of 1 deg. assumed. Even if the angle is increased to 5 deg and a loss of 3dB accepted, the Fig. 1 situation would require a 100ft mast, and bottomless ground exist only in mythology or mathematical fiction.

In practice, however, the steep slope is quite likely to sweep down like the Mountains of Mourne, or even Mull where the author conducted some experiments, to the sea, as illustrated by Fig. 3. A flat plain, however, is also a possibility and will serve equally well for the next part of this discussion.

It will be seen that there are now four waves to be considered, including two single and one double reflection, and if all these can be made to add in phase there is a possibility of obtaining not 6 but 12dB gain compared with free-space propagation. This may appear complicated, but resolves quite simply into a practicable combination of the two situations which have just been criticised as absurd: 6dB gain being obtained from each of them.

For numerical consistency with the previous examples there is required only a sloping patch of mountainside extending for at least 25ft above and 175ft below the aerial. It should be centred on 1,000ft altitude with an unobstructed view of the sea, of which the nearest visible point should be not more than 2½ miles away.

Since the mountain is, in effect, being used as a "tall mast", however, this entails the penalty of a multiple-lobe radiation pattern in the vertical plane (as in the case of Fig. 1 with a tall mast). So that if the appropriate angle of radiation happens

Fig. 3 Ground sloping down into the sea. The direct wave Aa, foreground reflection Abc, distant reflection Agh, and double reflection Adef add in phase if 0 is small, \( h_g \approx 1/(4 \sin \theta) \), \( h_b \approx 1/(4 \sin \theta) \), these being the heights of A above ground and sea respectively.

Fig. 4 Typical ground profile for mountainous country. Distant low-angle reflections are non-existent for transmitter at B, and probably unimportant (due to break up of Fresnel zones) for transmitter at A. In both cases low-angle reflections (not shown) are obtained from the foreground. (Isle of Mull, grid ref: NM 568332 bearing 104 deg.)

Fig. 5 Comparison of short horizontal and vertical radiators at h.f. assuming flat open country. "Zero loss" occurs with in-phase addition of the direct wave and a reflected wave of equal amplitude. Aerial heights are indicated in wavelengths for horizontal polarization (dotted curves). Vertical polarization curves are calculated for low height and a frequency of 7MHz; performance deteriorates slightly as frequency increases.
to not be 1 deg. but 2 deg. signals will be almost completely cancelled and even if the operator were aware of this he would scarcely relish the idea of moving the aerial down 500ft to put the matter right. He might even prefer to sacrifice the 6dB gain obtainable from the sea reflection. But at this point it becomes appropriate to consider the situation sketched in Fig. 4.

Locations such as this are usually easier to find than those corresponding to Fig. 3 and it will be noticed that the distant reflecting areas are either blocked off by the foreground or badly broken up, thus failing to meet the required specification for the Fresnel zones. If the distant reflections are sufficiently reduced, Fig. 2 becomes after all a valid representation for the practical case and low-angle radiation should then be obtained with a gain of 6dB relative to free-space propagation.

Neglecting diffraction, this would be true for angles of elevation down to zero, assuming an aerial height of, say, 0.71 above any 45 deg slope 200ft in extent. For a 15 deg slope an aerial height of 2.1 and an extent of 1,800ft would be needed for the same result, but these dimensions are not critical and could probably be halved without serious loss of performance.

Polarization

With sloping ground horizontal polarization is preferable, because in the vertical case efficient use of the reflected wave is usually prevented by the Brewster-angle effect, tilting of the image, or both. In the case of flat ground, the best choice of polarization depends on the available aerial height, soil characteristics, and frequency.

Fig. 5 has been calculated from handbook data for vertical aials at various types of ground and on the basis of Fig. 1 for horizontal aials at various heights. This provides a rough comparison between different aials for given angles of radiation and soil conditions assuming, in the vertical case, heights low enough for the effect illustrated by Fig. 1 to be negligible.

In using these curves two points should be noted. Where horizontal polarization appears to be better, equally good results could usually be obtained with vertical aials by raising them to the same height. The vertical aial is then likely to be the more difficult of the two to support and feed. On the other hand height is usually the main problem in aial construction. Horizontal supporting wires for vertical elements can be used to provide end-loading which allows considerable reduction of vertical length and, therefore, height.

Although the useful energy radiated per element is rather small, it is often easier at the lower frequencies to construct, say, a 5- or 10-element vertical aial in this manner than to put up a horizontal dipole at a height which would give comparable performance.

Fig. 5 shows the possibility of radiation at 0.5 deg. elevation with a loss of only 6dB by using vertical aials surrounded by sea water, which may appeal to amateur enthusiasts with portable transceivers and a preference for paddling rather than mountain climbing.

Experimental results

The good results at 14MHz in the direction of the long path to Australia mentioned earlier, were attributable to a steep ground slope (22 deg.) in that direction. Aerial height was only 23ft which was adequate for the down-slope direction, but resulted in poor propagation in the opposite direction even for short ranges.

The use of a full-wave dipole, later backed by reflectors, produced a narrow azimuthal pattern, thus discriminating against directions other than towards Australia. Comparative tests were carried out over several years with the cooperation of numerous Australian stations plus a local amateur (G3DVM), whose location was more conventional, his aerial being located at a height of 1/2 over flat ground.

Comparative reports, allowing for power differences and assuming 6dB per S-point, usually indicated an advantage of about 8dB in favour of the author's location and aerial system. Referring to Fig. 5, the loss for 6 deg. elevation at G3DVM would be 10dB, and a loss of 2dB would be applicable to G6XN for the same angle, which would, therefore, be the "most probable". It was noticed, however, that quite often the path remained open longer at G6XN with signal-strength differences reaching 20dB or more. This would be consistent with radiation angles in the region of 1-2 deg. On other occasions the advantage in favour of G6XN almost disappeared, suggesting angles in excess of 10 deg.

It is interesting to note that good conditions on the long path to Australia occur when the path is mainly in darkness, and complementary ionospheric tilts might be expected at each end of the circuit due to the darkness-daylight transition. This leads to the chordal hop mode of propagation first described by Albrecht7 depicted in Fig. 6, in which waves travel by successive F-layer reflections without intermediate ground reflection.

Note that the lower the angle at which the ray strikes the ionosphere, the less likely it is to be reflected back to earth. Similar modes of propagation occur frequently on other long-distance paths especially north-south paths. Because of reduced D-layer absorption and ground-reflection losses, these modes tend to produce very high signal levels over very long paths.

Tests with the portable s.b. transceiver have been carried out from steep ground slopes, using an inverted-V dipole having its centre propped up to a height of 20-25ft and about 1W of peak r.f. power. Attempts to communicate with Australia over the long path were made from six different locations having features typified by Figs. 3 or 4, with success in every case. The inverted-V dipole when erected over ground sloping at angles of 30-40 deg. appeared roughly equivalent to a Quad aerial at the home location erected at a height of 50ft, although direct comparison was not possible.

This result is consistent with the previous estimate of a 6deg. angle of radiation since, from Fig. 5, a loss of 7/5dB would be expected for the Quad despite its greater height, but this would be offset by an estimated 6dB or so of aerial gain. Insufficient results have so far been obtained to establish the practical advantage, if any, of using distant as well as foreground reflections on the lines of Fig. 3.

These tests were conducted in the 14MHz amateur band, but other contacts were made with Australia on 21MHz (short path), and with North America on 28, 21 and 14MHz. In these cases also, the combination of portable dipole plus steep ground slope appeared roughly comparable with the home "Quad". This was judged by the degree of difficulty in establishing contacts.

Fig. 7 shows one of the two "bays" of a...
Radio Fire alarm

Personal call-out system for firemen

Production techniques are not in general the concern of Wireless World but this month one is featured on our front cover. It shows, albeit in an artistic setting, a watchmaker's wheel which has been adopted by Pye Telecommunications Ltd to facilitate the production of the "microboards" used in the pocket receivers for a fireman's call-out system. The system, which is being adopted by the fire brigades in several areas, operates in the 142-174 MHz band. The transmitter carrier of the 25-W base station is frequency modulated by two signalling tones—one as a test call and the other for a fire call.

The pocket receiver, which measures 12.7 x 6.3 x 2.5 cm and clips in a breast pocket, has a built-in aerial and is powered by a rechargeable 9-V nickel-cadmium battery giving 30 hours operation. The receiver incorporates a battery economizer circuit which switches it on for 0.5 sec and then off for 2.5 sec until the carrier is received and locks it on. Studs fitted to the receiver enable it to be inserted in a bedside battery charger. It remains fully operative while in the charger.

(Right) Chassis of the fireman's pocket receiver which has an operating range of between 5 and 8 km from the base station according to terrain.

(Below) The watchmaker's wheel in use at Pye's Cambridge works.

REFERENCES

Some improvements in the design of
Class-B Audio Amplifier Circuits

by K. C. Johnson

A bewildering number of articles have appeared both in this journal and elsewhere describing class-B audio amplifiers using transistors. The reader might well think that all the possibilities had been thoroughly explored already. When, however, I started to build a new system myself I was surprised to discover just how many small improvements can be made even to a well-tried design. It is true that none of them is either overwhelmingly important or even really original, but taken together they make an appreciably better circuit and so seem to justify yet another article on this subject.

The amplifier from which I started was the Fairchild AF11, which was offered as a kit of semiconductor devices and a tested circuit, though it is no longer in production. The arrangement had been clearly derived from the pioneer circuit of Tobey and Dinsdale, but was brought up to date and much improved by the use of diffused silicon transistors throughout. The first stage was changed so as to use a complementary type of device, since these are now scarcely more expensive in the small sizes and allow some advantage to be gained in the feedback arrangements, but the final power stage still employed two identical devices.

My final circuit is shown opposite, and the various ways in which it differs from the more conventional arrangement will be described in turn.

Earthing arrangements
Several writers have pointed out that it is an advantage to return the "dead" sides of the input, the feedback network, and the output all to the same power rail so as to avoid instability troubles. The first unusual feature of this circuit is that it is the upper rail which is chosen for this service rather than the lower one. One obvious advantage of this is that it allows the bootstrap line to be taken directly from the loudspeaker and so saves the need for a second electrolytic capacitor network. But there is a further advantage in that variations in the power supply voltage are much less important since there are no longer any large coupling capacitors bridging the supply rails. If the two rails are taken abruptly to the full working voltage, at switch-on for example, only the 40µF high-frequency bypass capacitor C4 carries any large current and it is essentially just an extension of the power supply. The long time-constant at the base of Tr1 controls the charging rate of all the other capacitors and the maximum current in the loudspeaker is no more than 30mA.

In the same way this use of a common return rail and the absence of any signal capacitors bridging the power rails allows a considerable amount of ripple to be tolerated on the power-supply voltage so that power-pack requirements are eased. There are just four places in the circuit where signals change their reference from one power rail to the other, and in every case the collector junction of a transistor is used so that only the current flow is of importance and the voltage is relatively immaterial.

To keep the loudspeaker current surge within similar limits at switch-off it is only necessary to ensure that at least 1000µF of charged capacitor are left connected across the power rails. This enables the currents in Tr1 and Tr2 to be kept flowing so that the circuit is able to shut itself down at the rate determined again by the long time-constant at the base of Tr1. This requirement will normally present no problem, but even if it is not met the surge generated will certainly be no worse than in most other circuits of this type. R16 serves to keep the circuit biased properly if the loudspeaker is disconnected whilst the power remains switched on.

The pre-amplifier for this circuit must also be arranged so that the positive rail is the earth and so that the output voltage measured this way changes smoothly when the power is switched.

Middle rail voltage
In any circuit of this type the average voltage at the middle point between the output transistors must be set about half-way between the power rails so that equal output swings can be developed. The first-stage transistor is used at its full gain in this circuit for this purpose. The potentiometer which is applied through R5 to the base of Tr1, whilst the actual average level is set on C1 by R8 and fed to the emitter. If these voltages do not correspond, the full power of the amplifier is available to correct the situation, with C1 ensuring that the action is stable.

Thus if slow variations of the supply voltage occur, or if the amplifier is used on different supplies, the middle voltage is always automatically adjusted so as to be close to the actual half-way value rather than remaining at some pre-set level. As a refinement the precise value of R5 can be set so that limiting of the output on overloading occurs symmetrically at the normal supply voltage, but if components of ordinary tolerance are used the loss of output swing if this is not done will be quite small.

Transistor currents
In contrast to the above it is desirable that the levels of average current at which the various transistor stages work should remain comparatively constant when the power supply is altered. There is no reason to drive a stage with less current just because less voltage is applied, although it is true that a lower impedance loudspeaker system must be used if advantage is to be taken of the current available.

In the conventional form of circuit these standing currents are in fact stabilized in every stage except the second. The third improvement in this circuit is that the diodes D1 and D2 are added so as to control this stage also.

With the circuit shown the supply voltage can be reduced from 60V to as little as 18V and the full output current of 2A remains available at almost the full swing the voltage allows, without any adjustment. To match this the loudspeaker impedance required must be reduced from 15Ω at the high voltage to about 4Ω at the lowest. If the loudspeaker is not matched then some output is lost, since either the voltage or the current reaches its limit whilst the other one is less than maximum, but there is no other serious penalty if the mis-match is not worse than a factor of two or so.

Cross-over current stabilization
Thermal runaway of the final transistors is not the problem with silicon devices that it was with germanium. Nevertheless the circuit has the resistor-diode networks R13 D1 and R14 D2 included between Tr1 and Tr4 to stabilize the cross-over current level more tightly. These resistors act to give a proportionate voltage for currents near the design value of 20mA, whilst the

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diodes take over for currents greater than about 50mA so that the peak output capability is scarcely reduced at all.

Now it might be thought that non-linear networks of this kind would cause serious distortion—and arguments to this effect have indeed appeared in print—but consider what is actually happening. The signal being amplified leaves $T_R$, as a collector constant current. $T_R$ is arranged to supply a constant current and thus the signal is still in the form of a current when it arrives at $T_R$ and $T_{R^c}$. It is amplified there and again at $T_R$ and $T_{R^c}$, but at no point in these stages is there any sort of load resistance. Thus the voltages are irrelevant, except in so far as small amounts of current can be lost since no system is ever perfect.

There is, however, an improvement of the thermal stability of the cross-over current by a factor of about five over the customary arrangement of linear resistors of about 0.5Ω at these positions, and less output swing is lost. Thus these networks are well worth having even though silicon devices have so much less leakage and much better stability anyway. The diodes used for $D_1$ and $D_2$ should be of germanium, so that they take over at about 250mV, and they must be capable of carrying the full output safely. Their reverse characteristics and switching speeds are clearly of little importance and Mullard type OA 10 is suitable. The resistors can be of the ordinary small composition type, as they never have to carry more than perhaps 50mW of power at the most, and there is then no worry about their being inductive.

**Constant current transistor**

The transistor $T_R$ has been added to serve as a constant current source, as has already been mentioned. It supplies the collector of $T_R$ with about 2mA and draws this current from the loudspeaker side of $C_4$ so as to obtain the customary bootstrap action. The resistor $R$, and capacitor $C$, help to keep the current constant, whilst $D_4$, $D_5$, and $R_s$ stabilize the value against variations of the supply voltage. The transistor for this position must be capable of withstanding half the maximum supply voltage but need have no other special features. The Fairchild type BC116, as used already in the first stage, meets the requirements. In conventional circuits a simple feed resistor carries the current to $T_R$, and the value used is usually no greater than 5kΩ. But the input impedance to $T_R$ and $T_{R^c}$ can easily rise to this same sort of value at the cross-over region, since the input impedances of the final transistors rise sharply at low currents and the value is directly multiplied by the current-gains of the driver stage devices. Away from cross-over these input impedances are very much lower, so that the effect is a fall in the value of the open-loop gain at cross-over. Put in figures we can say that the open-loop gain is multiplied by a factor of about 0.5 in this region.

Now the purpose of $T_{R^c}$ is to force as much as possible of the signal current from $T_R$ into the driver stage devices and so reduce this form of distortion. Since the effective resistance value obtained is in the region of 100kΩ the improvement is substantial despite the increase of the input impedance that results from the inclusion of $R_{12}$ and $R_{13}$. The cost of the extra transistor required is comparatively small and in return we have obtained less distortion and better current stabilization in two stages of the amplifier.

**Voltage reference transistor**

The transistor $T_{R_6}$ together with $R_{14}, R_{15}$ and $C_{14}$, determines the voltage used as a reference in the fixing of the value of the cross-over current. A transistor replaces the usual chain of diodes as it can provide a more satisfactory form of adjustment and may perhaps now even actually be cheaper. Almost any type of transistor will do provided that there is a gain of at least ten at a current of 1.5mA. Clearly a silicon device can be expected to be more stable and to provide a better tracking when the stages being stabilized all use this same material.

Resistor $R_s$ has to be reduced in value if the cross-over current is too large whilst $R_m$ must be reduced if it is too small. Make any adjustment carefully as this setting is fairly critical. Capacitor $C_4$ serves merely to provide an easy path for the signal current to reach $T_{R^c}$.

With silicon transistors of this kind the cross-over current is not at all critical. The value can rise to 50mA or more before the heating effect becomes significant whilst it can fall as low as 5mA before there is any appreciable increase in the distortion. The temperature differences would have to be in the region of 100°C before either of these limits could be approached, and temperatures of this order are certainly not developed in ordinary domestic usage even when no special heat-sink arrangements are made as is the case with my amplifiers.

**Matching the transistor gains**

The gain from the collector of $T_{R_6}$ to the output in a circuit of this type is determined primarily by the products of the current-gains of the driver and final transistor on the two sides. Thus in this circuit it is the product for $T_{R_6}$ and $T_{R_5}$ for negative swings and $T_{R_6}$ and $T_{R_5}$ for positive ones. It is these products, rather than the gains of the corresponding devices, that ought to be matched to reduce distortion. There is no great difficulty in doing this and indeed it offers the big advantage that relatively poor specimens of one device can be sold paired with star performers of the other.

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so as to give a standard product despite production spreads. So far as I know, though, no manufacturer has ever offered devices from. When building an
amplifier of this kind it is well worth taking the trouble to test the devices available and to select pairs for a constant value of this gain product.

An amplifier of this type has then, in principle, got a constant gain right through the cross-over region. The current from TRr is indeed split into two pieces in some cases determined by the relative impedances at the inputs of TRr and TRs, and these are amplified separately. But they are simply added together again for the output, so that if the amplification factors are equal the exact manner of the splitting is of no importance. This situation is quite different from that in a valve class-B circuit where the signal is applied as a voltage to the two devices equally at all times, and their characteristics must be so shaped that the sum of their responses remains constant as the action transfers from one to the other. In this latter case a critical level of biasing, determined by the design of the valves, must be maintained so that the responses do not fall together, but there is no corresponding requirement in the transistor circuit.

The only objection to an indefinite increase in the cross-over current here comes from excessive heating of the power stage and the need for a larger power-pack. There is no clear distinction with this type of circuit if it is done with a larger cross-over current and class A. The distortion decreases as the standing current is increased, and a compromise must be made between the distortion acceptable and the power level.

Choice of cross-over current

The value chosen for the cross-over current in my amplifiers is 20mA. This gives a standing power dissipation in the final transistors of 0.6W each at the full voltage. A power pack of this level no heat-sinks are required in normal service, so that the devices can be mounted directly on the same small paxolin board as the other components. This in turn means that none of the wires concerned in the feedback loop need be more than 3in long and the stability problems are correspondingly reduced. There is no objection, however, to running at a higher level of standing current simply by reducing Rr, if a different compromise is required and heat-sinks and stabilization capacitors are provided.

But how serious is the distortion even at this level of 20mA? With modern diffused power devices, such as the Fairchild BD116, well over half the peak gain is still available at this sort of current. If we assume that the amount left is actually 75%, then this gain loss will cause a fall in the open-loop gain, due to the simple product of the betas, by a factor 0.75 at the cross-over point.

Further to this there is a loss of signal in the resistors Rr and Rr, due to the rise of the input impedances of TRr and TRs at low currents. With typical silicon devices this is no worse than a factor of 0.95, and it is far less serious now than it was with germanium where the leak resistors had to be made much lower in value. It is tempting to omit these resistors altogether with silicon but, in fact, this is foolish as they are required to help the power devices turn off after fast transients.

Lastly there is the fact that TRr is not really a perfect current source, but has a finite output impedance. Even if the standing current in this stage is cut to the bare amount required for driving the full output together with a minimum safety margin (2mA in this circuit) the collector impedance will still be no higher than about 50kΩ, as the base is current fed. The input impedance to TRr and TRs is, however, 45kΩ or more, since the 152Ω of the loudspeaker is multiplied by at least 3000 due to the current-gains of the stages. Moreover, there is a further 10kΩ added to this, due again to the rise of transistor input impedances, at the cross-over point. Thus the loss of gain here is a factor 0.55 worsening to 0.45 at cross-over. The corresponding effect at TRs is rather less than this as it is voltage fed and returned to the bootstrap line. Its inclusion does not make any serious difference to the general picture.

The most serious effect here comes again from the collector impedance of TRr and is due to the fact that this impedance is inversely proportional to the current in the device. Thus at the peak negative swing this impedance will fall as low as 30kΩ, while at the positive peak it will rise to perhaps 100kΩ. This causes a factor of loss of open-loop gain of 0.4 for 0.7. This effect is thus comparable with the factor 0.6 due to the effects at cross-over. The conclusion from this is that although a further increase of the cross-over current would indeed reduce the distortion rate of reduction is becoming rapidly less so that, on balance, this value represents a reasonable compromise. If a more constant openloop gain is required then something must be done to increase the effective output impedance of TRs.

Stability of the feedback loop

The full product of the current-gains of the second, third and fourth stages of this circuit is in the region of 350,000, but, as we have seen, this is reduced by various factors so as to be perhaps 140,000 at the least and 250,000 at the most with variations over the signal swing. Now roughly 1/600 of the output current is fed back through Rr, Rr and TRs, so that the effective gain round the feedback loop in the passband varies over the range from 230 to 420. This very large amount of feedback serves to make the correct gain fall short of the value determined by the potentiometer formed by Rr and Rr, by no more than 0.43% at the worst and 0.24% at the best.

This variation is less than ±0.1% from the mean and indicates that the performance of this type of circuit is good indeed. It is quite probable, in fact, that the linearity of the resistors used for Rr and Rr is not even as good as this and that they are, therefore, a major source of distortion. In any case there is little doubt that there are other components in any real audio system which are far worse than this circuit, so that there is little point in worrying about it excessively.

However, this feedback will be quite useless unless the loop can be kept stable. The last feature in which my circuit is unconventional is in the fact that adequate stability is obtained without any extra capacitance having to be added between the collector and base of TRr. The network Rr, Cr provides the usual dummy load to restrain the output voltage at the very high frequencies where the loudspeaker system is likely to be inductive and where oscillation is likely to occur, but the amplifiers as built have a response time to a sharp step input of about 1ms rise-time with an overshoot of no more than perhaps 10%. Notice that the sort of wiring commonly used to feed loudspeakers has a characteristic impedance substantially greater than the load resistance, so that a long lead will make the inductive effect greater rather than less.

As already mentioned, the layout used is very compact with no signal lead more than 3in long, but the rather unexpected stability seems to come from the very high impedance at the collector of TRr due to the constant-current effect of TRr. This apparently makes the ordinary stray capacitances at this point have a time-constant which dominates the feedback action. At the same time the diffused power transistors used for TRr and TRs are so fast (they have fT = 40MHz), that they no longer make a serious second time-constant. With germanium the final devices used were more than a hundred times slower than this and their inherent parasitic capacitance was a major factor in the stability considerations.

It follows from this step-input behaviour that the high-frequency cut-off of this circuit is at over 100kHz. If this is thought to be excessive it can be reduced as required by adding collector-base capacitance at TRr, and this will further ensure stability. The low-frequency cut-off action of the circuit comes directly from the increase of the feedback factor due to the time-constant of Rr and C, The value of this is 10ms, so that the cut will come at about 16Hz. If this value is to be changed then C, C, C, and C must all be multiplied by the required factor.

The result of the modifications is an amplifier arrangement that works appreciably better than corresponding circuits of the same general type with only a marginal increase in the complexity. It is even possible that the total cost is no greater when the savings that can be made in the power pack are taken into account. Certainly there is no doubt that the component tolerances have been made substantially easier, and that these various features deserve consideration in the design of any future amplifier of this type.
Speakers in Corners

A disagreement with the widely held view that placing a loudspeaker in a corner of a room gives better sound quality

by H. D. Harwood,* B.Sc.

In his article "Loudspeaker Performance" in the February issue of Wireless World, P. W. Klipsch, states that "All speakers (I have found no exceptions) work better in a corner". This view, which seems to be very commonly held, does not agree with experience in the B.B.C.1 Historically it has been found that as the general sound quality of loudspeakers has improved, so the deleterious effects of mounting the loudspeaker in a corner have become more and more noticeable. The deterioration in quality has been found to be mainly in the middle and upper bass regions. It sounded as though the loudspeaker had a very irregular response-frequency characteristic and that the sound was apparently more reverberant and coloured. The effects in the lower frequency range were particularly noticeable on polyphonic organ music, the separate parts of which are changed in level according to their positions in the scale.

In the B.B.C. television sound control rooms have been chiefly affected, as the most convenient position for the monitoring loudspeaker has been above a group of picture monitors which are placed across a corner. This listening position is largely a forced choice because the listener's strong directional sense in the horizontal plane discourages the use of positions to one side of the monitors, while the space below is normally screened by the control desk and other obstacles. The monitoring loudspeaker is therefore normally placed near the ceiling in a corner, exactly the acoustic position favoured by Mr. Klipsch.

The hanging version of the LSU/10 studio monitoring loudspeaker (introduced in 1959) sounded satisfactory in such a position after a bass lift had been added. With the completion of Television Centre and the introduction in 1959 of the LS5/2A, it was found that these loudspeakers, which performed very well in most circumstances, gave inferior quality when hung in a corner, although it was often possible partially to overcome this by changes in the acoustics of the room. When the LS5/62 was introduced recently, the effect of mounting it in a corner was quite marked.

Three hypotheses have been suggested to explain the effects:
1. The release of load on the base of the cabinet when the loudspeaker is removed from its plinth allows the cabinet to vibrate more freely, thus colouring the sound at a series of resonance frequencies.
2. The quality change is entirely due to interference effects between the direct sound from the loudspeaker units and that reflected from the walls and ceiling in the neighbourhood of the loudspeaker.
3. The effects are psychological in origin and associated with the unnatural or unaccustomed direction of the sound reaching the listener. This is very difficult to check and therefore the first two suggestions were examined first.

To check the first suggestion, listening tests were carried out, using both speech and music, when the loudspeaker was on its plinth near the middle of a wall and when it was raised just free of the plinth by means of a rope and pulley. No difference in sound quality could be detected at all and it was concluded that vibration of the base of the cabinet was not a cause.

If interference from reflections was the cause of the changes in quality, then past experience1 would indicate that their amplitudes would be comparable with that of the direct sound, and the output of a microphone placed in the listening position would have a series of easily identified fluctuations.

Fig. 1 shows the arrangement used for experiments to test the hypothesis that the deterioration in quality was caused by reflections from the surfaces of the walls.

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Fig. 1. Experimental set up used for investigating effects of corner placing.

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Fig. 2. Response/frequency characteristic with loudspeaker symmetrically placed in upper corner of room. The signal source was a warble tone.
and ceiling. For clarity it is shown in two dimensions only, but the extension to three dimensions is fairly obvious. For walls at right angles three images are formed, \( I_1, I_2, \) and \( I_3. \) If the walls are not at right angles then \( I_3 \) is split into two images, but for most rooms these two will coalesce at the wavelengths we are concerned with. Corresponding images will be formed in the ceiling.

In the tests the loudspeaker could be fed with pink noise, pure tone modulated over a range of \( \pm 63 \) Hz at a rate of 10 times a second or with programme from recordings. A microphone with a cardioid directional pattern was used to reduce the effect of room reflections elsewhere and the output could be recorded on a graphic level recorder or on a magnetic tape recorder.

Fig. 2 shows the steady state characteristics with the loudspeaker in a symmetrical position in the corner of a room acoustically treated on surfaces other than that of the corner. The microphone was 1.3m above floor level on the loudspeaker axis.

Fig. 3 shows the curve obtained in a listening room in an asymmetrical position with respect to the walls of the room. These curves of course represent the combined effect of room and loudspeaker and should in no way be confused with those of the loudspeaker alone.

Compared with Fig. 3, the curve in Fig. 2 shows a series of broad maxima and minima at low and middle frequencies, the maxima occurring at 50, 280, 630 and 950 Hz, the peak to trough variations reaching 11 dB; at high frequencies, too, there is a series of interferences. Listening tests on the loudspeaker using both pink noise and speech, in the condition corresponding to Fig. 2, showed a definite colouration just below 300 Hz, which agrees with the main peak in this region. There is a clear suggestion therefore that the colourations at low frequencies are associated with these peaks.

Fig. 4, curve A, shows the expected resultant of the sound pressure from the loudspeaker and its images calculated by ordinary vector summation from the following data:
1. Measured positions of loudspeaker and microphone.
2. Assumption of a value of 90% for the reflection coefficient at the walls with no significant phase change in reflection.
3. The assumption that the two images lying directly behind the loudspeaker could be neglected. One of these is formed by two successive reflections and the other by three, and both are formed by radiation inside a small solid angle at the back of the loudspeaker where the radiation is in any case low; otherwise the loudspeaker was assumed to be omnidirectional.

Curve B in Fig. 4 is a smoothed reproduction of a portion of Fig. 2 deliberately displaced from curve A. The similarity between the two curves is sufficiently close to confirm that interference by reflections from the surfaces surrounding the corner is an adequate explanation of the low frequency effects.

As the frequency is increased the fluctuations of Fig. 2 vary in depth owing to the varying directivity of the loudspeaker and the interaction of images at several different distances. From 3 kHz, however, the pattern becomes more regular, probably because the tweeter is in operation here and is more omnidirectional, giving stronger reflections from the nearby surfaces. The fluctuations still seem to be harmonically related to 270 Hz.

Fig. 5 is the steady state characteristic, for comparison with Fig. 2, obtained after moving the loudspeaker from its symmetrical position by 45 cm parallel to one wall. In this position the path lengths from two of the primary images are different and the fluctuations are therefore reduced at low frequencies.

A further response characteristic was taken at a symmetrical corner floor position, a carpet being on the floor. The low frequency fluctuations were similar to those in Fig. 2 but the high frequency ones were smaller, presumably due to the absorption of the carpet.

Fig. 6 shows the disastrous effect of placing the loudspeaker right in the corner so that it touches each of the walls.

The evidence given above shows that interference between reflections and the direct sound is sufficient to explain the measurable effects of the loudspeaker environment. It is also consistent with the subjective observations which were the starting point of the investigation. It may be a matter of some surprise that such large fluctuations as exist even in the best curves, i.e. Fig. 3, do not make the loudspeakers completely unacceptable in any other situation than that of a free field room, but it is a common observation that one does not normally notice the even larger fluctuations due to room modes which must equally affect live speech in a room. The faculties of binaural hearing and central nervous analysis give considerable weight to the direct sound.

Assuming that the effects are entirely due to interference, there are thus three alternative methods for improving reproduction from a corner placed loudspeaker.

1. To absorb sound falling on the neighbouring surfaces. This will require a highly efficient absorber working over the entire audio bandwidth to be applied to a suitable area around the loudspeaker position. A suitable type is a partitioned air space 15 cm deep closed by 5 cm of dense rockwool and a fabric or highly perforated cover.
2. To use unsymmetrical loudspeaker positions, preferably chosen to eliminate the major fluctuations.
3. To avoid the corner as far as possible, will give the best results.

An opportunity to test out these conclusions arose in the sound-control cubicle of Studio 1 in Television Centre. A loudspeaker, type LS5/2, which it was agreed gave a high quality of reproduction when near the floor, gave an objectionable quality described as "tunnelly" when hung above the television monitors in a corner of the room. The position of the loudspeaker is such that very little can be done in the way of adding absorbent at the sides of the loudspeaker without covering large areas of viewing window in the

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**Fig. 3.** Characteristic with loudspeaker in an asymmetrical position in a quality listening room (warble tone).

**Fig. 4.** Calculated response/frequency characteristics from loudspeaker in corner of room: curve A, calculated from direct and strongest three images; curve B, smoothed from measured characteristic in Fig. 2.

**Fig. 5.** Speaker moved to unsymmetrical position in room (warble tone).
control room. The wall area available behind the loudspeaker was treated as described above, but the quantity of absorbent involved was so small that it was not surprising that very little benefit resulted.

A response/frequency curve was taken with a cardioid-type microphone at the edge of the control desk facing the axis of the loudspeaker and with warbled tone applied as in the earlier curves. The result is shown in Fig. 7 and the expected irregularities are evident in the 500 Hz to 2 kHz region. To check that the irregularities were not due to interference from a reflection off the desk the measurement was repeated, the microphone having a figure-of-eight polar characteristic, the null being directed towards the desk. Results were substantially the same.

It was noted that the sound quality varied rapidly with distance from the desk and indeed throughout the whole room, although the impression of "tunnelliness" persisted everywhere.

Since the first suggestion of improving the sound quality was inapplicable, the second was tried. The loudspeaker was lowered about 35 cm from the ceiling until it touched the monitors and the angle adjusted until it again faced the sound supervisor.

It was immediately obvious on listening that the sound quality had greatly improved in the normal monitoring position and furthermore that it did not vary substantially with position and was acceptable throughout the whole room.

A further response/frequency curve was taken at the monitoring position with the microphone in the cardioid condition. It was observed that the irregularities in the 500 Hz to 2 kHz region had almost disappeared, and that even those at high frequencies had been somewhat reduced. As a matter of interest, it was not possible even on careful listening to attribute any effect to these latter irregularities and it appears, therefore, that the ear is more tolerant in this frequency range.

Enough has been said to show that, far from all loudspeakers working better in a corner, this position is to be avoided for direct radiator loudspeakers whenever possible, if high quality sound is the criterion and not just a loud noise. If such a position is unavoidable, try first to make the distances to neighbouring surfaces appreciably different and if the floor is one surface use a thick carpet. If this measure is insufficient, acoustic absorbent material should be placed on the surfaces involved.

Acknowledgement. This article is published by permission of the Director of Engineering, B.B.C.

REFERENCES


"Digitally-controlled Tape-recorder Pre-amplifiers" (March p.127). In Fig. 2, $T_a$ is n-p-n and should be drawn as is $T_{11}$. In Fig. 4(b) $D_b$ should be inverted and $C_{43}$, $D_{1}$, $D_{2}$ and $D_{3}$ should share a common connection. In the caption to Fig. 4(a) and in Fig. 5 it is suggested that diode JN914 is a germanium type while it is actually a silicon planar device. Four such silicon diodes should be employed ($D_{a} = D_{b} = D_{c})$ to give $V_{ce}$.

The following amendments should be made to the article "80-metre S. S. B. Receiver" by W. B. de Ruyter which appeared in the March issue: $R_{2}$ should be connected to the a.g.c. line and not chassis as shown and the values of $R_{2}$ and $R_{1}$ should be interchanged.

Two corrections should be made to the article "Pulse Generator using Integrating Circuits" by C. Djokic (March p.130). The variable resistors in the output amplifiers (Fig.4) should be connected across the power supply as potential dividers with the wipers connected to the upper end of the 470 $\Omega$ resistors, and gate C pin connections should be altered to 5 and 6 as per Fig. 6.

"Simple Linear A.C. Voltmeter": A printer’s error in G. W. Short’s letter (March, p.113) made nonsense of his correction. The oblique stroke was again omitted from the expression $R_{1} = (V_{CC} - V_{CE})/I_{C}$.

"Pickup Characteristics" (December, p. 553): The stylus supplied with the Bang & Olufsen SP10 cartridge is spherical (0.6 thou) and not elliptical.

Corrections

& Amendments

We regret the need to draw readers’ attention to the following amendments and corrections to recently published articles.

L. Ibbotson writes: My attention has been drawn to an error in question 15 of "Test Your Knowledge" No. 20 on Colour (January issue). The supposed correct answer, (Bd) is wrong in the following particular. The three spectral wavelengths quoted were selected because the triangle on the chromaticity diagram with these as apices includes the largest pos-
An Electronic Dice

Design for a digital novelty, the final details of which are left to the reader

by Brian Crank*

A chance remark made at a game of snakes and ladders led to an interesting excursion into logic design. The dice had fallen off the table and as people searched the floor for it someone said “At least in this house you would think that there would be an electronic something to save all this trouble”. Later the possibilities of making an electronic dice were investigated.

The circuit must have six stable conditions or states, each state corresponding to one of the sides of a dice as shown in Fig. 1(a), and it must be capable of selecting anyone of these states at random. In practice the random element is provided by a high-speed multivibrator.

The groups of spots on the sides of the dice can be made up by using one, or by superimposing more than one, of the four patterns given in Fig. 1(b). There are several ways in which these patterns can be displayed. One possibility is to use seven lamps, one lamp for each spot; in this case all the lamps to form a particular pattern in Fig. 1(b) would be connected in parallel. Another solution would be to partially drill the spots in four sheets of Perspex, one sheet for each pattern, and to illuminate them using the edge lighting method employed in some numerical indicators. Finally, fibre optics could be tried. This would entail guiding the light from the lamps along fibre “light pipes” on to some form of translucent screen. (Fibre optic light guides which might be suitable can be obtained from Proops.)

The precise method of display is left to the ingenuity of the reader. However, it has been established that the logic circuit needed to drive the display must have four outputs, that is one output to illuminate each pattern.

Several logic circuits were tried in the search for one using the minimum number of parts. The circuit finally chosen, although very simple, was arrived at after a good deal of effort had been expended. The first stage in analysing the problem is to decide which of the four patterns are required to form the six sides of the dice and to present this information in a logical manner:

<table>
<thead>
<tr>
<th>Dice score</th>
<th>Patterns required</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a</td>
</tr>
<tr>
<td>2</td>
<td>b</td>
</tr>
<tr>
<td>3</td>
<td>ab</td>
</tr>
<tr>
<td>4</td>
<td>bc</td>
</tr>
<tr>
<td>5</td>
<td>abc</td>
</tr>
<tr>
<td>6</td>
<td>bcd</td>
</tr>
</tbody>
</table>

This states the facts but not in a way that is very meaningful. However, from these facts a table can be constructed. In this table a 1 is written when a particular pattern is required and a 0 is written when it is not.

<table>
<thead>
<tr>
<th>Dice score</th>
<th>Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a b c d</td>
</tr>
<tr>
<td>2</td>
<td>1 0 0 0</td>
</tr>
<tr>
<td>3</td>
<td>1 1 0 0</td>
</tr>
<tr>
<td>4</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>5</td>
<td>1 1 1 0</td>
</tr>
<tr>
<td>6</td>
<td>0 1 1 1</td>
</tr>
</tbody>
</table>

Do the first three columns of this table look familiar? If not some re-arrangement may help:

<table>
<thead>
<tr>
<th>Dice score</th>
<th>Patterns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>a c b d</td>
</tr>
<tr>
<td>2</td>
<td>1 0 0 0</td>
</tr>
<tr>
<td>3</td>
<td>1 1 0 0</td>
</tr>
<tr>
<td>4</td>
<td>0 1 1 0</td>
</tr>
<tr>
<td>5</td>
<td>1 1 1 0</td>
</tr>
<tr>
<td>6</td>
<td>0 1 1 1</td>
</tr>
</tbody>
</table>

The first three columns closely resemble

*Assistant editor Wireless World

Fig. 1. (a) The arrangement of spots on a conventional dice; (b) the six scores of (a) can be formed with these four patterns

Fig. 2. The suggested circuit for a digital dice, the method of display is left to the reader, almost any general-purpose silicon transistors may be used.
the Johnson code. For readers who are not familiar with it the Johnson code is as follows:

\[
\begin{align*}
0 & : 000 \\
1 & : 100 \\
2 & : 110 \\
3 & : 011 \\
4 & : 001 \\
5 & : 111
\end{align*}
\]

This code is formed by a counter called a Johnson counter, sometimes known as a switch-tail ring counter. If the pattern requirements can be made to follow the Johnson code the lamps illuminating the patterns could be controlled directly by the counter and no gating at all would be required. Although we cannot reach this ideal solution we can come very close to it.

We will consider only the columns for patterns a, b and c at this stage; column d will be dealt with later.

The first line to depart from the Johnson code is the line for score two. This is 010 instead of the Johnson 001. This means that the Johnson code would have us illuminate pattern c instead of the required pattern b. Examining Fig. 1(b) we find that patterns b and c both show a score of two so it does not matter which is used; 001 instead of 010 can be used, therefore, with no circuit changes.

The other line that needs modification is for score six. This should be 000 in Johnson code instead of 011. If the Johnson code is used no patterns would be shown at all for six, but we require patterns b, c and d to be illuminated. A gate must be employed to detect 000 and light the required patterns. A new table can now be drawn up:

**Dice Patterns**

\[
\begin{align*}
\text{score} & \quad a & \quad b & \quad c & \quad d \\
0 0 0 & : & \text{light b, c} & \text{and d} \\
1 1 0 & : & a & & \\
3 1 1 & : & c & + & A C \\
5 1 1 & : & c & + & A C \\
4 0 1 & : & c & + & A C \\
2 0 1 & : & d & = & A C
\end{align*}
\]

The term AC detects line 000 for score six and illuminates the lamps b, c and d.

A circuit based on the foregoing is given in Fig. 2. The Johnson counter is a standard shift register with the output crossed and fed back to the input. The term AC is formed by a NOR gate fed with A and C. The + AC function for lamps b and c is carried out using two resistors from the output of the NOR gate. Connection details for Fairchild µ L 923 bistables are given although any similar device may be employed.

To "throw the dice" the push-button is pressed and released; during the time that the button is "made" the counter counts pulses from the multivibrator; the score is then displayed.

The Johnson counter has one serious drawback. Three bistables have eight possible states, only six of these being used in the Johnson counter. If on switch-on the counter goes into one of the two unused states it will switch between these states on each input pulse and will never get into the proper counting sequence. This is eliminated by the resistor and electrolytic capacitor shown in the inset of Fig. 2. These cause the preset inputs of the bistables to go positive for a short period after switch-on ensuring that the counter starts at 000. The value of this capacitor can be found by experiment and is not critical.

An experimental lash-up of this circuit was found to perform well. If required more push buttons can be connected in parallel with the one shown in the circuit so that each player may have one.

The logic side of the circuit has been reduced to three bistables, one gate and two resistors. This is thought by the author to be the minimal form of the circuit, but perhaps this is a "dicey" statement as *Wireless World* readers are almost certain to find a better solution?

**Announcements**

Revised dates have been announced for this year's *London Audio Festival and Fair* which will again be held at Olympia. The new dates are October 19th to 24th—the first day being reserved for the trade.

A summer school in applied optics for non-specialists is to be held from June 8th to 19th at Imperial College, London S.W.7. The course fee is £35 and further information and application forms may be obtained from the Registrar.

"Hybrid Computer 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 April 14th. Fee £15.

Marconi Marine has received orders from three Japanese shipyards for the supply of communications equipment, navigational aids and dual radar installations for each of four new ore/oil carriers. The company is also supplying the communications and navigational equipment for *Esso Northumbria*, the largest ship ever to be built in the United Kingdom.

S.T.C. have been awarded a £350,000 contract by the Ministry of Technology for the development and construction of two functional models of a fully electronic access exchange for the Mallard project.

The Solartron Electronic Group Ltd, of Farnborough, Hants, has received an order from the Australian Government worth £2m to design, manufacture and install a combined action information and tactical trainer for the Royal Australian Navy.

An agreement has been signed between Siemens of West Germany and Ferranti Ltd, Edinburgh, according to which these two companies will collaborate on the design, development and production of laser systems for the Multi-role Combat Aircraft (M.R.C.A.) project.

The Channel Electronic Division of LRW Electronics Ltd, Chertsey, has been awarded a £60,000 contract for the supply of 'Safetlink' marine radio telephones by Channel Marine Commercial Ltd.

Link Electronics Ltd, has received a contract from the Post Office, valued at just under £20,000, for the supply of 40 portable waveform generators to be used in conjunction with differential gain and phase testing equipment.

The Aeronautical Division of Marconi has received an order worth nearly £100,000 from Air New Zealand for additional Marconi Doppler equipment to be fitted to their DC8 fleet.

GEC-AEI (Electronics), Leicester, have been awarded a share of a £10m contract for work on the Singapore Government's 'Bloodhound' missile defence system.

GEC-AEI Telecommunications Ltd has received orders worth £750,000 from the Post Office for microwave radio equipment to expand three routes in the P.O. network of high capacity-radio trunk transmission routes.

Microwave Associates Ltd, of Cradock Road, Luton, Beds, have received an order, valued in the region of £40,000, from Sveriges Radio of Stockholm, for mobile all solid-state television relay systems for outside broadcast use.

H. Tinsley & Co. Ltd, Werndee Hall, South Norwood, London S.E.25, will in future manufacture and market the range of air-spaced variable capacitors and trimmers previously made under the "Cyldon" name by Sydney S. Bird & Sons Ltd.

Highgate Acoustics, 184 Great Portland Street, London W.1, have been appointed distributors in the United Kingdom and Eire for the Pickering range of cartridges previously handled by Auraiema.

A new division of Amphenol has been set up to manufacture components under licence from Entrelec, of Villeurbanne, France.

Electroustic Ltd, of 73b North Street, Guildford, Surrey, have been appointed the sole U.K. agent for the 'Silec' range of semiconductors.

Tranchani Electronics (U.K.) Ltd. 17 Charing Cross Road, London W.C.2, have been appointed exclusive agents in Great Britain for the Intersil semiconductor range.

Intertechnique Ltd, Victoria Road, Portslade, Sussex BN4 1XQ, have been appointed sole representatives for the U.K. and other territories for the complete range of equipment manufactured by IGAB of Sweden.

Cole Electronics Ltd, Lansdowne Road, Croydon CR9 2HB, have been appointed sole U.K. agents for the range of contactless solid-state switches manufactured by Rafi Electronic, of Ravensburg, W. Germany.
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The multimeter that's not just a toy but a real step forward in instrument technology.
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You get Amps, Volts, Ohms - a.c. and d.c. - down to 100 microvolts and dual slope integration for noise rejection.
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WW-097 FOR FURTHER DETAILS

Have the experience
News of the Month

Parliamentary affairs committee

The Council of Engineering Institutions has formed a committee which will keep chartered engineers in Parliament informed of developments and opinion within the engineering profession. The committee is made up of representatives from the fourteen member institutions of the Council and members from both Houses of Parliament.

The parliamentary members are: Mr. E. Lubbock, Sir Ian Orr-Ewing and Mr. A. Palmer. The chairman of the committee will be the present chairman of C.E.I., Sir Eric Mensforth, and the electrical, electronics and radio representative will be Sir Harold Bishop.

P.C.M. for B.B.C. stereo distribution?

It is now well known that the B.B.C. is experimenting with p.c.m. for distribution of high-quality sound—the advantages being, of course, the inherently stable characteristics of the system and immunity from noise and distortion in the sound transmission links. In fact, the Corporation has just finished a series of trials of the “sound-in-syncs” system using p.c.m. for television sound (Wireless World January 1969, page 38) between London and Kirk O’Shotts and this is expected to come into service within a year.

Writing in the first issue of B.B.C. Engineering (a journal replacing the Engineering Monographs), D.E.L. Shorter of the B.B.C. Research Department outlines what might be done in applying p.c.m. to monophonic and stereo sound signal distribution. If the stereo signal were applied to the p.c.m. system in the coded multiplex form in which it is required at the transmitter input, he says, it would be unnecessary to have a stereo coder at each transmitter. In the pilot-tone system used by the B.B.C., however, the spectrum of the multiplex stereophonic signals extends to 53 kHz and it would be a formidable task to design a system to accept the composite signal while meeting the requirements for signal-to-noise ratio. Even if this were done such an arrangement would not allow the information capacity of the channel to be fully utilised, if necessary, for other purposes. A more flexible arrangement could be achieved by transmitting the left- and right-hand signals over separate p.c.m. channels, each of which could then be used independently when required. This would also make more economical use of the capacity of the transmission circuit. By using separate p.c.m. channels for the left- and right-hand signals, it would be possible to provide stereo coding in a rugged and simple way at the transmitter if the sampling frequency of the p.c.m. system were 38 kHz. The left-right switching, which is part of the stereo coding operation, could be done on the audio frequency signals appearing in sample-hold form at the output of the digital-analogue converters. The signal resulting from this switching would then need only the addition of the 19-kHz pilot tone and filtration in a simple low-pass filter to remove components above 53 kHz in order to form the standard stereo signal.

This artifice would avoid the need for a conventional analogue stereo coder at each transmitter and would be more economical in circuit capacity than digital distribution of the fully coded stereo signal. However, the use of a 38 kHz sampling frequency would still need some 12% greater capacity in the distribution system than the otherwise satisfactory sampling rate of 33.5 kHz. The higher sampling rate and novel stereo coder are thus of doubtful value.

In the same article, Mr. Shorter discusses the general problem of maintaining the high quality of sound (stereo or mono) in the coding and decoding processes involved in digital distribution. The main problems, it seems, are quantizing noise and distortion from the low level signals. Investigations have shown, however, that the required performance on both counts can be obtained from a 13-bit p.c.m. code using a process of interpolation between quantizing levels. Thus a p.c.m. system is in principle capable of satisfying all the requirements of a high-quality sound signal distribution network which would be able to cope with monophonic and stereophonic signals.

What, not who, is calling

For many people the telephone is the only means of directly communicating with someone else. At the present time a subscriber to the telephone system has at his disposal a vast switching network and he can set selectors clicking in this country, in Europe or in America merely by dialling; a direct pair of wires can be established between one telephone and any other—it does not matter if this

A fully equipped laboratory for the design and manufacture of bipolar micro-circuits has just been completed at Enfield College of Technology. The centre occupies only 750 square feet of floor space and cost about £40,000. The main idea seems to be to involve as many students as possible, in as many process steps as possible, and in projects of industrial value. Courses will be provided at all levels, from technician to post graduate. Special courses can also be devised to meet particular needs, such as those of company managers and salesmen. Details of the three two-week practical courses to be held this year can be obtained from J. B. Butcher, Director, Microelectronics Centre, Enfield College of Technology, Queensway, Enfield, Middx.
connection be over land lines, submarine cable, satellite or microwave link.

Computers now chatter to one another over the telephone and many firms send picture facsimiles to and from equipment associated with a telephone. However, for the majority of users the telephone is only a means of voice communication; a fact which means that the telephone system is largely being wasted at the present time.

Perhaps the most important additional use of a telephone would be as a computer terminal. This opens up a vast number of possibilities, too many to go into here, that could place at the disposal of subscribers huge amounts of information. Such a system could hit the printing industry hard, and who knows, in years to come you may receive your Wireless World on a c.r.t. display associated with a telephone—with optional line printer of course!

You may wish to switch on your central heating or cooker when you are away from home; this could easily be done by dialling a code on your telephone after connection has been established; and so on and so forth.

The present method of dialling, the Strowger system, does not lend itself to being used in any of the above ways. Before additional services could be provided it would be necessary to go over to the push button method of dialling using tones instead of pulses. The main advantage of the touch-tone system is not a question of novelty or aesthetics it lies in the fact that the push-buttons can be used to send codes after the appropriate number has been dialled.

Unfortunately push-button telephones require special exchange equipment. The Post Office say that this equipment will be installed over the next few years, in fact the Post Office already use push-button telephones in some of their buildings.

The telephone can be used as a means of sending huge amounts of information to a household, it can also be used as a means of extracting data from that household. In fact Bell Labs in America are running a pilot scheme at Holmdel, New Jersey, which reads domestic gas and electricity meters by computer over telephone lines. The computer "dials" the consumer’s telephone number and is connected via special exchange equipment, which prevents the telephone bell from ringing, to transducers attached to the meters. The computer, on receiving the readings, carries out all the necessary accounting and recording. The process does not interfere with the normal operation of the telephone in any way.

Although all the above is technically feasible, and the main problem is one of economics, one is bound to ask if the meter reading system is socially acceptable. Apart from possible “big brother” implications many consumers rely on a chat with the “meter man” to gain some idea of what their bill is likely to be. In many areas, with modern high-speed computer processing, there is a gap of about a month between the meter being read and the bill arriving. This gives consumers time to prepare; with the proposed system there would be no early warning.

Tracking vehicle movements

An experimental computer control system designed to simplify and improve the operation of large vehicle fleets has just been demonstrated by Marconi to senior representatives of the London Transport Executive. Centred on a Myriad computer, the system is capable of continuously locating and identifying every vehicle throughout a network, presenting this information on a display screen, and immediately detecting any variations from schedule. This is done automatically without any involvement on the part of the vehicle driver. Additionally, it provides voice communication between the control centre and driver so that fresh instructions may be passed as and when necessary.

Each vehicle is fitted with a distance digitizer which counts the revolutions of its wheels, and therefore measures, digitally, the elapsed distance along a particular fixed route. Vehicles are also fitted with a radio telephone, adapted for two-channel operation, and a telemetry unit.

Digital information from each digitizer is passed into a register and is continuously updated at a prescribed rate—typically this might be every 25 feet of elapsed distance. The control room computer can interrogate any register, via the telemetry channel of the radio telephone, and the total elapsed distance count currently held in it will be passed over the link. This data is processed by the computer and displayed on the screen of a cathode-ray tube controlled by it. The display can take one of two basic forms. The route can be represented by a pair of straight lines, one for each direction, with prominent features such as fare stages identified. A vehicle is then continuously represented by a symbol at its current position on the route.

Alternatively, a second method of display allows all the vehicles in a particular area, a city centre for example, to be shown on a map electronically drawn on the screen.

The control room computer can be programmed to provide a number of other facilities. It can compare actual running times with those scheduled, and warn the operator if significant discrepancies are occurring. It can also generate a typewritten log of a day's operation, highlighting any "out of schedule" running, and can provide this sort of "history" for longer periods as well. Additional information such as crew meal break schedules may also be held on disc.

Finally, the radio telephone can easily be switched from the telemetry to a speech channel, to allow fresh instructions to be passed to drivers, or to allow emergency calls from them to base.

Sykes-Robertson (Electronics) Ltd. came into being in February 1968, mainly as a result of proposals made to Mr. J. Sykes, an electronics engineering consultant, who went to Sanday (Orkney) to escape the hurly-burly of the South of England. The idea was to find interesting work, mainly for youths and girls who otherwise would have to leave their homes and families to seek employment in the South. The scheme has been a success and the firm, working in a former school and school-house, is currently manufacturing and exporting electronic equipment mainly in the civil and military fields. A recent despatch from Sanday is a high-quality language laboratory for Hong Kong which is shown in the photograph.

University to industry, bridging the gap

A new four-phase sandwich course, lasting one year, is to be introduced by Birmingham University in October 1970. The first in a new series, this course has been developed on the principle that industrially related M.Sc. courses should be designed to bridge the gap between university and industry. It has been designed by several of the leading electronics companies in close collabora-
tion with the University and is sponsored by the Conference of the Electronics Industry, with the support of the Ministry of Technology, the Engineering Industry Training Board, the Science Research Council and the Electronic Engineering Association.

The electronics industry has been concerned for some time over the difficulty of training high-grade systems engineers in the fields of radio communications and radar technology. Normally, each student will be sponsored by a firm in the electronics industry, which, with the assistance of the Science Research Council and the Engineering Industry Training Board will provide his salary and pay all his fees.

Features of the course are that a high proportion of the lectures will be given by people from industry and that the lecture periods have been designed in the form of "modules", each of about three to four weeks' duration which will be available to industry to use as short up-dating courses.

This presents a unique opportunity to graduates to enjoy an intensive course of study and training in industrial research and development while receiving the salary of a full-time staff member of the company by which they are sponsored. The two industry centres for the first year of the course are to be at the Marconi Company in Chelmsford and the Plessey Company at Ilford.

The normal entry qualifications are a first or second class honours degree in electronics, electrical engineering, physics or mathematics or an equivalent qualification "with experience". For further information contact the Post-Graduate Admission Tutor, Department of Electronic and Electrical Engineering, University of Birmingham, P.O. Box 363, Birmingham, 15.

NEW COMPUTER TYPEFACE

A new computer typeface, shown above, has been chosen as the in-house style of Marconi-Elliott Computer Systems Ltd. The typeface, which is based on a square and has no curves or diagonals, makes the design of automatic readers a simpler task; it can also be easily read, even by the untrained eye, and it is not difficult to print by hand.

Keeping passengers informed

Nelson Tansley, in co-operation with Southern Rail's signal and telecommunication engineers, have developed a public address system which has been installed along the fifty miles of line between Woking and Southampton airport. In this system there are three control points; taking the one at the signal box at Basingstoke as an example, the signalman can address any of the five Basingstoke platforms and/or the "up" or "down" platforms at any of the four other stations under his control (Hook, Winchfield, Fleet and Farnborough).

The system employs two pairs of audio cable that already existed along the line. A signalman presses a button corresponding to the particular platform, at the required station, he wishes to address. All four wires are used to send a parallel digital address code which selects the p.a. equipment at the required platform. If the p.a. equipment is not already in use a cable pair is released from the addressing task and is used to inform the control point that this is so. The signalman can then make his announcement. The communication system employs a 20kHz f.m. carrier which is amplified at each remote point and then passed on to the next point.

The circuit is arranged to automatically provide a warning should any part of the transmission path be interrupted.

Post-doctoral research fellowships

The Science Research Council has announced a new scheme of post-doctoral fellowships for outstanding young British research workers to enable them to devote the whole of their time to original and independent research. Under this scheme, starting in October, there will be about 25 awards of much higher value than the 40 awards made last year.

Selection will be based on ability and independent achievement. Graduates in the U.K. may, with the approval of their head of department, apply to S.R.C. for research grants. The new fellowships, which will normally be held for a period of two years and which will be worth between £1,450 and £1,800, will be tenable at institutions in the U.K. or abroad acceptable to the Council—these include universities, colleges and government or industrial laboratories—which can provide the facilities necessary for the proposed research.

Component distributors association formed

With the primary objective of "defining clearly the role that the distributor plays in the chain of events from the creation and production of a product to bringing it to the market place", nineteen companies have formed the Association of Franchised Distributors of Electronic Components (AFDEC). Prime mover was Waldo Thorin, of Celdis Ltd, who called a meeting in February attended by 48 representatives of electronic component distributors. Following the election of a preliminary council with Mr. Thorin as chairman, objectives of AFDEC were discussed including its relationship with the Ministry of Technology and other associations such as the Radio and Electronic Manufacturers' Federation.

Domestic receiver deliveries

The British Radio Equipment Manufacturers' Association has released details of the total disposals of receivers to the trade during 1969. In the list below the 1969 figure is followed by the 1968 figure in brackets and the percentage change. Totals given should be multiplied by 1,000.

Radio receivers 737 (1,025) - 28%; car radios 340 (388) - 12%; radiograms 201 (226) - 11%; monochrome television receivers 1,673 (1,753) - 5%; colour television receivers 154 (121) + 27%.

The highlight during 1969 was, without a doubt, the colour television disposals which showed a large increase, particularly in the last four months of the year.

The Electronic Industries Association of America has also produced results for 1969; these are presented as above, however a multiplication factor of one million should be applied.

Radio receivers 9.7 (11.8) - 17.7%; car radios 10.1 (10.7) - 4.5%; monochrome television receivers 5 (5.5) - 10.4%; colour television receivers 5.5 (5.8) - 7.6%.

It is interesting to note that of the 39.4M radio receivers sold in America in 1969 only 4.7M were home produced.

Wildlife tape recording competition

The European Broadcasting Union felt that the European Conservation Year 1970 was an ideal time to recognize the importance of wildlife sound recording, so, at the suggestion of the B.B.C., it decided to sponsor a wildlife tape recording contest. The competition is open to all living in Europe and Iceland.

There will be four categories and the winner in each will receive a "silver nightingale trophy" and the runner up a "bronce nightingale trophy". An outright winner will be chosen from the category winners who will be presented with a "golden nightingale award". Enquiries for entry forms and rules should be addressed to the Wildlife Sound Librarian, B.B.C. Natural History Unit, Broadcasting House, Whiteladies Rd, Bristol BS8 2LR.

Travelling award

The Royal Television Society invites applications for the 1970 John Logie Baird Travelling Award which has been increased this year to £500.

What they say

"It wasn't until I joined the B.B.C. that I learned that the Heaveiside layer was not the top brass at Broadcasting House!"—Lord Hill, chairman, B.B.C., speaking at the I.E.E. annual dinner.
Letter from America

Sales of recorded stereo tapes accounted for approximately 26% of all recorded music sold in America during 1969 and should increase to 35% in 1970, according to Donald Hall, vice-president of Ampex. He went on to forecast that tape sales would equal sales of discs by 1972 or 1973.

At the moment, 8-track cartridges are still more than holding their own with 74% of the sales, followed by 15% for cassettes. There is no doubt that cassettes will gain in popularity and eventually overtake the 8-track cartridges which are mainly used in car-players. North American Philips confirm the rapid increase in popularity of cassettes and a spokesman said "Cassette equipment represents the fastest growing segment of the home entertainment industry — and it will gain a further impetus when cassette players are fitted to the new 1971 cars". Incidentally, nearly 10 million car radios are sold in the U.S.A. every year — more than the sales of domestic radios!

Before leaving the subject of sales — a few words about television. Last year colour sets sold just over 5 million — about 10% more than black-and-white. RCA have just announced plans to build a 20,000-ft plant in Mexico for the manufacture of colour tubes, and a larger one in Puerto Rico which will concentrate on shadow masks. One of the new RCA portables features a remote control unit which "gives instant shut off without need to turn down the volume control first". This is accomplished with a "computer-tested integrated circuit amplifier". The automatic fine tuning is also "computer designed"!

Meanwhile, that flat television screen is still just around the corner and the latest contender in the race is International Devices Ltd., of Fort Erie in Canada, who say they will have a flat-screen receiver in production by the end of the year. An electro-luminescent coated screen is used with vertical and horizontal potentials applied by an XY grid. It is claimed that picture brightness has been achieved up to 25% better than on standard colour TV sets now on the market. According to the company president they are only working with colour because "black and white is more difficult" and he is reported as saying that screen sizes up to 36 by 50 inches would present no problems.

Much work is going on behind the scenes with video cassette recorders and Capitol announced recently that they had one on the drawing board awaiting the establishment of industry standards. They stated that "a cassette television programme of a half hour or full hour would probably sell for about $30 ( £12 10s.) and they also forecast a TV programme rental library system. The Capitol unit is simply wired to the aerial input of the home television set, and then all the user has to do is to insert a cassette and he can watch his favourite programme as many times as he likes.

Big news in the Hi-Fi world is the introduction of 4-channel stereo sound, or Quadrasonics. With present techniques this involves the use of two broadcasting stations but stations in Boston, New York and in other parts of the country have been pairing up to broadcast live concerts and tapes (made by Vanguard) and so have created considerable interest. True, there was some (predictable) criticism from a few sceptics who believe the whole idea is a gimmick thought up by speaker manufacturers or tape companies, but the majority of people who have heard 4-channel sound have been most impressed. How are the microphones placed? Well, for the initial Boston experiments (with the Boston Symphony Orchestra) two microphones were in the usual stereo positions and two more were placed at the rear. One station carried the signals from the left front and left rear and the other from the right front and right rear. This unusual arrangement was in the interests of compatibility but recently the organizers had second thoughts and now one station transmits the signals from the front pair and the other station from the rear two. Not compatible at all, but I wonder how many complaints were received?

It is claimed that 4-channel stereo is much more immediate, more exciting than 2-channel (you could not use it as background music) and some enthusiasts are even saying "the difference between 4-channel and conventional stereo sound is greater than between 2-channel stereo and monophonic reproduction". It is certainly true that room acoustics become less important and there is a greater feeling of being at the actual performance. Some of the demonstrations feature large orchestral works where the rear channels supply most of the reverberation and this does help to give that 'you are there' feeling. However, I believe opera and drama will gain the most from the extra dimension. On the other hand, many contemporary composers are very enthusiastic about the possibilities and Henry Brant finds it ideal for his "space music". In a recent recording session at the large Eastman theatre, no less than five different groups of performers were used, on stage, in the balconies and in the aisles.

If Quadrasonics becomes popular, what are the record companies going to do about it? You may be sure they are not ignoring it and several companies are busily working on 4-channel discs using multiplex systems and it is rumoured that some will be demonstrated at a meeting of the Audio Engineering Society in New York very soon. It is obvious that it is not really feasible to use two separate broadcasting stations (except for experimental purposes) and so various schemes have been proposed that will allow 4-channel transmissions from one station. One of the most practical involves a multiplex arrangement and it is described by L. Feldman in Audio for January 1970. The only disadvantage is a slight loss in bandwidth of the rear channels but this may have to be accepted. Tapes, of course, present no problems and several recorders are now available with stacked heads. Scott brought out a Quadrasonic receiver in December but the majority of manufacturers are waiting to see what happens before they commit themselves. Among them curiously enough is Acoustic Research (AR) who have played a large part in organizing the Boston experiments.

G. W. Tillett

Our contributor George Tillett has been appointed editor of "Audio". Since going to the U.S.A. five years ago he has successively been director of engineering in the Pennsylvania plant of Fisher Radio Corp. and executive vice-president of Audio Dynamics Corp. Prior to leaving this country he had been with Daystrom, as chief engineer, and laterly with Wharfedale as technical director.
SONEX 70

Exhibitors at the forthcoming London Hi-Fi Show

With the transfer of the annual London Audio Festival & Fair from a hotel setting to Olympia and from the spring to the autumn there has apparently been agitation by some manufacturers for a spring show similar to those run first at the Waldorf Hotel (under the auspices of the defunct British Sound Recording Association) and latterly at the Hotel Russell. As a result the Federation of British Audio formed a company—British Audio Promotions Ltd—to organize a specialist hi-fi exhibition. The first of what is planned as an annual event, is to be held for four days (April 23rd-26th) at the Skyway Hotel, near London Airport, Heathrow. Each of the 50 manufacturers taking space at ‘Sonex 70’, as the exhibition is called, will have an individual hotel room for demonstrations. One advantage of the Skyway Hotel is that, because of its proximity to the airport, all the rooms are sound proof. The list of manufacturers exhibiting is given below.

It is encouraging to note that although the show is sponsored by the Federation of British Audio, there are a number of overseas names among the exhibitors.

The show will be open from 11.00 to 21.00 on each of the first three days. On the last day (Sunday) it will open at 11.00 but close at 18.00. Admission on the first day is restricted to the trade. Tickets for the other days are obtainable free from exhibitors, audio dealers or the exhibition organizers British Audio Promotions Ltd., 49 Russell Square, London W.C.1.

In our June issue we plan to include a more detailed account of some of the new products, a few of which are illustrated here.

Manufacturers at the Show

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Goldring’s G.850 stereo magnetic cartridge costs £6 10s and is designed to operate at a playing weight of between 2 and 3 1/2 gm. The stylus has a 0.0007 in diamond tip.

The XV-15 series of Pickering magnetic cartridges range in price from £15 15s (XV-15/100) to £39 (XV-15/750E). Some units have spherical and others eliptical styli. A groove-cleaning brush is fitted to each cartridge.

A reverberation amplifier, the SR202, from Pioneer enables controlled reverberation effects to be added to recordings that are judged to be too dry or dead. The system employs two time-delay circuits and the output is claimed to be free from peaks. The price is £45 9s 11d.
Measuring crossover distortion

Even by allowing Mr. J. F. Golding his margin of decibels by calculating-out the noise up to a level 3dB above that of the t.h.d. ("Letters" March 1970 issue), his 57dB s/n ratio amplifier turned down from maximum power to 10mW by means of the volume control would—based on 10W maximum power—permit easy measurement of little less than 0.5% t.h.d. Not easily down to 0.1% as stated by Mr. Golding in his letter. The reason for this, of course, is that the noise of the power amplifier although relatively small is significant. The full-power s/n ratio would not be retained at the low power, for this implies that the ratio of noise relative to full power is enhanced in exactly the same ratio as the power is diminished. In reality, while the output power is reduced from maximum by, say, 30dB by turning down the volume control, the noise yield at the output rarely falls by more than 10 to 15dB over the same volume control range. Obviously, the noise of the pre-amplifier section passed by the volume control adds to the noise of the power amplifier by a square law.

I initially test at maximum setting of the volume control because some pre-amplifiers tend to veer towards non-linearity more easily than may be appreciated. Moreover, the control might affect the frequency response either unintentionally or purposely (e.g., fixed 'loudness' action lifting treble and/or bass as the control is turned down), and the maximum setting ensures that an established test datum level can be quickly repeated, not always as simple as it may seem, by using the amplifier's volume control. Nevertheless, subsequent to exploratory tests there may be merit in rechecking at low-volume-control settings and when so warranted I do this. It is also noteworthy that the noise decrease at the output, on turning the volume control right down to minimum from maximum, can be quite small, depending on the nature of the volume control circuit and the noise performance of the circuits either side.

Mr. Golding fails to specify the wave analyser which provides the 3,000:1 input noise bandwidth to filter bandwidth, but I am sure he will agree that the readout of such low-level distortion components as implied by his dB values relative to a low impedance output load is not exactly an 'easy' matter. I have found that an s/n ratio improvement of about 30dB based on a 10W 8-ohm 80dB s/n ratio amplifier running at 0.1mW allows a threshold readout little better than 0.1% selected harmonic. For ultimate measurements deep into noise one has to adopt phase detection and correlation techniques, the latter allowing useful signal indication up to 60dB deep in noise.

T.H.D. is a popular way of amplifier distortion appraisal in spite of all the other more sophisticated methods. It is less costly and less time consuming than analysis of individual waves. It is ideal for speedy distortion comparisons, and with a 'scope attached to the readout the knowledgeable operator can quickly glean useful information about the nature of the distortion and observe crossover artifacts if they exist. Treble-end performance can also be highlighted and the presence of odd-numbered high-order harmonics is revealed to the owners of both sensitive and cloth ears.

GORDON J. KING, Brixham, Devon.

V.H.F. services

I was touched to notice in his March contribution that "Vector" has been studying the wisdom of the ages. Now that my friendly neighbourhood tower crane has moved away I think I was probably right in 1947 to urge a more detailed study of pulse modulation. But after all, was it in 1933 that the quite successful tests of single sideband and carrier were made from Daventry? And where did they lead us?

Two other articles of the period still have some interest. The f.m.-a.m. controversy was bedevilled by the statement in the House of Commons by the P.M.G. of the day that no discussion could fruitfully take place until he had considered an entirely new system of modulation. He did not tell the Post Office engineers what it was. He did not tell the BBC engineers what it was. But it was entirely new and there was a change of Government and when his party came back they didn't make him P.M.G. So we shall never know.

Another topical article followed, I think, my discovery that at Copenhagen the British contingent regarded engineers and foreign office staff as Falstaff saw bread and wine.

Without going into details we can split music into three classes: pop, palm court and proper. Land-lines need not be rationed, so that by using synchronized carrier only a small number of m.f. channels need be locked up to provide three European music programmes. The remaining channels are available for speech programmes, which are essentially national or local. Any country getting two or three national channels then would offer a choice of five or six programmes, even though its share of the production costs of the three common programmes would be small. The only trouble is that this solution provides the most listening, not the most jobs.

A final memory is of a letter, circa 1946, urging that television services should not be resumed. As an engineering problem the transmission of moving pictures was worth doing, because it was there. But there would never be the talent to produce 30 or 40 hours of programmes a week. How right I was.

THOMAS RODDAM

Theoretical and measured response

While musing on the operation of the tone circuitry in the pre-amplifier designed by Dr. Bailey, I did a few mental calculations, and was interested to note an apparently large discrepancy between the measured and theoretical treble response curve.

Fig. 1. Circuit of tone control.

Consider Fig. 1. At high frequencies all capacitors can be assumed low impedance, and in the limiting case, zero impedance. So for maximum treble-setting the high-frequency gain asymptote can be calculated if it is assumed that the two arms of the network are acting operationally. The limiting high-frequency equivalent circuit of Fig. 1 is shown in Fig. 2.

So the high-frequency gain asymptote is given as below:

\[ G = \frac{1.2 + \frac{21 \times 10}{21 + 10}}{2.2 + \frac{1 \times 10}{1 + 10}} = 3.1 \]

So \[20 \log G = 8.2 \text{ dB} \]

This value of \( G \) is about 10dB less than the apparent high-frequency asymptote given by Dr. Bailey. I would like, with
respect, to suggest that perhaps the frequency response curves given were measured before the output attenuator \( R_1, R_2 \) and the input resistor \( R_3 \), were added. These are respectively included to increase the overall gain of the circuit to about 2, and as load impedance to match the treble filter which feeds directly into this stage.

Similarly my treble controls are nearly always ‘flat’ and I use only a small amount of bass boost to make up for dynamic levels in playback. For my part I cannot see the need for \( \pm 20 \text{dB} \) variation in controls, but I must agree that it looks better on a specification than say \( \pm 12 \text{dB} \).

Perhaps this is the reason why only one or two people have queried the performance (and then only h.f. boost). However it becomes obvious from Mr. Quilter’s deductions that the two end-stop resistors of 1k \( \Omega \) on the treble control are redundant. Also the 2.2k \( \Omega \) resistor \( R_3 \) should be 1.2 k \( \Omega \) for accurately balanced controls.

All this goes to show how simple modifications for one purpose can seriously modify the performance of a circuit in other directions. Many thanks Mr. Quilter, for a very useful lesson in the value of fully analysing the effects of modifications.

Arthur R. Bailey

Capacitor-discharge ignition

During the last five years I have been interested in electronic ignition systems and after seeing Mr. Marston’s article in the January issue of Wireless World I am prompted to write offering several comments on my own experiences.

In winter sub-zero conditions, the battery may drop to as low as 7V with a big engine and can rise to 15.5V under alternator charging. These limits are very severe on any ignition circuit, and accordingly in this continent [America] nearly standard ignition systems consist of a 1.5V ignition coil and a 1.5V series ballast resistor. While starting the ballast resistor is shorted out and the system gives fantastically good cold-weather starting. I doubted whether Mr. Marston’s self-regulating converter would regulate well over a 2 to 1 voltage range, so I set about constructing his converter with a 17V 2A transformer that I happened to have brought back to Canada from a recent two-year stay in Cambridge. It has 210-220- and 240-volt primary taps. After rewinding two times 65 turns (the original had 136 turns) the converter put out about 500V in an ignition circuit with identical high-voltage components to Mr. Marston’s circuit! There were rather large spikes at the transistor collectors and even at a very low sparking rate (induced manually) the voltage went down to 400V quickly. It seems the spikes do not have much energy to charge the 1\( \mu \)F discharge capacitor. At 10V d.c. input, the output was still 400V unloaded but this dropped to 300V at a low sparking rate. At 7V d.c. input the spark was inadequate. Mr. Marston’s circuit may have regulated better (no two transformers are alike) but I feel such circuit action is not desirable where reliability is necessary.

My friends and I have solved low starting voltage problems in several ways. One friend designed his system for 500V with 15V d.c. input, and this suffices until the battery falls below about 8V. Another friend uses a relay to switch in extra secondary turns on the converter transformer only during starting. My own solution is to add across the s.c.r. a large electrolytic capacitor in series with a 10- \( \Omega \) 2-W resistor. The converter is a high-frequency unit (\( \sim 1\text{kHz} \)) with no spikes, which supplies 400V with 15V input. When the ignition key is first turned on, the capacitor (\( \sim 40\mu \text{F} \)) charges in a fraction of a second to \( \sim 400V \), and the first 30 sparks are good and hot, no matter what the battery voltage.

Another serious problem is caused by the ballast resistor. After an ignition pulse, the converter again charges the discharge capacitor, causing typically several volts drop in the resistor. When charging ceases, the increasing voltage applied to the s.c.r. firing circuit could initiate a trigger. This has happened to some of my designs in the past and to combat any spurious triggering a 6-V 1-W zener diode was placed across the contact breaker. Any noise on the battery line produced by an erratic regulator will also be squelched by this zener. In Mr. Marston’s circuit, transistor \( T_r \), has an emitter-base breakdown voltage of about 7V, and the zener will also prevent very large base reverse currents which must flow when the contact breaker closes in the circuit as drawn. I do admire the trigger circuit for its positive ability to remove harmful effects of point bounce, and have already adopted it in my own unit.

The last point which I should mention as a purist is that a spark plug fires with lower voltage when the central electrode is negative, due to thermionic electron emission.

Arthur R. Bailey

The author replies:

I was very interested in the letter from Mr. Quilter and his comments on the performance of the tone-control circuit. He is perfectly correct in his deductions and I must confess that the original curves were obtained with the treble filter circuit omitted. For this reason it is better to use the modified circuit where the filter components are bypassed with the filter out.

Personally, I have found that ‘with speaker systems of low resonance (and similar performance pickups), treble filters are unnecessary unless a particularly dreadful recording is being played. ‘Edginess’ in reproduction is nearly always due to defects in speaker and/or pickup transient response—assuming that there is no crossover distortion trouble in the amplifier in use.

Mr. Vanderkooy and I are always due to defects in speaker and/or pickup transient response—assuming that there is no crossover distortion trouble in the amplifier in use.

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Personally, I have found that ‘with speaker systems of low resonance (and similar performance pickups), treble filters are unnecessary unless a particularly dreadful recording is being played. ‘Edginess’ in reproduction is nearly always due to defects in speaker and/or
from the hot electrode. All ignition systems, whether negative or positive earth, operate this way, and this feature should be preserved in an electronic system. A little analysis will show that in a standard ignition coil designed for a positive earth system (many British cars) the SW terminal should be grounded. (Fig. 6 in Mr. Marston's article.)

In conclusion perhaps readers would like to see a final circuit.

**JOHN VANDERKOOPY,**
University of Waterloo, Ontario.

The author replies:

From his letter, it seems that Mr. Vanderkoopy has failed to grasp the operating principles of the converter circuit, and does not appreciate the electrical requirements of an ignition system under cold start conditions.

I can assure Mr. Vanderkoopy that the design of the converter section is such that it is virtually impossible for its output to exceed 414V ± 5%. If higher voltages are obtained, it can only be because T has been given a turns ratio greater than 15:1, or because ZD₁ and ZD₂ are not 27V ± 5% types. If output voltages rise appreciably above the designed value, the s.c.r. (à 400V type) may be destroyed.

The ignition system has been specifically designed to give good cold start characteristics; overshoot regulation is utilized to this end. While it is true that the over-shoot (what Mr. Vanderkoopy calls 'rather large spikes') contains very little energy, this energy is sufficient to meet cold start needs. Typically, a starter motor will turn an engine over at a brisk rate of about 300 r.p.m. under 10V cold start conditions, and at a sluggish rate of only 150 r.p.m. at 8V. The table below shows the measured performance of the circuit under these conditions, and also at 7V cold start: I consider the performance to be adequate under all conditions, and I feel sure that Mr. Vanderkoopy will agree with me if he carries out a little practical research into the subject.

<table>
<thead>
<tr>
<th>No. of cylinders</th>
<th>C, charge voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7V, 150 r.p.m.</td>
</tr>
<tr>
<td>4</td>
<td>260</td>
</tr>
<tr>
<td>6</td>
<td>290</td>
</tr>
<tr>
<td>8</td>
<td>320</td>
</tr>
<tr>
<td>12</td>
<td>237</td>
</tr>
</tbody>
</table>

Finally, I suggest that if Mr. Vanderkoopy's battery potential does in fact fall as low as 7V under cold start conditions, there is something seriously wrong with either his battery, his starter motor, or his choice of lubricating oil; battery potential should in fact never fall below 8 volts, even under the most severe cold start conditions.

**R. M. MARSTON**

Having done some work on this system of ignition may I bring out a few points which may be of interest to readers? The converter transformer can conveniently be one of the centre tapped l.t. types which are on the market. Working backwards a 9–0–9 volt secondary is about right for square-wave working at 12V d.c. and gives a frequency of a few hundred Hz. The capacitor C₂ does need to be a low-loss type, a paper capacitor was found to become very warm at spark rates of 300 per second corresponding to 6000 revolutions per minute with a six-cylinder engine and 9000 with four cylinders. It is worthwhile to include a recovery diode across the s.c.r.: nearly 20% of the energy can be recovered from the leakage reactance on the backswing. Best results are usually obtained with a 6V 'sports' type coil which has a low primary inductance and resistance, the rated voltage of the coil does not matter much with this type of circuit. Putting a "crowbar" across the inverter output at each spark seems rather brutal and I have always used choke charging with an inductance of 3 to 5 henries between the inverter and C₁. The circuit can be simplified by using a small differentiating transformer to produce the s.c.r. firing pulse.

Diode D and the 22kΩ resistor give a delayed recovery to avoid misfiring as a result of contact bounce. The normal ignition capacitor is removed when using this circuit.

I have had an ignition system of this type in use now for some 6 years and 70,000 miles with complete success.

H. HARPER,
Fleet, Hants.

The author replies:

When designing the original circuit I tried to find a standard l.t. transformer that could be used in the system; I ended up with the possibility of using a 9–0–9 volt one, but found that they were generally available in 2- and 4-amp ratings only. Unfortunately the 4-amp type (which is essential for operation up to c.b. frequencies of 660Hz) was found to be physically too large to fit inside the standard chassis in which I built the unit. The 2-amp type was found to give a reasonable performance when used on a four-cylinder engine at speeds up to 6000 r.p.m., but to be inadequate when used on engines with six or more cylinders (the reasons for this should be self evident).

Regarding the use of a diode to give energy recovery on the backswing; D₂ already perform this function in the original circuit.

Regarding the use of a 6V 'sports' coil and the removal of the normal c.b. capacitor; the original system was designed to use the existing coil and c.b. components, thus keeping building cost to a minimum and enabling the ignition to be changed from C-D to normal, and vice versa, with great ease. Mr. Harper's mods nullify these features.

R. M. MARSTON

I have been developing a capacitor-discharge ignition system for some time and I think you may be interested to know how I have attempted to overcome some of the problems mentioned by correspondents.

I have positively prevented s.c.r. latching by doing two things. I have arranged a feedback system to provide the gate drive. This consists of a monostable with a feedback connection from the s.c.r. anode which causes the drive pulse to be switched off as the s.c.r. switches on. This prevents gate drive from latching the s.c.r. I have also used a driver h.t. converter. In this the pulses from the driver circuit are fed through a gating circuit before being fed to the output transistors, driving the transformer. So by using the gating circuit to switch the converter on and off, very fast and reliable turn on, and turn off may be obtained. This facility may also be used to regulate the voltage to which the capacitor is charged by using a comparator to measure this voltage and switch the converter off when the capacitor is suitably charged.

I finally would like to make a few comments about the e.h.t. coil and the contact breaker points. Standard coils are not the best for use with capacitor-discharge systems. A far better coil would be a low-inductance primary, closed-iron type. These offer higher efficiency, higher operating speeds and less need for energy retrieval to recharge the capacitor (that is using the coil's back e.m.f. to charge the capacitor).

Also I believe it would be worthwhile for the more ambitious constructor to try to replace the points with a photo-electric magnetic or reed switch pick-up as points can be quite troublesome when lightly loaded.

D. J. WHITE,
Harborne,
Birmingham.

**Modular pre-amplifier design**

Some users of this design (W. W. July 1969) have found a somewhat higher level of background 'hisst' than had been expected at very low settings of the volume control. Where this has occurred it is usually due to the f.e.t. used as T₄ in the tone control circuit.

A much improved performance in this respect can be obtained by the use of an Amelco 2N4302 or 4303. In the former case it may be necessary to modify the biasing of the f.e.t. to ensure that the drain current is at a suitable level. (The voltage measured at the emitter of T₁ₑ, which is a convenient point, should be somewhere in the range 6–11 volts.)

The adjustment of the f.e.t. bias can be done either by alteration to the 33-kΩ source resistor, or by connecting a resistor of about 3.3MΩ between the emitter of T₁ₑ and the gate of the f.e.t.

J. L. LINSLEY HOO, Taunton, Som.
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Digital Remote Control System

Up to fifteen circuits may be controlled from a remote point with this system

by H. N. Griffiths*

Up to fifteen circuits can be remotely controlled using this system, the block diagram of which is given in Fig. 1. As can be seen the system consists of two units, a coder and a decoder, connected by some form of data link; this could be a pair of wires or a radio transmitter and receiver.

The coder is a pulse generator which can generate a train of between one and fifteen pulses under the control of the switches $S_1$ to $S_{15}$.

Initially the stop and set zero lines in the coder are UP (positive) so that the multivibrator is stopped and the counter is set to zero. Operation of any control switch ($S_1$ to $S_{15}$) earths the stop and set zero lines and the counter starts to count pulses from the multivibrator which will have started. When the counter reaches a preselected state, as determined by the logic network and the operated switch, the inhibit line goes UP and the multivibrator stops.

The decoder counter also counts the pulses from the multivibrator which are sent over the data link. When the multivibrator is inhibited the two counters will hold the same number. The logic network in the decoder now actuates the required control.

It is arranged that when the input to the decoder is UP (no signal) the decoder set zero line is also UP, resetting the counter. On receipt of the first negative edge the set zero line of the decoder goes down and is held down by capacitor $C_2$ so that the counter can accept the incoming pulses.

On release of the control switch in the coder the stop and set zero lines in the coder go UP returning the coder to its initial state and the input to the decoder also goes UP (and stays there) so that the decoder counter also resets. The operated control is now released.

When fewer than fifteen controls are required, the decoder logic network can be simplified. Indeed, if relays are used to operate the controls it is possible to eliminate the logic network by using the relay contacts to perform the decoding logic functions. In such a system (Fig. 2) the relay coils are controlled directly by each stage of the binary counter via the transistor switches (see inset Fig. 3). Fewer relays are required to perform a given number of on-off control functions than is the case when a separate relay is used for each control. The overall reliability of the system is degraded, however, because each control is operated through a group of contacts in series and failure of any one of these will cause at least one control (and possibly half the total number of controls, depending on the position of the fault) to fail. However, the saving in circuitry and the increased simplicity of the system will, in many cases, offset the risk of simultaneous failure of more than one control.

Communication Channel

The simplest form of data link is two wires between coder and decoder. In
Fig. 3. The circuit of the coder (Above) and decoder (Below). If wished the decoder may be used with the relay decoding system of Fig. 2 or with the same AND gate networks as the coder. The inset above gives the circuit for the AND gates. A relay drive circuit for use with relay decoding and an alternative decoder input circuit for use with a relay input are given in the lower inset.
cases where complete freedom of movement of the remote unit is required, a radio communication channel can be used to carry the control information. In fact, the original system was conceived as a means for the remote control of a model via a 27MHz radio link. Since amplitude modulation is used in the prototype, the system is susceptible to impulse interference which may be generated, for example, by the electric motors being controlled. It is therefore essential, in such a case, to incorporate a device which rejects impulsive spikes of short duration and allows the decoder to respond only to the relatively slow rate of the signal pulses.

Erratic operation may also occur if the supply voltages to the integrated circuits are allowed to drop too far below the nominal value of 3.6V. Since the decoder input is controlled by a relay in the radio control receiver, special precautions are taken to eliminate faulty triggering due to contact bounce. A 'set-reset' bistable is therefore interposed between the relay contacts and the counter input (see inset Fig. 3).

Transient operation of intermediate controls may occur when the counter in the decoder is stepping to its final state. One method of eliminating this is to connect a suitable capacitor in parallel with each relay.

The pulse rate in the prototype is chosen to be 20Hz. This is high enough to permit rapid selection of controls but sufficiently low to ensure reliable operation of the relay in the radio control receiver. This relay also provides a measure of impulse interference rejection since it responds to the signal pulses but rejects impulsive 'spikes' of short duration.

**Circuitry**

The circuit is given in Fig. 3. Simple diode AND gates are employed in the logic network. If used with a radio control receiver which employs a relay the alternative decoder input circuit should be used. The decoder may be built with the relay decoding circuit of Fig. 2 or with the same logic circuit as the coder, in this case the outputs of the AND gates are used to actuate the required controls.

Adjustment is confined to setting the pre-set potentiometer in the coder for satisfactory operation. It will be found that a mark-space ratio of 1:2 is about right.

In order to simplify the electronic design and improve reliability integrated circuits have been employed in both the coder and decoder. The coder uses three dual-in-line packages: a dual buffer (multivibrator) and two dual J-K flip-flops (counter). The decoder also uses three dual-in-line packages: a quad two-input gate and two dual J-K flip-flops (counter). The dual buffer (MC799P), quad two-input gate (MC724P) and dual J-K flip-flops (MC790P) are all from the Motorola range of r.t.l. circuits.

The prototype uses printed circuit construction but it is suggested that the first attempt at construction be made by mounting the packages on unclad 0.1-inch matrix Veroboard and interconnecting by direct wiring. Any mistakes are more easily rectified when the direct wiring technique is employed.

![Decoder waveforms](https://www.americanradiohistory.com)
Transients

What happens to an LCR circuit when it's shocked

by Thomas Roddam

Two articles (W.W. February and March) have been devoted to considering the "natural" behaviour of simple circuits containing at most one inductance, one capacitance and one resistance. Even so, only one form of the LCR circuit has been considered, the form in which the same current appears at the terminals of each element. The same kind of result will be obtained for the other form, in which the same voltage appears at the terminals of each element. I do not propose to prove this: the actual solution can be obtained in an easier way and there is a limit to the amount of detailed examination which the editor, the reader and the author will stand.

Natural behaviour is the term used for the current which flows in a circuit when, having managed to get some energy in one of the energy stores, either as current in an inductance or charge in a capacitance, or both, the circuit is left isolated while the energy is being dissipated in the resistance element. We have seen that, as a general conclusion, we obtain a characteristic time for each storage type element in the circuit. If we have an LR or a CR circuit we get the current following the simple decay function

\[ \exp(-t/\tau) \]

in which \( \tau = CR \) or \( L/R \), which we call the time constant. For the LCR circuit the general form depends on

\[ \exp(-t \cdot R/2L) \exp(\frac{1}{LC} \left( \frac{R}{2L} \right)^2) \]

But the we must take both positive and negative signs for the square root term. The interesting case at the moment is when \( L/C > R^2/4 \), which leads to the form

\[ \exp(-t \cdot R/2L) \cos(\omega t) \]

It is usual to take, not \( \tau = 2L/R \), but \( \alpha = R/2L \), the damping constant. Then we have

\[ \exp(-\alpha t) \cos(\omega t) \]

Fig. 1 shows the shape of this behaviour. As we increase \( R \) keeping \( L \) and \( C \) constant, the decay envelope has a shorter time constant, a tighter time scale. In addition, \( \omega \), the square root term, becomes smaller, thus increasing the time scale of the oscillatory wave. If the decay envelope is falling faster than the oscillatory wave it will dominate the situation. This is rather dull, in waveform terms, and will not be discussed until we get to the complex plane. I had, indeed, intended to devote this article to the idea of complex frequency, but when I came to sort out the basic facts I found that transients must come first.

The great problem with the study of the transient behaviour of circuits is that it is complicated and tedious, rather than difficult. There are basically two kinds of transient behaviour. In one, the circuit is given an instantaneous shock, by closing a switch or some other equivalent means, but essentially just hit with a package of energy. We have already the sort of solution we shall expect, although whether it is to be \( \cos \omega t \) or \( \sin \omega t \) or \( \cos(\omega t + \theta) \) depends on how the shock is delivered. The other kind of behaviour arises when we apply an energy source which can produce a continued action. The natural kind of source, which will go on indefinitely, is given by the function the circuit itself has defined, but with an infinite value for the decay time, \( 1/\alpha \). This means simply the common cosine wave, \( \cos \omega t \). We set up the circuit of Fig. 2. After a good few times, the time \( 1/\alpha \) (for the LCR circuit), any energy involved in the starting process will have been dissipated and the system will have settled to the steady state. The voltage across the capacitor will be given by the equation

\[ V_C = \frac{1}{C} \int V_0 \exp(\omega t) - L \frac{dI}{dt} - RI \]

The point of writing \( V_0 \exp(\omega t) \), with the implied operation of taking real parts later, is to make the mathematics have a simpler pattern. The equation is rearranged to the standard form

\[ L \frac{dI}{dt} + RI + \frac{1}{C} \int I dt = V_0 \exp(\omega t) \]

We are going on for ever, so the current will have the same shape as the voltage, or so we guess.

\[ I = I_0 \exp(\omega t) \]

If so:

\[ \int (\omega L + R + \frac{1}{\omega C}) I_0 \exp(\omega t) = V_0 \exp(\omega t) \]

or

\[ I_0 = \frac{V_0}{R + j\omega L + \frac{1}{j\omega C}} \]

\[ V_0 \]

\[ I_0 = R + \frac{1}{j\omega C} = R + jX \]

This general form of Ohm's Law is one we use every day. \( X \) is the reactance and, if \( \omega L > 1/\omega C \), \( X \) is of an inductive kind: if \( \omega L < 1/\omega C \), \( X \) is of a capacitive kind. Because \( I = I_0 \exp(\omega t) \), we can write

\[ I = \frac{V_0}{R + jX} \cos(\omega t + j \tan \theta) \]

\[ = \frac{V_0}{R^2 + X^2} (R \cos \omega t + X \sin \omega t) \]

\[ = \frac{V_0}{R^2 + X^2} \cos(\omega t - \theta) \]

We take the real part of this, giving

\[ I = \frac{V_0}{R^2 + X^2} (R \cos \omega t + X \sin \omega t) \]

If \( X/R = \tan \theta \)

\[ R(R^2 + X^2)^{1/2} = \cos \theta \]

\[ X(R^2 + X^2)^{1/2} = \sin \theta \]

and then

\[ I = \frac{V_0}{Z} \cos(\omega t - \theta) \]

in which \( Z^2 = (R^2 + X^2) \)

The voltage on the capacitance, \( V_C \), is

\[ V_C = \frac{1}{C} \int V_0 \frac{1}{Z} \exp(\omega t - \theta) \]

Fig. 1. The shape of \( \exp(-\alpha t) \cos(\omega t) \) enclosed in the decay curve \( \exp(-\alpha t) \).

Fig. 2. The driven circuit.
The voltage across the inductance is

$$V_L = L \frac{dI}{dt} = -\frac{V_0}{Z} \cdot \omega L \cdot \sin(\omega t - \theta)$$

Notice how, if $\omega L = 1/\alpha C$, $V_L$ becomes zero. In a study of transient conditions we shall see that $I_L$ and $V_C$ are the terms we want.

The usual method of studying what happens when the oscillator signal is switched on is a straightforward affair of formal mathematics, followed by the consideration of a number of particular cases. The variety arises from the fact that we have the natural frequency of the circuit itself, $\omega_0 = 1/(LC)^{1/2}$ (leaving out the damping correction), the damping correction, the frequency of the supply. The drive may be $\omega = \omega_0$ near, or well above or below the natural frequency. The actual switching instant may be when the generator voltage is a maximum, or zero, or somewhere in between. There may even be some current flowing in the inductor, some charge in the capacitor. So, find the general solution and put in the boundary conditions.

When I came to do this I found it was totally incomprehensible. At the end of the process one emerges with an answer, for the specific conditions, but on the way one had no contact with any sort of physical reality. In more advanced circuit work this is normal, and the more advanced the theory the more likely you are to have a large amount of "reality" wrapped up in a single symbol. With tears pouring down my cheeks I scrapped the elegant analysis and began to look for a more direct way of determining the transient behaviour of the circuit. The approach I chose is not in any of the books I looked at, although that is probably my bad luck.

The key to all transient behaviour is the way the free circuit settles down to the rest state. When we looked at its behaviour before we found that the current was of the form

$$I = \exp(-\alpha t) \cos(\omega t)$$

This form does not contain any constants of integration. The voltage on the capacitance is best worked out from scratch. If we start with the capacitor charged, the correct with the way we started with current flowing in the inductor, we get again

$$V = \exp(-\alpha t) \cos(\omega t)$$

By working through the analysis for the two cases in which we consider either fixed current starting and capacitor voltage or fixed voltage starting and inductor current we get expressions of the form

$$\exp(-\alpha t) \sin(\omega t)$$

and

$$\exp(-\alpha t) \cos(\omega t)$$

In general, whatever the starting condition may be, we would expect the function to be of the form

$$A \exp(-\alpha t) \cos(\omega t + \theta)$$

whichever we choose, provided we adjust $\theta$.

We have two constants of integration, which can be chosen to fit the initial current and voltage. Apart from the actual size of these functions, we can always write

$$\cos(\omega t + \theta) = \cos(\omega t) \cdot \cos \theta - \sin(\omega t) \cdot \sin \theta,$$

So that any value of $\theta$ can be realized if we take the right mix of the two curves, Fig. 1 and Fig. 3.

Let us adopt some low trickery. We set our circuit off with a current $I_1$, and a voltage $V_1$, $I_1$ is flowing into the capacitor, so that it will tend to increase $V_1$. Obviously $V_1$ is opposing the flow of $I_1$ and will tend to reduce it. We assume, since this is a fairly normal assumption among the more theoretical treatments, that $\alpha$ is small compared with $\omega$. There is not much difference between successive cycles. So, we began with a total energy of

$$\frac{1}{2} L I_1^2 + \frac{1}{C} V_1^2$$

After a short time, all the energy will be in the capacitance and the current will have fallen to zero. The capacitance voltage will then be $V_{max}$, given by

$$\frac{1}{C} V_1^2 = \frac{1}{C} V_{max}^2 + \frac{1}{2} L I_1^2$$

Thus we can find $V_{max}$.

All this is on paper, so negative time is quite an acceptable thing. At a small value of $r$, with $r$ negative, the curves show all the energy in the inductance, and $V = 0$. At this time

$$\frac{1}{2} L I_1^2 = \frac{1}{C} V_1^2 + \frac{1}{2} L I_1^2$$

As we have decided that we will take the case of $\alpha \ll \omega_0$, then two quantities, $V_{max}$ and $I_{max}$, are very close to the correct values for the envelopes ($V$, $I$)$_{max}$ $\exp(-\alpha t)$.

At this point I began drawing Fig. 4. I mark in $V_{max}$ and $-V_{max}$, $I_{max}$ and $-I_{max}$, and then $V_1$ and $I_1$, I also draw the exponential envelopes.

Now if $V_1$ $V_{max}$ or $\sin(\omega_0 t)$, the voltage wave shape must have crossed the zero axis at $-\theta$. We can measure along from here in angle units of $\pi/2$, or time units of $\pi/2\alpha$ ($\approx 1/4\alpha$). Now we sketch in the waveform. The error in this is always less than

$$\exp(-\alpha t/2\alpha)$$

Because $\alpha$ is small compared with $\omega$, it is tempting to take $\omega = \omega_0$, but this, it would appear to me that it leaves a nasty ambiguity in one of the cases we are now going to study.

The really tricky problem is that of switching on a sine-wave generator in the circuit. We are allowed to simplify it by assuming that the circuit had not recently been disturbed, so that it contains no stored energy. As it happens, the method we are now going to use makes it relatively easy to take account of any stored energy. The applied waveform is shown in Fig. 5, where the switch has been closed at a quite arbitrary point in the cycle. "Typical cases" in the textbooks usually amount to the choice of either switching at cross-over or switching at the peak. A typical case means one which is fairly easy to calculate, and I am not sure if these are, in fact, the easiest. Wait and see.

I am determined to do no more thinking than I need. I know that if I look for the steady state, the current in an $RLC$ circuit from a voltage $V_0$ $\sin \omega t$ will be given by

$$V_0 \sin \omega t = I(R + j\omega L + 1/j\omega C)$$

To make the expressions look simpler we write

$$R + j\omega L + 1/j\omega C = R + j(\omega L - 1/j\omega C)$$

Now choose $\omega_0 = 1/\alpha C$, giving

$$R + j\omega_0 L \left( \frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) \omega$$

If we now write $\omega_0 \left( \frac{\omega}{\omega_0} - \frac{\omega_0}{\omega} \right) \omega = \Omega$, we have

$$I = \frac{V_0}{\Omega} \sin\omega t$$

$$\exp(-\alpha t) \cos(\omega t - \theta)$$

where $\tan \theta = \Omega L/R$. Although this looks like an $LR$ circuit only, we can now have $\Omega$ negative for positive values of $\omega$, whenever $\omega < \omega_0$ in fact. So that this way of writing the result involves a range

$$\omega = \begin{array}{c|c|c|c|c}
\Omega & \omega_0 & -\omega_0 & 0 & +\omega_0 \\
\hline
\infty & -\infty & -\infty & -\infty & -\infty \\
\end{array}$$

The voltage across the capacitor is given by

$$V_C = \frac{1}{C} \int dt$$

$$= \frac{V_0}{C} \int \sin(\omega t - \theta) dt$$

$$= \frac{V_0}{C} \cos(\omega t - \theta)$$

Now we know the two important terms in the steady state solution. Let us adopt a
simple trick. We use two voltage generators,
\[ V_0 \sin \omega t \quad \text{and} \quad V_0 \sin (\omega t + \pi) \]
For one we get some current \( I_1 \), given by the equation above, and a capacitor voltage of \( -V_0 \). The other produces a current \( I_2 = -I_1 \), and a voltage \( V_0 = -V_0 \). They might just as well not be there. Let us now, however, switch off the second generator. This is indicated in Fig. 6. The current produced by

the first generator continues to flow quite unperturbed. The stored energy associated with the second generator is the transient energy, and this sets us the decaying oscillation which we discussed earlier in the article. The formal justification for this method is that the equations are all linear.

If I were writing a rather grand textbook I should at this point begin to calculate a vast variety of examples. One simple way of doing this used to be to invite a selected group of students to lunch, flatter them by asking for unspecified help and then dole out the drudgery. Advances in modern technology make it possible to get one student to do it all on the department computer, and buy his own lunch into the bargain. But let us be realistic. In transient problems with a switched sine wave we normally have one of two situations. Either we don't know the switching phase, as in the ordinary switching on situation, or the phase may vary systematically over a wide range, as in a phase controlled rectifier circuit. We need a picture of the kind of behaviour we can expect. I am well aware that there are occasions when a detailed study of a special situation is required. Such problems can be solved by working out \( I_1 \) and \( V_{C1} \), using the equations just given, and then using these in determining the ring shown in Fig. 4. This is just added to the steady state solution. What sort of an answer do we expect.

First of all, notice that we are concerned with two frequencies, for which I shall use the letter \( f \). We have the generator frequency, \( f_g \), and the frequency of the transient ring, \( f_t \). With \( f_g \) goes the damping coefficient, which is \( \alpha = R/2L \) and which modifies the undamped frequency slightly. For a lightly damped circuit we want \( \alpha < 2\pi f_g \). This does not necessarily mean that \( \alpha < 2\pi f_g \). A circuit with a very low \( Q \), or very high damping, at the working frequency may ring vigorously at its natural frequency. Notice that this is likely when \( f_g > f_t \).

Now we may proceed to pick out a few special situations. Suppose that \( f_g \) is very much less than \( f_t \). When the circuit is being driven by the two opposing generators, the quantity \( \Omega \) will be

\[ 2\pi f_g \left( \frac{f_t}{f_g} - \frac{f_g}{f_t} \right) = 2\pi \left( \frac{f_t}{f_g} - 1 \right) \]

This is very close to \( 2\pi f_g \) the value we should get if we made \( f_g = 0 \). The circuit is virtually that we should get in an RL circuit. It is quite easy to sketch out Fig. 7, which shows the current in the circuit. The switched-off generator leaves current flowing, and this decays exponentially. If we have a low value of \( \alpha \), i.e. \( \alpha < 2\pi f_g \), this exponential would be replaced by a long, slow, oscillation. The two generator sine waves show represent the currents, not the voltages: we can job back to the voltage from the tan \( \theta = \alpha L/R \) equation. Obviously the most important case is when the current is a maximum. It should be noticed that one very important feature of this circuit is that the current must follow a continuous curve. The inductance will always prevent a sharp step in current. Similarly the capacitance will always prevent a sharp step in voltage.

The second example is for the case when \( f_g \) and \( f_t \) are fairly close together. This is a rather tedious one to draw, because a good drawing needs about \( 2\pi f_t/\alpha \) cycles to show the pattern. We set about it as before, though now for \( t > 0 \) we have an exponentially decaying sine wave which does not necessarily have its peak at \( t = 0 \). To draw it properly we must work out the peak from the total stored energy equation and for this we need to draw the capacitance voltage curve too. Physically what happens is this. When the transient situation occurs, the stored energy appears as a damped sine wave of frequency \( f_g \). The generator produces an undamped sine wave of frequency \( f_t \). The two current waves beat together at \( f_t - f_g \) to produce the modulation effect shown more clearly in the sketch of Fig. 8(b). As the ring dies away the current settles to the steady state value. The detail at the beginning depends on the phase of the switch operation. It makes little difference to the kind of response whether \( f_g > f_t \) or \( f_g < f_t \). What is important is that the current may double its normal peak value. It is logical to guess that it is also possible for the capacitor voltage to reach double its normal peak value. Practical circuits in which this kind of transient condition can arise need tougher components than you thought.

At the desk one considers \( f_g = f_t \). The analysis then finds that there are some small terms to throw away, and in the whole process I rather lose track of whether \( f_g \) is the damped or undamped frequency. Anyway, I do not believe in this sort of equality. If we go back to the nearly equal frequency problem, and then say that the beats are so slow that they have died away before the first maximum is reached, we get a normal "soft keying" growth in a straightforward sine wave. Rather roughly, this means that we consider the case where

\[ \alpha > \left( \frac{f_t}{f_g} - f_t \right) \]

Since \( \alpha \) will always exist, we never need to consider \( f_g < f_t \); we just take them near enough together. In this way we avoid any awkward questions about roots of an equation coinciding.

Finally we come to the very interesting case when \( f_g < f_t \); the ring frequency is high compared with the frequency of the drive. This is the kind of situation which is encountered when a mains transformer is switched on or off and the leakage inductance and stray capacitance form the ringing circuit. A feature of this situation is that if it is treated by purely analytical methods the result which emerges is totally unexpected in form. The conscientious student goes back over the analysis to find out just what went wrong. The method we adopt here gives us a direct feeling of the nature of the solution, with no surprises, or perhaps more appropriately, no unexpected shocks.

At the low drive frequency we can more or less ignore the circuit inductance. If the damping coefficient is low enough, we can even ignore the resistance. For this extreme case, the full generator voltage appears across the capacitance. If the resistance is not as low as all that, the voltage is split between capacitance and resistance and it is very easy to calculate the peak value of capacitance voltage. It is

\[ V_C = V_0 \left[ 1 + (\omega CR)^2 \right]^{1/2} \]

Let us consider the extreme case. Let us also assume that the switching instant is when \( V_C \) is a maximum. The energy stored in the capacitance is \( \frac{1}{2} C V_C^2 \). For the transient waveform we have an exchange of energy between capacitance and inductance, and, as we have assumed that \( \alpha \) is very small, the
first current maximum, \( I_p \), must satisfy the equation:

\[
\frac{1}{2} L \frac{d^2 I}{dt^2} = CV^2
\]

Thus \( I_p = V_2(C/L) \).

But if \( \omega_p = 2\pi f_p \), we know that \( \omega_p^2 LC = 1 \).

Then \( C/L = \omega_p^2 C \) and so \( I_p = V_2 \omega_p C \).

The steady state current through the inductance is limited by the capacitance, and is \( I_{L,s} = V_0 \omega_p C \). Taking \( V_c = V_0 \)

\[
I_{L,s} = \frac{f_p}{f_0} \cdot I_{L,s}
\]

It will be seen that the transient current is very large indeed compared with the normal current (Fig. 9). We could have chosen a differ-

![Fig. 9. For \( \omega_p \gg \omega_c \), the current ring is very much larger than the steady state current.](imageURL)

rent switching phase. Had we done so we should have found a smaller value of transient current, which we can work out for any phase by the energy equations. Worst case solutions are, however, the ones which normally interest us.

Very much the same pattern of results is obtained when we study the way a parallel tuned circuit behaves with the switching of a current source. The commonest form here, numerically, is the line transformer of a television set. Here, as in all the variations, we would study the voltage across the capacitance and we know, in the similar but more general form of a transistor with an inductive load, that is energy associated with all the transients. Energy is generally associated with the switching of voltages, because second breakdown is not a linear phenomenon.

More complex circuits can be handled on a piece by piece basis, but the labour involved is often prohibitive. Transients are not normally central to the main problem, and the main problem takes most of our effort. A knowledge of some of the consequences of sudden current to expect, together with a quick calculation of the stored energy which is easy access to the danger points, is normally sufficient. Then, if the situation is potentially dangerous, it is not the oscilloscope.

Nowhere in this article is there any mention of musical transients in amplifiers. This is, of course, a topic of great importance. There are two aspects which make it unsuitable for treatment here and now. Musical transients are not produced by a click-on mechanism, but have finite rise and fall times; they pass through circuits, feedback amplifiers, with a much sharper phase shift characteristic than our single tuned circuit. Anyway, this article is quite long enough.

### Conferences and Exhibitions

Further details are obtainable from the addresses in parentheses.

**LONDON**
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
Atomic and Molecular Physics
(I.P.P.S., 47 Belgrave Sq., London S.W.1)
Apr. 23-26 Skyway Hotel
Sonex '70 HiFi Exhibition
(Federation 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)

**BIRMINGHAM**
Apr. 14-17 The University
Automatic Test Systems
(I.E.R.E., 8-9 Bedford Sq., London W.C.1)

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

**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.)

**READING**
Apr. 6-8 The University
Thin Films Conference
(I.P.P.S., 47 Belgrave Sq., London S.W.1)
Apr. 15-17 The University
Defects in Semiconductors
(I.P.P.S., 47 Belgrave Sq., London S.W.1)

**UXBRIDGE**
Apr. 14-16 Brunel University
Computer Graphics International Symposium
(R. Elliot Green, Brunel University, Uxbridge, Middx.)

**OVERSEAS**
Mar. 31-Apr. 2 New York
Submillimetre Waves
(Polytechnic Inst. of Brooklyn, 333 Jay St., Brooklyn, New York 11201)

Mar. 31-Apr. 3 Paris
Electrical-Electronic Engineering Seminar
(E.E.E. Seminar, 80 rue Jouffroy 75-Paris 17e)
Apr. 3-8 Paris
Electronic Components Show
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15e)
Apr. 3-9 Berlin
Cybernetics Congress
(Deutsche Gesellschaft für Cybernetik, 21 Stresemann Allee, 6 Frankfurt/Main 70)
Apr. 6-10 Paris
Advanced Microelectronics Conference
(Fed. Nat. des Ind. Electroniques, 16 rue de Presles, Paris 15e)
Apr. 7-9 Las Vegas
Reliability Physics Symposium
(K. H. Zaininger, RCA Labs, Princeton, N.J. 08540)
Apr. 10-20 Tokyo
Japanese Electronics Show
(Japan Elec. Show Assoc., Tokyo Chamber of Commerce Bldg., 2-2 Marunouchi 3-chome, Chiyoda-ku, Tokyo)
Apr. 14-17 Washington
Geoscience Electronics Symposium
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)
Apr. 14-19 Frankfurt
Hi-Fi Show
(U.S. Trade Centre, Frankfurt/Main)
Apr. 21-24 Washington
International Magnetics Conference
(INTERMAG)
(D. S. Shull, Bell Telephone Labs, 3300 Lexington Ave, Winston-Salem, N.C. 27102)
Apr. 21-24 Budapest
Microwave Communication Colloquium
(Microwave—Technica Háza Budapest, V. Szabadság tér 17, Hungary)
Apr. 22-24 Dallas
Southwestern I.E.E.E. Conference
(A. P. Sage, Inst. of Tech., S.M.U., Dallas, Texas 75222)
Apr. 27-29 Atlantic City
Frequency Control Symposium
(Electrodynamic Components Lab., U.S. Army Electronics Command, Fort Monmouth, New Jersey 07703)
Apr. 27-30 Los Angeles
National Telemetering Conference
(A. V. Balakrishnan, UCLA, Rm. 3531, 405 Hågård Ave, Los Angeles, Calif. 90024)
Circuit Ideas

H. F. Predictions—April

High-gain f.e.t. tuned amplifier

The reverse transfer capacitance of a field-effect transistor can be employed as a very stable Q multiplier with inherent automatic bandwidth control. Essentials are (Fig. 1) resistive drain and source loads and selection of C, which is smaller in value than a bypass capacitor. C determines the no-signal Q: decreasing the value moves the stage towards oscillation; increasing it has the reverse effect. This circuit, with no additional components, will replace two double-tuned 470-kHz i.f. stages. With a constant current supply it is reproduceable using wide-tolerance f.e.t.s. The response of Fig. 2, after optimum adjustment of C, is a shallow curve, peaking reasonably close to oscillation over the middle third of each band. The detector stage assists in bandwidth control (varying the impedance of D1), and even on weak signals accurate tuning is indicated by wideband quality. For operation at frequencies higher than 2MHz the drain load must be progressively reduced.

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Logic circuit gates astable multibrator

When TR1—the output transistor of a d.t.l. logic stage—is switched off, the current in R1 is very slight and TR2 is effectively off: R1 is chosen so that when TR1 saturates, TR2 saturates thus permitting the multi to function. D1 and D2 are included to prevent base-emitter breakdown in TR1 and TR2 for a large voltage at the collector of TR2: C, is a small capacitor (100pF) included to make the collector circuits of TR1 and TR2 dissimilar: this ensures that the multi will not block. Conventional design theory governs the choice of C, R1, Rp. The circuit functions just as well if R2 is omitted and the base of TR2 is driven from a high impedance source, e.g. the collector of a current-mode switch. For a 5V rail suitable values of R1, and R2, are R1 = 1kΩ and R2 = 2.2kΩ, for current in R1 up to 16mA. Typical low-cost devices which are suitable are: diode IN4148 (G.E.); transistors (Ferranti plastic ‘E’ line) ZTX 500. B. L. HART,
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F.E.T. push-pull oscillator

Wide frequency range LC oscillators are usually Colpitts or Hartley configurations. Higher output can be obtained using a push-pull arrangement. Many thermionic valve circuits have been evolved and n-channel field-effect devices can be substituted without significant modifications. The use of p-channel enhancement devices can however simplify the bias arrangement using no

Fig. 1. Oscillator operating up to 300MHz.

Fig. 2. Arrangement for operation between 50 kHz and 350MHz.

components other than the active devices and the tuning components is shown in Fig. 1. The tap on the coil can be omitted if a pair of chokes or resistors are used to feed f.e.t. drain connections.

The unusual re-arrangement shown in Fig. 2 allows the tuning components to be at ground potential. The circuit is no longer balanced and a resistor (R1) or choke is required.

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Active Filters

9. Synthesis by factors

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

It is shown how a filter may be synthesized as a product of factors, and a number of numerical examples are given.

So far in this series we have dealt mainly with principles. In this article, although some important methods of realization still remain to be described, it is shown how some of the circuits already described can be put to use. The method is that of synthesizing the complete filter as a cascade of 1st- and 2nd-order sections, each with output impedance low enough for its response to be unaffected by the connection to it of the following section. Thus the response of the whole filter is the product of the responses of the individual sections. It is a practical method of design for specifications of moderate stringency, and also throws light on the nature of filters of higher order and their transfer functions.

It is not possible in this series to say very much about the design of filters as such, but an attempt is made in this Part to help the non-specialist reader—partly by calculation, and partly by the use of reference works—to make a start on the design of filters to a variety of specifications.

5th-order low-pass filter with Darlington response

In a conventional wave filter the important characteristic is the steady-state amplitude (or gain-versus-frequency) response. This can be specified, Fig. 1, by three parameters: $A$, the maximum deviation from level response in the pass band; $A$, the minimum attenuation in the stop band; $\Omega_1$—1 the relative width of the transition band, $\Omega_1$ being the start of the stop band in the normalized characteristic ($\omega_p = 1$). And if any two are specified, the work of Darlington shows how to proportion the elements of a given structure to give the best value of the third. The nature of the relationship between the three is that, if for constant $A$, a smaller value of $\Omega_1$ is required, then either a greater ripple in the pass band ($A$) must be accepted or a structure of greater complexity must be adopted.

Thus we may quote from Reference 1 as a representative optimum set of values for the structure shown in Fig. 2: $A_0 = 0.1$ dB, $A_1 = 40$ dB, $\Omega_1 = 1.44$; and the "ladder coefficients"; i.e. the element values for the normalized filter, are given in Table 1. $\omega_p$ being used as the reference frequency, not $\omega_0$ as in the paper referred to.

![Diagrammatic representation of 5th-order Darlington response.](image)

**Table 1**

<table>
<thead>
<tr>
<th>$A_0$</th>
<th>0.1 dB</th>
<th>$A_1$</th>
<th>40 dB</th>
<th>$\Omega_1$</th>
<th>1.44</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\omega_p$</td>
<td>1 radian/second</td>
<td>$R_1 - R_2$</td>
<td>1 ohm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_1$</td>
<td>1.016</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_2$</td>
<td>1.197</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_2$</td>
<td>0.175</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_3$</td>
<td>1.596</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_4$</td>
<td>0.521</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_5$</td>
<td>0.982</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$L_6$</td>
<td>0.857</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$C_3$</td>
<td>0.676</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although of symmetrical topology the filter is not symmetrical, since $C_1 \neq C_1$, $L_2 \neq L_4$, etc. This is always the case in an efficient filter of order higher than three; one reason is that the rejector circuits $(L_3C_3$ and $L_4C_4)$ are tuned to different frequencies.

The five elements in the left-hand column of the table, by themselves, form a 5th-order simple ladder filter and give the transfer function a 5th-order denominator. The addition of the capacitances $C_3$ and $C_4$ does not change this order (although it does change the coefficients of the terms, but the numerator becomes 4th-order. Because $R_1 = R_2$ and the reactances are assumed to be without loss, the voltage ratio at zero frequency is one half. Consequently the transfer function may be written

$$G(p) = \frac{V_m}{V_i} = \frac{1}{2} \frac{N(p)}{D(p)}$$

$1 + ap + b^2 + cp^3 + dp^4 = 2(1 + Ap + Bp^2 + C^3 + Dp^4 + Ep^4)$

(1)

The industrious may find the coefficients by analyzing the network:

$$I_0 = V_m/R_L$$

$$I_1 = V_m/pC_1$$

$$I_2 = I_0 + I_1$$

$$V_2 = I_2Z_2 = \frac{(I_0 + I_1)pL_2}{1 + p^2L_2C_2}$$

$$V_3 = V_2 + V_0$$

$$I_3 = V_3pC_3$$

and so on. It is only fair to give warning, however, that over forty products have to be formed in working out the denominator. The numerator, however, is easily obtained. It is

$$1 + p^2(L_3C_3 + L_4C_4) + p^4L_2C_2$$

and so depends only on the components of the two infinite-rejection circuits. For the chosen example the numerical values of the denominator coefficients are: $A = 2.73$, $B = 4.19$, $C = 4.68$, $D = 2.85$, $E = 1.38$.

For our present purpose the transfer function is required factored. This may be regarded as the mathematical exercise of finding the roots of the equations $N(p) = 0$ and $D(p) = 0$. These roots are the $z_1$, $z_2$, etc., and $p_1$, $p_2$, etc. of the identities

$$N(p) = d(p-z_1)(p-z_2)(p-z_3)(p-z_4)$$

$$D(p) = E(p-p_1)(p-p_2)(p-p_3)(p-p_4)$$

(2)

and are referred to as the zeroes and poles of $G(p)$, since if $p = 0$ of $z_1$, etc. $G(p) = 0$, while if $p = a$ of $p_1$, etc. $G(p) = \infty$. The numerator of the chosen example can be treated generally as it factorizes into

$$N(p) = (1 + p^2L_2C_2)(1 + p^2L_2C_4)$$

(4)

but $p_1$, $p_2$, etc. can be expressed only as particular numerical values:

$p_1$, $p_2 = -0.1080 \pm j1.065$

$p_3$, $p_4 = -0.413 \pm j0.784$

$p_5 = -0.667$

By multiplying together the denominator factors containing the complex conjugates $p_1$ and $p_2$, a 2nd-order factor: with real coefficients is formed,

$$(p^2 + a_1p + \omega_1^2)^2$$

and by writing $p_1$, $p_2 = -a \pm \omega_1$, it is seen that

$$\omega_1^2 = a^2 + b^2$$

$a_1 \omega_1 = 2a$

(5)

(6)

i.e. $a_1 = 2a/(a^2 + b^2)^{1/2}$

(7)

* Royal Radar Establishment.
If the factor is now divided by \( a_1^2 \), which gives

\[
p^2 + \frac{a_1 p}{a_1^2} + \frac{1}{a_1^2} + 1,
\]

it is easily compared with the preferred form

\[
1 + pTq + p^2T^2,
\]

whence \( T = \alpha_1 / \omega_i = (a_1^2 + b_1^2)^{-\frac{1}{2}} \) (8) and

\[
q = \frac{1}{\alpha_1} = (a_1^2 + b_1^2)^{\frac{1}{2}} / 2b_1
\]

(9)

Or, by reference to Fig. 3,

\[
T = \frac{1}{OP}, \quad q = \frac{OP}{20A}
\]

(10),(11)

For the example then

\[
T_1 = 0.9357, \quad q_1 = 4.94
\]

\[
T_2 = 1.073, \quad q_3 = 1.073
\]

and for the real 1st-order factor

\[
T_3 = -1/p, \quad q = 1.499.
\]

Thus the transfer function has been obtained in the form \( N(p)/D(p) \)

\[
= \frac{(1 + pT_1^2)}{(1 + pT_1/q + p^2T_1^2)} \times
\]

\[
\frac{(1 + pT_2^2)}{(1 + pT_2/q + p^2T_2^2)} \times
\]

\[
\frac{(1 + pT_3^2)}{(1 + pT_3/q + p^2T_3^2)} \times
\]

\[
(1 + pT_4^2)
\]

(12)

with parameters as given above, and \( T_2 = \sqrt{L_2C_2} = 0.4576, T_3 = \sqrt{L_3C_3} = 0.6780. \)

The 2nd-order numerator and denominator factors may now be paired arbitrarily to give sections with unsymmetrical notch response, Part 2, Fig. 19. As the highest \( Q \)

factor is not very high, both sections may conveniently be realized by the Sallen-and-

key type of circuit with added parallel-path, Part 6, Fig. 11(b).

Consider the transfer function

\[
G(p) = \frac{1 + pT_1^2}{1 + (1/q)pT_1 + p^2T_1^2}
\]

(13)

and let it be identical equal to the standard form

\[
\frac{1 + apT_1^2}{1 + (1/q)pT_1 + p^2T_1^2}
\]

(14)

Then \( a_1 = T_2^2/T_3^2 = 0.523. \) Similarly for the other 2nd-order section, \( a_2 = T_3^2/T_4^2 = 0.164. \) Hence the schematic for the whole filter may be as in Fig. 4. This gives the relative component values for the case of ideal amplifiers, \( K = 1, A = \infty. \)

Equation (8) of Part 6, which becomes when \( b = 1 \)

\[
\frac{1}{q} = \frac{2aq_1}{A + 1}
\]

(15)

shows that for \( q_1 = 5 \) and \( A = 1000 \) the

ideal component values would give an actual \( Q \) approximately 5% low, and that if compensation is made by increasing the ratio \( C_i/C_r \), the appropriate value of \( q_0 \) is 5.28. If this method is used it should be remembered that for a good zero the equality

\[
C_6R_6 = C_7R_7/4
\]

(16)
must be maintained. Hence \( C_6 \) may have to be changed. A more convenient method of compensation would perhaps be to increase \( K \) slightly by using less than 100% feedback as shown in Fig. 5 of Part 6. The calculation really shows, however, that for accurate design \( A \) should be high, say 10,000 minimum, for \( q \) of this value. Alternatively a two-integrator loop may be used (Part 7), or a parallel-T system (to be described in a following Part). For the other 2nd-order section, \( q = 1.073, \) a moderate value of \( A \) is sufficient, although for practical convenience the same type of amplifier is likely to be used.

Moving the cut-off frequency to the required value is a simple matter of scaling. So, to set the -3 dB frequency at 1000 radians/second (\( = 159 \) Hz) \( \omega_i \) must be 923 radians/second and all time constants of the normalized filter must be divided by this figure. This gives (including small adjustments based on an accurate computation of the overall response) the values shown in Table 2 below.

### TABLE 2

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 = 1.823 )</td>
<td>( q_1 = 1.073 )</td>
<td>( q_1 = 5 )</td>
</tr>
<tr>
<td>( R_1 = 16 \times 2 )kΩ</td>
<td>( T_2 = 1.222 \times 2 )kΩ</td>
<td>( T_2 = 1.018 \times 2 )kΩ</td>
</tr>
<tr>
<td>( C_7 = 0.1 )µF</td>
<td>( T_3 = 1.313 \times 2 )kΩ</td>
<td>( T_3 = 0.698 \times 2 )kΩ</td>
</tr>
<tr>
<td>( C_6 = 1.2 \times 2 )kΩ</td>
<td>( R_4/2 = 26 \times 2 )kΩ</td>
<td>( R_4/2 = 20 \times 4 )kΩ</td>
</tr>
<tr>
<td>( C_6 = 0.001 )µF</td>
<td>( R_4/2 = 20 \times 4 )kΩ</td>
<td>( R_4/2 = 0.05 )µF</td>
</tr>
<tr>
<td>( 40 \times 2 )kΩ</td>
<td>( C_6 = 0.005 )µF</td>
<td>( C_6 = 0.005 )µF</td>
</tr>
<tr>
<td>( 1000 )Ω</td>
<td>( R_4/2 = 0.05 )µF</td>
<td>( R_4/2 = 0.05 )µF</td>
</tr>
<tr>
<td>( 110 )kΩ</td>
<td>( 1000 )Ω</td>
<td>( 110 )kΩ</td>
</tr>
<tr>
<td>( \alpha = 1.2 )µF</td>
<td>( \alpha = 1.2 )µF</td>
<td>( \alpha = 1.2 )µF</td>
</tr>
<tr>
<td>( \alpha/2 = 0.6 )µF</td>
<td>( \alpha/2 = 0.6 )µF</td>
<td>( \alpha/2 = 0.6 )µF</td>
</tr>
<tr>
<td>( \alpha/4 = 0.3 )µF</td>
<td>( \alpha/4 = 0.3 )µF</td>
<td>( \alpha/4 = 0.3 )µF</td>
</tr>
<tr>
<td>( \alpha/8 = 0.15 )µF</td>
<td>( \alpha/8 = 0.15 )µF</td>
<td>( \alpha/8 = 0.15 )µF</td>
</tr>
<tr>
<td>( \alpha/16 = 0.075 )µF</td>
<td>( \alpha/16 = 0.075 )µF</td>
<td>( \alpha/16 = 0.075 )µF</td>
</tr>
</tbody>
</table>

### TABLE 3

<table>
<thead>
<tr>
<th>Parameters for 5th-order Darlington response, normalized to cut-off frequency ( \omega_i = 1 ) rad/s.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A_1 ) (dB)</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>0.95</td>
</tr>
<tr>
<td>0.7</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>0.25</td>
</tr>
<tr>
<td>0.0</td>
</tr>
<tr>
<td>0.2</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 3. \( p \) is the position of a pole, \( p = -a + jb. \)
In the pass band distortion from the theoretical curve is most likely to be caused by misalignment of the high-\( q \) section with respect to the other two. The greatest slope of the response of this section in the pass band is \( \frac{1}{4} \) dB for a \( 1\% \) change in frequency. For not more than \( 2\% \) dB error in the passband, therefore, an accuracy in the component values of \( ±0.4\% \) is indicated.

Points in favour of realization by factors are that requirements for amplifier gain and the effect of errors in component values are easily calculated, and hence amplifier gains and component tolerances are easily specified. A further convenience is that errors can be localized by measuring the responses of the individual sections. These responses for the given example are shown in Fig. 5. The overall response was given in Part 1, Fig. 1.

An experimental filter of this design was shown by the Royal Radar Establishment on the Ministry of Aviation stand at the I.E.A. Exhibition, London, in 1964; and at the Physics Exhibition, London, in 1969. G.E.C., Ltd., (Hirst Research Centre, Wembley) showed some interesting developments of the same type of circuit.

The derivation of the factors of the transfer function from the element values of the passive filter serves to show the relationship between the several ways of specifying the filter and its responses. For accuracy, however, the \( q \) and \( T \) of the factors are better computed directly from the Darlington theory as given in Ref. 1, Ref. 2, and elsewhere; and some sets of values so obtained are given in Table 3. The \( k \) of Ref. 1 = \( 1/\alpha_1 \). Tables of poles and zeroes for Darlington and some other types of filter are given in Ref. 3 and may be converted into real factors as shown above, Fig. 3 and equations (10) and (11).

### 3rd-order Darlington response

3rd-order Darlington is specified as in Fig. 1, though there is only one trough in the pass band, and one zero in the stop band. Such a specification is met by a structure as shown in Fig. 6. There is no longer any necessity to use an unsymmetrical structure, and in practice a symmetrical structure is used. This can be bisected into two equal halves, and hence a general expression for the transfer function found in factorized-form,

\[
G(p) = \frac{1+T_3^2}{1+(1/q_1)pT_1 + pT_1^2}(1+pT_2) \quad (17)
\]

The response may then be analyzed by simple algebraic methods. However, some ready-computed results are given here:

### Table 4

<table>
<thead>
<tr>
<th>( A_1 ) (% of ( 1/\alpha_1 ) )</th>
<th>( A_2 )</th>
<th>( q_1 )</th>
<th>( T_1 )</th>
<th>( T_2 )</th>
<th>( T_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>0.05</td>
<td>1.635</td>
<td>0.704</td>
<td>0.699</td>
<td>0.441</td>
</tr>
<tr>
<td>0.6</td>
<td>0.15</td>
<td>1.929</td>
<td>0.826</td>
<td>0.826</td>
<td>0.533</td>
</tr>
<tr>
<td>0.7</td>
<td>0.25</td>
<td>2.480</td>
<td>0.931</td>
<td>1.252</td>
<td>0.630</td>
</tr>
<tr>
<td>0.8</td>
<td>1.15</td>
<td>3.731</td>
<td>1.007</td>
<td>1.778</td>
<td>0.731</td>
</tr>
<tr>
<td>0.4</td>
<td>0.1</td>
<td>1.515</td>
<td>0.766</td>
<td>0.919</td>
<td>0.351</td>
</tr>
<tr>
<td>0.5</td>
<td>0.4</td>
<td>1.909</td>
<td>0.969</td>
<td>1.328</td>
<td>0.441</td>
</tr>
<tr>
<td>0.6</td>
<td>1.3</td>
<td>2.685</td>
<td>1.010</td>
<td>1.950</td>
<td>0.533</td>
</tr>
<tr>
<td>0.8</td>
<td>2.2</td>
<td>3.564</td>
<td>1.036</td>
<td>2.418</td>
<td>0.581</td>
</tr>
<tr>
<td>0.3</td>
<td>0.15</td>
<td>1.486</td>
<td>0.807</td>
<td>1.074</td>
<td>0.261</td>
</tr>
<tr>
<td>0.4</td>
<td>0.8</td>
<td>2.080</td>
<td>0.978</td>
<td>1.778</td>
<td>0.350</td>
</tr>
<tr>
<td>0.5</td>
<td>1.6</td>
<td>2.604</td>
<td>1.036</td>
<td>2.305</td>
<td>0.395</td>
</tr>
<tr>
<td>0.7</td>
<td>2.9</td>
<td>3.737</td>
<td>1.074</td>
<td>3.012</td>
<td>0.441</td>
</tr>
</tbody>
</table>

### Butterworth response

The occasional designer may like to have at command without resort to reference books a few design formulae suitable for meeting specifications of only moderate stringency such as might occur in the experimental laboratory in acoustic and vibrational work. In such applications the steep cut off given by a zero in the stop band may not be required, and the easily defined Butterworth (or maximally flat) response is often used:

\[
[\text{Butterworth}][G(\omega)] = \frac{1}{\sqrt{1 + \omega^2 n^2}} \quad (18)
\]

where \( x = x_0/x_n \), \( x_0 \) is the -3 dB (or corner) frequency, \( n \) is the order of the response. The nature of this family of responses is shown in Fig. 7. Each for its own value of \( n \) is the best monotonic approximation to the two asymptotes, i.e. the closest-fitting curve with a slope continuously increasing in one direction, and all pass through -3 dB at \( \omega = \omega_n \), i.e. at \( x = 1 \).

The first three we already know in factorized transfer-function form, Table 5.

### Table 5

| \( G(p) \) |
|-----------------|------|--------|------|------|------|
| \( 1 \)         | \( 1 + (1/q_1)pT_1 + pT_1^2 \) |
| \( 1 \)         | \( 1 + p^2T_2 + p^2T_2^2 \) |
| \( 1 \)         | \( (1+pT_1)(1+pT_1^2) \) |

To find the remainder the amplitude function \( [G(\omega)] \) must be factorized. This involves finding the roots of the equation

\[
x^2 + 1 = 0
\]

i.e.,

\[
x^2 = -1,
\]

and is, therefore, an exercise in complex algebra using the concept of the \( \text{n} \)th roots of \( -1 \). (See, for example, Loney: Plane Trigonometry, Pt. 2, p. 141.) The complex conjugate factors so obtained are multiplied together, giving real 2nd-order factors in \( \omega^2 \), with one real \( \text{1st}-\text{order} \) factor when \( n \) is odd, and compared with the 2nd-order amplitude factor, equation (21) of Part 2, corresponding to the standard transfer-function factor

\[
\frac{1}{1 + (1/q)pT + pT^2}
\]

The result is that the \( \text{rth} \) factor has

\[
F = 2 \sin \left( \frac{2r-1}{n} \pi \right) \quad (21)
\]

and numerical results up to \( n = 10 \) are

---

**Fig. 7. Butterworth response, low-pass.**

**Fig. 8. Location of Butterworth poles.**
given in Table 6. For all odd values of \( n \) there is also a 1st-order (simple-lag) factor; hence for odd orders the products of the \( q \) is 1, and for even orders \( 1/2 \).

**TABLE 6**

<table>
<thead>
<tr>
<th>( n )</th>
<th>( q_1 )</th>
<th>( q_2 )</th>
<th>( q_3 )</th>
<th>( q_4 )</th>
<th>( q_5 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>0.707</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.306 0.541</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1.618 0.518</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.932 0.707 0.518</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>2.247 0.802 0.556</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>2.563 0.900 0.601 0.510</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>2.880 1.000 0.653 0.532</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3.196 1.101 0.707 0.561 0.506</td>
<td></td>
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The results of the analysis can also be given in memorable form as the positions of the poles of \( G(p) \) in the complex plane. As all \( 7s \) are equal the poles lie on a circle, and they are evenly spaced as shown in Fig. 8. It is clear that the highest \( Q \) factor increases with increasing \( n \), and the curves, Fig. 9, give an idea of how the opposing curvatures of the high-\( Q \) and low-\( Q \) factors go towards giving an approximation to a level response in the pass band and to a constant rate of fall above cutoff.

\[ V_{in} = \frac{2(1+\alpha R)}{(1+\alpha R)(1+pL(p+L)^2-LC)} \]

\[ T = \frac{R}{\omega_0 R} = \omega_0 CR \]

\[ q = \frac{R}{\alpha L} \]

\[ q = \frac{R}{\sqrt{L}} \]

This confirms that high \( R \) gives light damping (high \( q \)), and also shows that as \( q \) increases the corner frequency of the 1st-order factor, \( 1/\alpha \), moves down the frequency scale, giving increased attenuation at high frequency. This "corrects" the increased gain in the vicinity of \( \omega_0 \) contributed by the 2nd-order factor, and so is consistent with the fact that when \( R_L = R_S \) no peak in the response can rise higher than the zero-frequency level (–6 dB), since this is the optimum match between equal resistances.

Ignoring the factor \( \frac{1}{2} \), the normalized \( T = 1 \) amplitude response is given by

\[ G(j0) = [(1+q^2\omega^2)((1-\omega^2) + \omega^2(q^2)]^{-1} \]

\[ y = \omega(q-1/q) - qa^2 \]

Where \( q < 1 \), \( (q-1/q) \) is negative and the slope \( dy/\omega \) is continuously negative; but when \( q > 1 \), \( (q-1/q) \) is positive and \( y \) is zero at a finite positive value of \( \omega \) as well as at the origin, Fig. 12. Consequently when \( q > 1 \), the normalized amplitude response, which is given by \( (1+y)^{-1} \), has a trough and then returns to unity before descending towards zero. (See Fig. 13.) As \( Q \) increases the sharpness of the corner and the rate of attenuation just beyond the corner increase: so does the amplitude of ripple in the passband. This is a simple example of the general nature of Chebyshev or equal-ripple response. The peak occurs where

\[ \omega^2 = 1 - \frac{1}{d^2} \]

So as \( q \to \infty \) the peak approaches \( \omega_n \), while for \( q = 1 \) it is at \( \omega = 0 \) (i.e. the ripple disappears). As shown in Part 1 this is maximally-flat-amplitude (Butterworth) response, and here the corner frequency of the 1st-order factor is equal to that of the 2nd-order factor. For \( q < 1 \) the corner frequency of the 1st-order factor is at a higher frequency than that of the 2nd-order factor, and this adds to the greater roundness of the corner compared with the Butterworth.
The trough occurs at
\[ \omega_t = \frac{1}{3} \left( \frac{1}{q^2} \right) \]  
and the depth of the trough may be derived from the relationship
\[ y_t = 4q^4 \left( \frac{1}{q^2} \right)^3 \]

For 1 dB depth, maximum, \( q \) must be \( > 2 \) approx., Fig. 13.

As a compromise between low ripple and a sharper corner \( q \) may be chosen in the region 1:4 (0.15 dB ripple) to 1:5 (0.25 dB ripple), and Fig. 14(a) shows a schematic for an audio-frequency low-pass filter with \( q = 1:43 \) approx. The \( \omega_0 \) of the 2nd-order factor is \( 10^6/36 \) radians/second \( (= 4:4 \) kHz), and the \(-3\) dB point for the whole filter is at 4.75 kHz approximately.

The amplifiers may be of a variety of types, and will probably be chosen for convenience and ready availability. The circuit shown in Fig. 14(b) is suitable, and although of only moderate internal gain \( (c. 500) \), gives enough loop gain to reduce distortion at (say) 1 V r.m.s. output to a very low level. An input buffer amplifier should be used if the output impedance of the previous stage is not negligible or cannot be incorporated into the first resistance of the filter. Provided \( T_1 \) maintains a high current gain at low \( I_c \) all impedances, and the two resistances in the amplifier, may be increased several times, giving economy in h.t. current and in the size of capacitors.

For higher-order Chebyshev filters the parameters must form a proper set, or the ripples will not be equal. Table 8 gives the \( Q \) factors and the relative magnitudes of the \( T \)'s for five 5th-order curves with depth of ripple from 0.02 dB to 0.8 dB. All these may be considered a better approximation to constant gain in the pass band, and the table shows that all but the first give more attenuation than 5th-order Butterworth, both at twice the cut-off frequency and at higher frequencies (Fig. 15).

### Filters for pulse transmission

The high \( Q \) factor of at least one factor of a

![Fig. 15. Illustrating 5th-order Chebyshev response: (a) pass-band ripple, (b) increased attenuation compared with Butterworth 5th-order response, B.](image)

<table>
<thead>
<tr>
<th>Table 8</th>
<th>Parameters for 5th-order Chebyshev response</th>
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</thead>
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<tr>
<td>( T_1 )</td>
<td>( T_2 )</td>
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<tr>
<td>1.337</td>
<td>1.051</td>
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<tr>
<td>1.642</td>
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<td>2.164</td>
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<tr>
<td>2.377</td>
<td>1.383</td>
</tr>
<tr>
<td>3.236</td>
<td>1.508</td>
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</tbody>
</table>

![Fig. 16. Step responses of three filters: (a) a 5th-order Darlington, (b) a 5th-order Butterworth, (c) an approximate linear-phase filter.](image)

![Fig. 17. Amplitude responses of Butterworth and approximately linear-phase filters.](image)

![Fig. 18. Normalized group delay of Butterworth and approximately linear-phase filters.](image)
Application Notes

Circuitry selected from device manufacturers’ literature

Process Timer
The circuit will hold the relay on for a period of between one and ten seconds (determined by $R_v$) when actuated by a negative input pulse. This pulse could be provided by the switch and resistor shown. Extracted from the Ferranti “E-line Transistor Applications” handbook.

Four-Quadrant Division
The circuit produces $X/Y$ using type MX101 multipliers from Fenlow electronics. The inputs $X$ and $Y$ can be of any sign. Use is made of the fact that $X + Y = (XY)/Y^2$. 

![Circuit Diagram](image)

Fig. 19. Realization of the 8th-order Storey-and-Cullyer linear-phase characteristic. Resistors, $\Omega$; Capacitors, pF.

This function for the filter just mentioned, equation (33), is shown in Fig. 18, curve $a$ and for the 5th-order Butterworth filter in curve $b$. It can be seen that while the first is almost level up to 0.9 of the cut-off frequency, the second rises to a pronounced peak. Curves $c$ and $d$ give similar information for two 3rd-order filters: $d$, Butterworth, $c$ a similar filter with the $q$ of the quadratic factor reduced to 1/2. The frequency responses are shown in Fig. 17(b).

An example of a linear-phase filter designed empirically is given in Ref. 4. It is an 8th-order filter with two frequencies of infinite attenuation, and the transfer function may therefore be resolved into two numerator factors,

$$1 + p^2T_1^2, 1 + p^2T_2^2,,$$

and four denominator factors,

$$1 + (1/q_1)pT_1 + p^2T_1^2, 1 + (1/q_2)pT_2 + p^2T_2^2,$$

The poles are given as

$$-4.549 \pm j1.362, -3.305 \pm j4.549, -5.687 \pm j703, -4.174 \pm j5.251,\ldots$$

and the frequencies of infinite attenuation as

$$T_1 = 1.991 \text{ microseconds,}$$

$$T_2 = 1.137 \text{ kHz (314 x 10^3 rad/s, T = 3.18 kHz).}$$

The filter is made in two sections, giving the 5th and 8th order. The stop band, where the minimum attenuation is 30 dB, starts at 75 kHz. The end of the passband may be taken to be the -10 dB point, which is at 50 kHz (314 x 10^3 rad/s, $T = 3.18$ µs); and rectangular pulses, by a width of 20 µs are transmitted with full amplitude, though reduced to a shape similar to a single cycle of a cosine wave.

By following the procedure used before, the filter may be realized as a cascade of four Sallen-and-Key sections, two of simple low-pass type and two with a parallel path giving a zero, Fig. 19. As all $Q$ factors are low, the amplifiers do not need very high internal gain. Provided the filter is not required to pass zero-frequency signals with a tight specification on zero drift, pairs of transistors connected in the enhanced-emitter-follower arrangement would be satisfactory. In general a tolerance of $\pm 2\%$ on component values will be quite adequate, as none of the factors show rapid changes of attenuation in or near the pass band. For good zeroes, however, a somewhat closer match between the time constant of the side-chain network and the short-circuited-output time constant of the network in the main path is advisable.

REFERENCES


Dynamic Range versus Ambient Noise
A practical solution involving metal-cone loudspeakers and high-power amplifiers

by George Izzard O'Veering

The essential requirements for a high quality sound reproduction system are adequate power and adequate bandwidth. Since loudspeakers are inefficient, and the attainment of wide bandwidth systems is generally incompatible with high efficiency, the achievement of the desired acoustic spectrum from the subsonic to the ultrasonic makes heavy demands on amplifier output.

Moreover, it will be apparent on reflection that many of the musical and other instruments, the acoustic output of which it is desired to reproduce, are themselves both powerful and developed to a high degree of acoustic efficiency. It is clearly laughable to suppose that the majestic splendour of a full orchestral fortissimo or the lung power of a Wagnerian tenor in full cry can be represented adequately on an acoustic budget of a few hundred milliwatts. Inconvenient though it may be, there can be no doubt that to recreate the true dynamic range of much recorded sound over the required sonic spectrum makes demands on the output power of the audio amplifier/reproducer system which are well beyond the capabilities of most, if not all, of the equipment at present on the market.

Calculation of required power
The quietest sound which can be heard in a given environment depends entirely upon the background noise level of that environment. Unfortunately, most people live in close proximity to traffic, neighbours with television sets, dogs, and noisy children, and these things, together with the normal background sounds of the home, combine to give an ambient noise level of about 50dB. The minimum sound level which can be distinguished clearly above this background level is therefore 53dB. The dynamic range of orchestral music can be as much as 70dB, therefore in order to be able to hear the pianissimo as well as the fortissimo passages, a peak level of 123dB is required.

The acoustic power in watts required to produce a sound intensity level of 53dB is about 6W, for an average-size living room. Since a 10dB increase in power output requires a tenfold increase in power, the 123dB peak-power level will therefore require a maximum acoustic output of some 50W. If the loudspeaker efficiency is 5% (and this is significantly better than is obtained from most commercially available loudspeaker systems) a peak-power output of 1000W per stereo channel is obviously required if the total dynamic range of a symphony orchestra is to be heard in comfort.

It was clear from discussions both with manufacturers and distributors that no serious attempt had been made to meet the requirement for drive units capable of handling as little as 250W. Initial trials made with some of the more likely units, were generally unsatisfactory. In particular there was a tendency for the cone and speech coil to become detached, and for fraying of the surround. In addition, the failure was often made more serious by partial combustion of the inflammable materials within or in proximity to the speech-coil assembly.

When more substantial reproducer units had been evolved, this only brought to light the flimsy nature of the housings which had been supplied, and considerable annoyance was caused by a minor injury sustained when one of the cabinets burst during an orchestral transient and the room was filled with flying splinters. At this stage it was accepted that the cabinets used would require to be of comparable strength to the reproducers, and the assistance of the specialist who constructed the metal cone loudspeaker assemblies was sought to manufacture four sheet-steel column-loaded units, of a suitable type to take the 23in x 14in elliptical wide-band speakers. These are situated at the four corners of the listening room and the opposite units are connected in parallel but in antiphase. This has the effect of increasing the apparent dimensions of the listening room, in addition to reducing the FR losses in the speaker wires.

Each unit is rated at 500W, with a nominal 20Ω impedance. The required output from the amplifier is therefore 10A at 100V r.m.s. (282 volts pk-pk) per channel.

Power amplifier design
The use of a solid-state, transformerless amplifier to provide an output of 1kW into a 10Ω load imposes certain limitations on the designer. In particular, the normal complementary or quasi-complementary output stage configurations are no longer practicable since the only useful and relatively cheap high-voltage transistors which are available are all of the n-p-n construction.

The basic output stage configuration employed, to provide a fully symmetrical push-pull class B output stage using only n-p-n transistors, is shown in Fig. 1. As shown, this would be satisfactory for power outputs up to about 50W.

In this circuit arrangement, $T_r/T_{r'}$ and $T_p/T_{p'}$, are Darlington pairs with $T_p$ and $T_{p'}$ being normal small-power driver transistors, $T_r$, in combination with $R_r$ and $R_{r'}$, provides the necessary signal level and amplitude transformation for the lower half of the output stage, and $Z_D$, effectively stabilizes the voltage level at the power output point. This is chosen so that the largest symmetrical voltage swing is obtainable. The symmetry of this stage is maintained up to a frequency determined by the resistance of $R_r$ and $R_{r'}$ and the input shunt capacitance of $T_r$. This will normally be well above the audible spectrum.

The final circuit employed is shown in Fig. 2. Although for simplicity only four parallel-connected output transistors are shown in each half of the output stage, this is only adequate for intermittent use at 1kW output. In practice six parallel connected transistors are required in each half of the output stage.

The paraphase input is obtained from two medium-power high-voltage transistors, $T_I$ and $T_{I'}$, the h.t. supply for which is obtained from a separately smoothed 400-V line, because bootstrapping is not practicable with this type of driver stage.

The input is derived from a long-tailed pair of p-n-p transistors, of a type chosen for high voltage linearity, and freedom from avalanche or collector leakage (Early effect) distortion. Although 150V is applied to the end of the 'tail', the maximum collector-emitter voltage is limited to about 52V, because the base of $T_T$ is returned to the 50V tap on the zener diode chain. A variable resistor is included in the 'tail' to set the current through $T_T$ and $T_T'$. This controls the current through $T_T$ and $T_T'$, and, since the output d.c. level is determined by $Z_D$, thereby controls the

---

Paraphase input

Fig. 1. Symmetrical output stage using only n-p-n transistors.

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The bottom and base of the amplifier unit follows conventional lines, and no unusual precautions are required apart from the need for generous heat sinks. Very satisfactory results were obtained in the prototype by the use of a pair of old cast-iron radiators, such as can be found second-hand for a few pounds in a builder's yard, to which the transistors can be individually attached by small bridges made from a suitably substantial gauge of copper sheet. The bottom and sides of an old copper preserving pan would be ideal. Care should, of course, be taken in drilling the attachment holes to make sure that the radiator shell is still capable of retaining water without leakage.

If such radiators cannot be found, a copper hot-water storage cylinder would serve admirably, but it would probably be more difficult to introduce such an item inconspicuously into the listening room. The siting of the output transistors should combine shortness of signal leads with the required thermal separation of the power transistors one from another. It should also be borne in mind that the circulating currents at full power are of the order of 30A. The leads to the loudspeaker terminal bosses—

for which old car battery connectors are suggested—to the collector and emitter rails of the output transistors, and to the h.t. and earthy ends of the h.t. decoupling capacitor block must be substantial. A 3/4in bore copper pipe is preferable, but as an alternative, lengths of 12 s.w.g. copper wire may be plaited together.

After assembly, it is recommended that the amplifier units be bench-tested on a dummy load before attachment to the speaker units, since quite trivial faults can lead to a surprising amount of energy being released. For example, in preliminary listening trials with the prototype, an intermittent o/c in the earth braiding on an input to the pre-amp, led to the necessity for the listening room ceiling to be substantially restored and replastered.

Listening arrangements

Although the results obtained with good quality gramophone recordings have been most astonishing, and have brought home to the author in the most vivid way the qualities of stamina and emotional detachment required of an instrumental player situated, as the fortunate listener, in the midst of a large orchestra, it is clear that there are a large number of residual problems in the life-like reproduction of disc recordings, of which the major one is the avoidance of acoustic feedback. As with many other of these problems, it is suspected that the manufacturers of the equipment have not really got down to serious thought on this matter, and the solution which the author feels most people must adopt, that of housing the record player unit in some detached building, such as a small garden shed, is inconvenient and prevents the listener from hearing the beginning of the recorded piece. Moreover, if in one's hurry to return to the audition room, the pickup cartridge is left fall too rapidly upon the record, extensive damage can be caused to windows and other glazing.

Summing up

The performance of the equipment as installed is entirely satisfactory, and a wide variety of sound sources have been explored during the assessment of the scope of this system, and many sounds have been recaptured with a degree of realism not previously encountered. However, the development of this apparatus has not been without difficulty, scepticism and expense, and it has been suspected at times that unnecessary difficulties have been placed in the author's way. For these reasons, it is thought unlikely to appeal to those for whom high-fidelity reproduction is merely a passing interest. On the other hand, it has proved possible to purchase several of the adjoining properties at a very advantageous price, and this has undoubtedly offset a large part of the constructional costs.
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Amateurs urged to tackle TV interference

As a result of renewed efforts by many British amateurs to overcome the problem of causing interference to local television receivers, the number of stations to be heard operating during television programme hours has risen appreciably during the past year. However, there are signs that the Ministry of Posts & Telecommunications is concerned at the number of requests being made to the Post Office by both amateurs and viewers for assistance in overcoming television interference (TVI). While the Ministry is responsible for all technical matters relating to the orderly use of the r.f. spectrum, interference investigation field work is now carried out by Post Office engineers under contract to the Ministry. Interference investigation costs the Ministry about £2 per hour.

Amateurs are being urged to familiarize themselves with the basic causes of TVI and to tackle interference problems without calling in the Post Office teams. Amateurs are also being encouraged to persuade manufacturers of commercially built amateur transmitters to pay more attention to design features likely to reduce the problem, including the choice of oscillator frequencies. It is being suggested that only when cases of TVI prove intractable or where the viewers concerned adopt an unco-operative attitude should the Post Office investigation officers be called in.

Australis Oscar 5 satellite

The Australian-built Oscar 5 satellite carrying 28- and 144-MHz beacon transmitters (see the March issue), launched on January 23rd, continued to function as planned until February 14th when, during the 273rd orbit, a commanding "on" of the h.f. beacon brought the battery voltage below that needed to operate the v.h.f. beacon. At the time of writing, the h.f. beacon continues in operation but is expected to have ceased by the time these notes appear.

Bill Browning, G2AOX, the European co-ordinator, has already received over 100 reports on the Oscar 5 telemetry signals, including many from Germany, Sweden and the U.K. The reports cover reception of the 144-MHz beacon since telemetry signals were not satisfactory on 28MHz, due to a modulator malfunction, although the carrier and "HI" identification signals were radiated. The simple stabilizing system also proved rather less satisfactory than had been expected resulting in deep fading of signals when the satellite was overhead. Many novel techniques were used by amateurs to read out the telemetry, including matching of incoming tones with a local generator by means of stereo headphones (giving accurate results at low signal/noise ratios). Almost all the reports showed close agreement in results.

Another highly satisfactory feature was the effective amateur communications links which brought masses of orbital predictions and other information to the London co-ordinator. These included radio-teleprinter links with Australia and the United States operated by Reg Wigg, G6IF in Devon and fed to London on 3.5MHz a.m. Direct London to U.S. links on s.s.b. were also used.

Many amateurs are hoping that the next Oscar will include (as in 1965) an active transposer, possibly 144MHz down and 432MHz up, to allow long-distance contacts to be made via the satellite. It is not known yet when the next amateur satellite is likely to be launched.

New group for the north east

A new North East England amateur radio group has been formed from within local clubs and societies to organize major amateur radio events, mainly evening "technical conventions". It is hoped that some five or six large meetings can be arranged each year to attract speakers from all over the country. Members of the group cover the whole of County Durham, Tyneside and Teesside as well as parts of Northumberland and the North Riding of Yorkshire. Members will be free from the commitments normally associated with regional and local radio clubs.

The first event takes place in Durham City on Friday, March 20th when F. J. U. Ritson, G5RI, of the University of Newcastle-upon-Tyne, is to give a lecture demonstration on aerials.

The secretary, J. Melvin, G3LIV, 5 Lancahsire Drive, Belmont, Durham, will provide further details and a sample Newsletter to those interested. Peter Martin, G3PDM, is the interim chairman of what promises to be something new in the dissemination of technical information among amateurs.

Amateur microwave record?

An excellent contact was established during February between A. Wakenshaw, G3EEZ, operating portable on Clee Hill in the Midlands, and L. W. G. Sharrock, G3BNL, on Cleeve Common in the Cotswolds, on the 10-GHz (3-cm) band.

This is believed to be a new British record for amateur two-way operation on this band. A pulsed klystron transmitter was used at G3EEZ/P while frequency modulation was used at G3BNL/P.

A large number of v.h.f. and u.h.f. enthusiasts are expected to attend the 16th annual R.S.G.B. v.h.f./u.h.f. convention at the Winning Post hotel at Whinton on Saturday, April 25th. Technical lectures and an exhibition of equipment during the afternoon will be followed by a dinner. Tickets can be obtained from Frank Green, G3GMY, 48 Borough Way, Potters Bar, Hertfordshire.

In Brief: A change of address for the general secretary of the British Amateur Television Club: Ian Lever, G8CPJ, 65 Dynes Road, Kensiginton, Sevenoaks, Kent, replaces the former Swanley address.

The first totally blind Irish amateur, Cathal O'Reilly, has recently been licensed as E19CA. Amateur licences in force at the end of October 1965 included 13,413 class A, 1,897 class B and 179 amateur television—class B licences are increasing much faster than class A.

The 28.185 MHz beacon station, GB3SX at Crowborough operates on a 24-hour basis with an output power of 20 watts on a three-element Yagi aerial usually, but not always, pointing East, or alternatively with an omni-directional aerial. A German beacon station, DL0GI1 operates on 28.20 MHz with a power of 200 watts to a vertical dipole. The next U.K. Radio Amateurs Examination is being held on Monday, May 18th at 18.30 at many local venues. A low-power 3.5-MHz contest is being held on April 5th. W. E. Gardner, G3FYY, recently reported longish delay echoes during a contact with W2ELW on 28 MHz and received a letter from Professor O. G. Villard, Jr., W6QYT, acknowledging the usefulness of all such reports even though the present investigation (see December, 1969) is basically concerned with echoes of over one or two seconds and particularly those of five to ten seconds. These appear to be heard usually on only one station, and for time intervals of only a few minutes.

A printing error appeared in last month's note "50 years of callsigns"—line eight should refer to G4-three-letter callsigns.

PAT HAWKER, G3VA

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Personals

Several senior appointments in the Engineering Training Department have been announced by the B.C.C. H. V. Sims, M.I.E.E., F.I.E.R.E., previously head of training section (engineering) has been appointed to the new post of head of technical projects and services. He will be concerned with investigating new methods of presenting maintenance information and with the maintenance and installation of all the broadcasting training equipment at the Training Centre. J. H. Brooks, B.Sc.(Eng.), M.I.E.E., previously a senior lecturer, has become head of training section (engineering). He is responsible for the training of engineering and technical assistants in the Operating and Maintenance Departments of the Corporation. D. G. Enoch, M.I.E.R.E., previously a senior lecturer, has been appointed head of training section (technical operations) in succession to G. W. MacKenzie who was recently appointed head of engineering, Northern Ireland. Mr. Enoch is responsible for the technical training of the B.C.C.'s technical operators. A. W. Harris, B.Sc., A.C.G.I., M.I.E.E., is appointed assistant, overseas trainees, and is concerned with training courses and attachments for non-B.C.C. staff.

Among the 1970 recipients of awards by the Institute of Physics & Physical Society are: Professor A. B. Pippard, of Cambridge University, who receives the Guthrie Medal "for his contributions to low-temperature and solid-state physics"; Dr. E. Eastwood, director of research of the English Electric Company, who receives the Glazebrook Medal "for his work on radar and the application of physics in the electrical and electronics industry"; and Dr. A. Hewish, of Cambridge University, who receives the Charles Vernon Boys Prize "for his work in radio astronomy and particularly his discovery of the pulsar".

A. H. Ellison, M.B.E., B.Sc.(Eng.), M.I.E.E., has been appointed manager of the optical character reading group of the M.E.I.

East Kilbride, Scotland. Dr. Heikes received his degree in 1948 from the Massachusetts Institute of Technology and his doctorate in 1951 from the University of Chicago. Before joining Motorola he was associated with Westinghouse for 18 years.

Derek Ashby has joined Vener Electronics as their sales manager. Prior to joining Vener, Mr. Ashby, who is 34, was with Marconi Instruments for five years. He joined M.I. as a technical representative and was appointed manager of factored products in 1967. After National Service with the R.A.F. he joined Fairchild Electronic Laboratories as a development engineer.

Ferranti Ltd announces the appointment of John Begbie as Marketing Manager with responsibility for all service policy in the Scottish Group and for co-ordinating activities with other departments in the Company; an additional Mr. Begbie, who is 47, is appointed acting manager of the Ferranti factory at Dalkeith. Midlothian. Mr. Begbie studied at Edinburgh University, and after wartime radar experience joined Ferranti in Edinburgh in 1950 as a trials engineer. Following a spell in Australia as chief project engineer of American Pickersgill and Partners team, he returned to Ferranti in 1957 to start the service department in Edinburgh. He is succeeded as service manager by Mr. Henney who is 40. Mr. Henney was educated at the Royal College of Science and Technology, Glasgow, and after experience with I.B.M. and Barr & Stroud joined Ferranti in 1954.

Rank Precision Industries has announced the appointment of James Warden as chief engineer of the telecommunications production group of its Broadcast Division. Mr. Warden was formerly technical manager of the industrial products group of Cossor Electronics Ltd. He will be responsible for controlling the group's research and development programmes and will be based at Welwyn Garden City until June, when he will move to the new Rank Precision Industries factory at Ware.

Robert R. Heikes, B.Sc., Ph.D., director of engineering at Motor-ola's Semiconductor Products Division headquarters in Phoenix, Arizona, has been appointed as the company's managing director in Europe. Dr. Heikes will now be responsible for all Motorola activities in Europe. He will be based at the company's European Service Centre in Geneva and his responsibilities will cover the European sales offices and distributors and the manufacturing facilities in Toulouse, France, and

East Kilbride, Scotland. Dr. Heikes received his degree in 1948 from the Massachusetts Institute of Technology and his doctorate in 1951 from the University of Chicago. Before joining Motorola he was associated with Westinghouse for 18 years.

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Equipment Company and Th. P. Reed will lead the company's technical marketing group, responsible for market research, business and product planning. Mr. Elson was, until his new appointment, technical manager on the Microwave Division of M.E.L. and Mr. Reed joins M.E.L. from Philips Electrofina at Rijswijk in the Netherlands.

Norman Doyle, formerly market- ing manager of Cossor Electronics' Communications Division, has been promoted divisional manager with overall responsibility for all aspects of the sales and marketing of Cossor's "Commando" range of radotelephones and other v.h.f. and v.h.f. communications equipment. He is succeeded as marketing manager by John Bonser who recently joined the company. Mr. Bonser was previously sales promotion manager of Ultra Electronics for seven years.

Marconi-Elliott Computer Systems Ltd., Borehamwood, Herts., announces the appointment of lorwerth Evans, B.Sc., as marketing director. He joins the company from Marconi Radar Systems Ltd. in which he was general manager (Borehamwood) and a director. Born in 1932 Mr. Evans took a degree in mathematics at Imperial College, London. He joined the Guided Weapons Division of the British Telecommunications Research Laboratory in 1952 and stayed until 1959. After two years with Decca Radar Systems he joined Elliott Automation as chief systems analyst (defence system). In 1965 he ultimately became general manager of Elliott Space and Weapons Automation Ltd. The 1968 merger between G.E.C. and Elliott Electric resulted in his appointment to the formation of Marconi-Elliott Computer Systems Ltd.

D. G. Smeke, who joined Marconi in 1933, has been appointed an assistant managing director of both G.E.C-Marconi Electronics and of the Marconi Company. He has held various senior manage-
New Products

Two-hour Tape Cassette
The range of Scotch magnetic tape cassettes has been expanded to include a two-hour version. The new Philips-compatible cassette—the Scotch C-120—has an improved shim material which is reliable and eliminates tape binding and jamming. The shim material effectively reduces frictional drag and increases recorder battery life. The cassette uses Scotch Dynarange low-noise tape, giving good high-frequency response at slow (1/4 i.p.s.) recording speed. The cassette is supplied in a durable hinged plastic case. Price 33s 6d. 3M Company, 3M House, Wigmore Street, London W.1. WW 306 for further details.

Coherent Filter
An active filter claimed to be capable of recovering signals which are more than 100dB below noise level has been introduced by Brookdeal Electronics (who tend to specialize in signal recovery instruments). Called the Type 467, it is a narrow-band coherent filter using a multi-path filter technique*, and is designed particularly for use in the signal channel of "lock-in amplifiers" (perhaps better known to some readers as synchronous detectors). Its centre frequency is established by an external reference waveform, giving it the ability to follow a varying wanted signal, and normally it will use the same reference waveform as the synchronous detector. The bandwidth of the filter is 3Hz and the frequency range of operation is 10Hz to 100kHz. The output of the device is a square wave at the reference frequency with an amplitude 40dB greater than the in-phase component of that frequency at the input (max. output 3V pk-pk. from 600Q). Input impedance of the filter to the signal is 100kQ, 50pF, while the input impedance to the reference waveform is 10kQ, 80pF. The design is such that the instrument requires no setting up or adjustment by the user. Brookdeal Electronics Ltd., 1 Market Street, Bracknell, Berks. WW 301 for further details.

Milliwatt Test Set
Hatfield Instruments, Type 747 universal milliwatt test set is a precision thermocouple meter for checking the standard 0dBm send level in 75Q unbalanced, 140Q balanced, and 600Q balanced circuits. The 75Q input covers frequencies up to 20MHz, whilst the 140 and 600Q balanced inputs cover frequencies up to 1MHz. The instrument is protected against overloads of up to +25dBm on all inputs and the measurement range of -1 to +1dBm is displayed over the full 4-in scale of the meter. The accuracy of the standard version is ±0.05dB on all inputs. However, it is now available as option 1 with special calibration charts guaranteeing an accuracy of 0.02dB on all three inputs. Hatfield Instruments Ltd, Burrington Way, Plymouth PL5 3LZ, Devon. WW 307 for further details.

Memory Voltmeter with Chart Recorder
A dual-readout memory voltmeter with a built-in strip chart recorder, for use where a permanent record of transient or spike occurrences is desired, is available from Sintrom Electronics. This portable instrument, the 5201CR, has applications in monitoring power stations, power supplies, computer equipment and other similar installations. It employs amplitude memory to measure and hold 50 nanosecond or longer one-shot voltage peaks of single, transient, random or repetitive pulses permanently or until reset. A dual-shielded cabinet precludes common mode errors. The cabinet is isolated to 1000V. An optional gate circuit permits use as a sample-and-hold voltmeter. The recorder is a dry process, pressure-sensitive 63R chart with a front access window. It will deliver 25 hours of continuous recording from a 30in/hr standard chart speed. A five position high response selector control is provided permitting the instrument bandwidth to be reduced in specific applications where the waveform to be measured is of low frequency and where unwanted high-frequency noise is present. Voltage ranges are 0-3, 30, 100, 1000V to 30kV with optional probes. Input impedance is 10MQ to 30kQ depending on the range and accuracy ±3% of full scale. Sintrom Electronics Ltd, 2 Castle Hill Terrace, Maidenhead, Berks. WW 316 for further details.

Miniature Wire-wound Potentiometer
A miniature wire-wound trimmer potentiometer, the ADTOS, available from Guest International Ltd, is housed in a TO-5 type nickel-alloy case and may be mounted on a printed circuit board in exactly the same manner as a transistor. The terminal centres are spaced so as to enable flush fitting to a standard 2.54mm (0.1in) hole-in-pitch printed-circuit board. Rotation extends over 320° and mechanical overload protection is provided in the form of a slipping-clutch mechanism. Moulded-in terminations and a silicon rubber sealing ring help the device to withstand extremes of environmental conditions. The terminations are 0.28 to 0.36mm square copper/nickel alloy. The resistance range available covers from 15Q to 15kQ in preferred values. The power rating is 0.5W at 40°C and the temperature range is -55° to +150°C. The temperature

*See, for example, W.W. March 1966, p.130.
Laboratory Power Supplies

Guest Electronics have modified their recently announced type 606 laboratory bench power supplies. These all-transistor units feature continuously variable ranges of 0-7.5, 15, 30 and 60V. Voltage output is controlled by a precision 10-turn helical potentiometer fitted with a vernier scale allowing the voltage to be set to a predetermined value with guaranteed repeatability. A built-in meter enables the output voltage or current to be monitored. Ripple noise is less than 0.5mV pk-pk and overload protection limits the output current to 110% of maximum. Reset is automatic. The model 606 is available in current ranges from 0-500mA up to 0-2.5A. Dimensions are 156 x 152 x 102mm and prices from £34 15s. to £42 15s. Guest International Ltd, Nicholas House, Briggstock Road, Thornton Heath, Surrey.

WW 301 for further details.

Linear Power Controllers

A range of solid-state linear power controllers has been introduced by Eurotherm to provide efficient control of a.c. loads from 10 to 300A. Units supplying d.c. and three-phase loads are also available. Power is controlled by an inverse pair of thyristors in series with the load. R.F. suppression and protection against supply-voltage transients can be incorporated. An additional feature is a 'soft start' characteristic—the firing angle is gradually increased over the first few cycles after switching on, thus preventing the sudden application of full power which may be harmful to certain loads. In addition, facilities exist for an over-ride control via external contacts. The control module is calibrated 0-100% power, with a linear scale owing to the "square law" feedback employed, and is fully compensated against supply voltage variations from +10% to -15% at 240V a.c. Units can also be supplied for operation from 415V a.c. Eurotherm Ltd, Broadwater Trading Estate, Worthing, Sussex.

WW 305 for further details.

D.V.M. Multi-range Adaptor

Electrotech Instruments (of Coutant Electronics) have developed an adaptor unit that will convert any 1V full-scale digital voltmeter (input resistance $\geq 10\Omega$) to a multi-range digital meter for the measurement of a.c. and d.c. voltages, currents, and resistance. Known as the MMA 100 the adaptor is available either as a free-standing unit or built in to Electrotech's modular system cabinet which includes their new CDM 100 digital panel meter. The MMA 100 is built with push-button range selection and, when used in conjunction with a 1V full-scale digital meter, provides five voltage ranges and five current ranges for a.c. and d.c., and five resistance ranges. These are 0.1, 1, 10, 100 and 660V a.c.; 0.16, 1.6, 16, 160 and 1000V d.c.; 100 $\mu$A, 1mA, 10mA, 100mA and 1A a.c.; 160mA, 1.6mA, 16mA, 160mA and 1A d.c.; and 160 $\Omega$, 1.6k $\Omega$, 16k $\Omega$, 160k $\Omega$, and 1M $\Omega$. According to the measurement function and range selected, the full-scale accuracy is between 0.1% and 0.5% and the sampling rate is between 2 and 3 per sec. Overvoltage protection is provided on a.c. and d.c. ranges—1000V on the three highest d.c. ranges and 250V on the two lowest; and 700V for the three highest a.c. ranges and 180V for the two lowest. On a.c. it will operate at frequencies from 40Hz to 10kHz. In the free-standing form the multimeter adaptor unit measures $147 \times 60 \times 180$mm. The price is £10. Electrotech Instruments, Coutant Electronics Ltd, Instrument Division, 5 Loverock Road, Reading, Berks.

WW 331 for further details.

S-band Low-noise Transistor Amplifier

Watkins-Johnson Co. has placed on the market a low-noise microwave transistor amplifier for operation in the S-band (2 to 4GHz). Designated the WJ-5004-4, this amplifier, with integral power supply has a guaranteed noise figure of 8.5dB maximum and power output of +7dBm (for 1dB gain compression). Overall design is consistent with the respective environmental requirements of MIL-E-16400F. Watkins-Johnson International, Shirley Avenue, Windsor, Berks.

WW 308 for further details.

Oscilloscope for TV Servicing

Fully automatic television line and field triggering is featured in a new Philips oscilloscope, model PM3200X, specially designed for TV service and maintenance work. This ensures a completely stable display of all line- and field-signal waveforms. Other features are a 10MHz bandwidth, 2mV input sensitivity and the elimination of d.c. balance-correction by automatic drift compensation circuits in the vertical deflection pre-amplifier. The timebase circuit is triggered automatically but in the absence of a trigger it starts "free running". Sweep speeds cover the range 0.1sec/div to 0.5sec/div. A separate triggering facility is provided for line/field triggering giving a stable display of both line and field information. The unit measures 175 x 210 x 330mm and weighs 5.3kg. Pye Unicam Ltd, York Street, Cambridge.

WW 321 for further details.

Frequency monitor

Designed to provide an alarm or control signal when the input frequency deviates from a pre-determined figure, a new range of frequency monitors has been added to the Orbit 70 series of industrial control instruments. The principle of operation is based on the digital measurement of the period of the incoming signal giving a rapid single cycle response when the input frequency goes out of limits. Three versions, zero speed, underspeed and overspeed are available and combinations of under-
speed and overspeed modules can be housed in a single instrument to provide bandpass or high- and low-limit facilities. Thirteen overlapping ranges cover the frequency spectrum 1 Hz to 30kHz. Alarm operation is within 0.1% of the set point and reset is automatically carried out without hunting. Output can be in the form of a relay changeover or of a logic level change. Construction is of i.c.s mounted on plug-in p.c. modules. Orbit Controls Ltd, Alstone Lane Industrial Estate, Cheltenham, Glos. WW 310 for further details.

Field Intensity Receiver

A field intensity measuring receiver, designation number VSME1510, from Microwave International, covers the frequency band 30-300MHz in six ranges. The voltage measuring range covers 0-120dB (1μV to 1V). The unit employs transistors throughout and has an accuracy on its frequency calibration of 0.5% without a warm-up period. The frequency response is ±2.5dB on all ranges. The scale arrangement consists of a 340mm long cylindrical linear scale with continuously progressive frequency calibration. Total scale length is approximately 2 metres. The measuring accuracy when used on an accurate calibration source is better than ±1dB. By narrowing the bandwidth it is possible to measure sinusoidal voltages down to 0.1μV. The standard input impedance is 50Ω, and a 50-Ω unit is available on request. The bandwidth is 120-130kHz with 6dB drop. Microwave International (U.K.) Ltd, 33-37 Cowleaze Road, Kingston Upon Thames, Surrey. WW 303 for further details.

H.F. Receiver

Astro Communications have announced a new h.f. communications receiver, model S.R.502. This is a compact all-transistor modular unit suitable for table top or standard 19-in rack mounting. Only 3½ in high, the main frame contains fully protected power supplies, audio, demodulator and i.f. circuits. Two cavities are provided which will accept a variety of plug-in modules. The right-hand cavity will accept either an h.f. tuning unit (0.5-30MHz in one band) or a v.f.f. tuning unit (10-500kHz in one band). The left-hand cavity can accept a battery pack which contains its own automatic charging circuit, a panoramic display, a digital frequency read-out unit with digital a.f.c. facilities or a digital frequency synthesizer with 100-Hz resolution. The receiver has been designed for a.m., s.b., c.w. and f.m. operation. The use of separate upper and lower sideband filters enables independent sideband operation with a simple adaptor. A high m.t.b.f. of 10,000 hours is claimed. Astro Communications Laboratory (U.K.), Coventry. WW317 for further details.

Colour TV Pattern Generator

The Philips PM 5508 pattern generator, available from Pye Unicam, takes full advantage of the "self checking" properties of the PAL system which enables a receiver to be adjusted using the picture tube as the only indicator. This virtually eliminates the need for an oscilloscope, but, if one is used it can be synchronized by line and field sync pulses from the generator. The generator delivers ten signals which are selected by the push-bottons arranged across the front panel: (1) Black and white checkerboard of 6 squares by 8 squares for checking tuning, scanning, amplitude and linearity, (2) Blank raster with constant white content for purity check, (3) Blank raster with constant red content for purity check, (4) Eight-step staircase for grey scale tracking, (5) 11 dots by 15 dots for adjustment of static and dynamic convergence, on 625 lines only, (6) Cross hatch, 11 lines by 15 lines, for adjustment of static and dynamic convergence, on 625 lines only, (7) Four colour bars for delay line phase and amplitude adjustment, using tube as indicator, (8) Four colour bars for demodulator phase adjustment, using tube as indicator, (9) Four colour bars for matrix check, using an oscilloscope, (10) Eight colour bars similar to B.B.C. signal for general check. The lower half of the picture is white to serve as reference to enable the adjustment of the amplitude ratio of the colour-difference signals to the picture tube. Alternatively a simple modification enables colour bars to be produced over the whole screen if this is preferred. The ranges covered are bands I, III, IV and V, which are selected by push-buttons and continuous tuning is provided. Outputs are 15-20mV at r.f. (continuously variable) and 1V at video, both into 75Ω. Burst amplitude is variable for checking colour killer and a.g.c. The sound carrier can be modulated internally, unmodulated or switched off. The generator measures approximately 270 x 290 x 190mm and weighs approx. 5.6kg. Pye Unicam Ltd, York Street, Cambridge. WW331 for further details.

Transistors for switching 150W Pulses

Three new silicon planar transistors announced by Mullard have high switching rates and very low saturation voltages of not greater than 0.9V. Consequently, although the transistors, types BDY61 and BDY62, have a continuous power rating of only 15W they can switch 150W pulses that have a duration not exceeding 50µs and a duty factor of 0.1. Earlier devices that switched 150W pulses had to have a higher continuous rating because they could not switch so rapidly. Particularly suitable for use in high-frequency, silent, inverters and converters where efficiency is required, these types can also be used with advantage as pulse modulators in communications and radar systems. Typical transition frequency, \( f_{TR} \), \( U_C = 0.5A, V_{CE} = 5V \) is 100MHz, and minimum \( h_{FE} \) \( (I_e = 0.5A, V_{CE} = 10V) \) is 45. Mullard Ltd, Torrington Place, London W.C.1.

WW 313 for further details.

Sine/Cosine Module

Burr-Brown have announced a sine/cosine function generator, model 4118/25, that may be used to produce various trigonometric gain responses. The module provides non-linear gain-shaping such that the output is \( -10 \sin \theta \), where \( \pm 10V \) of input voltage represents a \( \pm 90^\circ \) angle \( \theta \). In addition, the unit may be connected to form cosine functions. By adding one or more external operational amplifiers, operation may be extended to include four-quadrant sine and cosine functions. Arc cosine and arc sine response functions may also be obtained. Accuracy is \( \pm 1\% \) of full-scale for \( \pm 10V \) input and
New Audio Transformers

A new range of line-matching and microphone transformers for audio equipment is announced by Gardners Transformers. These complement the existing range introduced in 1961 and they come in two basic sizes using international octal, British 7-pin or flying screen lead connections. They are suitable for general purpose applications at high and low signal levels. Some of the new transformers, although similar in size and performance to the existing types, now have a 20,000V capability to meet the Post Office requirement. They are protected mechanically by a new filling of closed-cell epoxide resin foam compound (the smaller types are vacuum-impregnated with a microcristalline wax). Advanced technical data sheets AT15, AT16 and AT17 are available from the makers, Gardners Transformers Ltd, Christchurch, Hants., BH23 3PN.

WW 304 for further details

Precision R.F. Power Leveller

Weinschel Engineering introduces its model 1805 precision r.f. power leveller. This instrument is specifically designed to ensure precision and simplicity in systems used for transferring calibration factors of primary standards to bolometer mounts or secondary power standards (terminating or feed-through type) and power meters. Model 1805 in conjunction with a d.c.-to-r.f. continuously variable attenuator, such as a p.n. modulator, establishes and maintains constant, precisely known reference values of r.f. power incident upon a terminating mount or emerging from a feedthrough mount into a Z0 load. Minimum power level control range of 20dB is employed and only d.c.-substituted and bias power is used to maintain precise power levels, thus eliminating the a.c./d.c. error which is commonly found in some r.f. power bridge circuits. Selectable d.c.-

General Coverage Receiver Kit

The GR-78 general coverage receiver recently announced by Heath Company provides a.m., c.w. and s.s.b. coverage from 190 kHz to 30 MHz in six switch-selected bands. Solid-state circuit employs field-effect transistors in the r.f. section and four ceramic i.f. filters for improved sensitivity and selectivity and eliminating the need for alignment. Built-in bandsweep tuning can be calibrated for either the shortwave broadcast or amateur bands, and a switchable 500-kHz crystal calibrator insures accurate dial calibration. This receiver comes complete with a rechargeable nickel-cadmium battery pack with a built-in charging circuit. Wiring options permit operation from either 120 or 240V a.e. and 12V d.c. Other features include switched a.g.c., an automatic noise limiter, receiving muting for use with a transmitter and a front panel relative signal strength meter. Price £68 18s. Daystrom Ltd, Heathkit Division, Gloucester.

WW 311 for further details

Time-interval Module

Time-interval measurements between pulses derived from two different lines can now be made with the addition of a time-interval unit, the PM6631, to the Philips PM6630 counter available from Pye Unicam. The unit can measure time intervals between pulses with the same or opposite polarity, and also with amplitude differences as great as 20:1. With the addition of the PM6631, the counter can measure time intervals in the range 50ns to 106 seconds on pulses with widths down to 5ns. The triggering level for both pulses is individually adjustable in the range ± 1.5V (no attenuation) to ± 30V (20:1 attenuation), and trigger sensitivity is 150mV (pk-pk) for all pulses with widths greater than 5ns. Also provided is a separate d.c. output which indicates the trigger level used on the stop pulse and an oscilloscope output which can be used to display the exact position of the stop pulse in relation to the start one. Apart from this new measuring facility, the PM6630 combines a 160MHz frequency range with a 50mV r.m.s. input-signal sensitivity and an input impedance of either 1MΩ/15pF or 50Ω. A 100 MHz internal clock makes the instrument useful for signal-generator and communications equipment calibration, oscillator drift measurements and computer-clock frequency checks. Pulse width and delay measurement can also be obtained. Pye Unicam Ltd, York Street, Cambridge.

WW 326 for further details

Rotary Stud Switch

The Elma sub-miniature rotary stud switch now features an improved case in glass-filled polycarbonate. This material is unaffected by most common solvents and is easily marked to aid wiring. Switches are available with tags for direct wiring to p.c. boards and may be supplied with screwdriver slots instead of shafts. Different torque settings are available. The standard torque setting is 200 gm/cm; 400 and 600 gm/cm can be supplied to order. A ceramic wafer and gold-plated stud contacts are used. Contact resistance is better than 5mΩ and wafer insulation better than 106Ω. Switching capacity is up to 1A. Radiation Components Ltd, 76 Crown Road, Twickenham, Middlesex.

WW 309 for further details
There is an M in Ferguson

It stands for Motorola and you'll see it in the Ferguson single standard 3000 colour TV chassis. It's the mark of Motorola quality and reliability that got radio on the road and helped to put men on the moon.

A few facts:
Motorola is one of the largest semiconductor manufacturers in the world. Principal manufacturing facility and development labs in Phoenix, Arizona; European HQ in Geneva; European factories in France and Scotland.
Motorola understands quality and reliability—it was their equipment that provided the essential communication links (radio and TV) between the moon's surface and earth.

That's why there is an M in Ferguson.—it stands for reliability
Motorola Semiconductors Limited
York House, Empire Way, Wembley, Middx.
Tel: 01-903 0944, Telex: 21740 Motsem Wembley.

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2.5µV-1000V
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Large, bright display
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Choice of 3 amplifiers, including differential.
3 time bases, including sweep delay.
An X-Y plotter and custom blanks.

Post the magazine's reply-paid card and we'll send you our data sheet of full details.

The Solartron Electronic Group Ltd Farnborough Hampshire England Telephone 44433

WW—106 FOR FURTHER DETAILS

www.americanradiohistory.com
Voltage-coupled Waveform Generator

A waveform generator with voltage-controlled frequency over a 1000:1 ratio, and a bandwidth from 0.1Hz to 3MHz, is being marketed by Environmental Equipment. The instrument, model 123, produces sine, square and triangular waveforms, as well as a sync pulse. Frequency is controlled to ±2% accuracy by a Kelvin-Varley divider in the form of a multiplier with both digital and vernier adjustments. External voltage control can either be d.c. programming or a.c. frequency modulation. The output for all waveforms is at least 20V pk-pk into an open circuit, or 10V pk-pk into a 50Ω load. Attenuation of 60dB in steps of 20dB is provided, as well as variable 5V d.c. offset and floating output. A search mode is provided so the operator can use the vernier in the multiplier to sweep over a 1000:1 (three-decade) range within the frequency range selected. Both top and bottom panels of the instrument case are easily removable for calibration and maintenance.

WW322 for further details.

50-MHz Counter/Timer

Latest addition to the Marconi Instruments counter/timer range, TF2411, features a choice of plug-in frequency standards permitting the user to order an instrument with a performance and accuracy best suited to his applications. The TF2411 performs a wide range of functions including period and multi-period measurements, time interval, ratio and frequency measurements up to 50MHz. Using mainly integrated circuits and based on a system of plug-in printed circuit boards, the counter/timer has an f.e.t. input giving 10mV sensitivity and 1MΩ input impedance. Seven-digit readout is provided with a binary memory, and there is an optional b.c.d. printer-output. The cabinet measures 89 × 280 × 254 mm. The three plug-in

frequency standards at present available for TF2411 are: TM9932—a high-performance crystal and oven with an age rate of 1 × 10⁻⁷ per month and a warm-up time of 10 minutes to reach 1 × 10⁻⁷ operation; TM9888H—simple crystal oscillator which includes a 10-MHz external standard panel; and TM9890 which accepts external standard frequency signals between 1 and 10MHz. The choice of standard is made at the time of ordering. Marconi Instruments Ltd, Longacres, St. Albans, Herts.
WW312 for further details.

Equipment Cases

A range of modular instrument cases from Case Systems has been designed to give a flexible and compact method of housing electronic equipment. The cases are constructed from aluminium extrusions and plastic mouldings. Each case is mechanically stable when placed on any of its six sides, and the handles protect panel components, such as meters and switches, when the case is placed face downwards or accidentally dropped. The protrusions at the rear which allow the case to stand face upwards, also protect rear connectors and components. The standard case, CS1 which is bench mounting can be converted to 19-in rack mounting simply by fitting brackets to each side. The CS1 will accept one module M1 or two modules M2. The CS2 or "half rack" case accepts one module M2 only. Case Systems, 20 Hunt Lane, Chadderton, Lancs.
WW329 for further details.

High-Q Varactor Diodes for X-Band

Four gallium arsenide, Schottky barrier diodes announced by Mullard are intended for use as tuning elements in microwave circuits. Because the four devices, which form the 821CX family, have resistances of not more than 3Ω, high Q-factors can be achieved. The diodes have zero-bias 'juncion' capacitances of 0.8 to 2.5pF, depending on the type. Breakdown voltage is not less than 12V, and the minimum ratio of junction capacitance at zero bias to capacitance at 12V reverse bias is 3.

Mullard Ltd, Mullard House, Torrington Place, London W.C.1.
WW327 for further details.

Colour-coded Audio Output Transistors

The full range of G.E. (U.S.A.) Power Tab a.f. output transistors is now available from Jermy Industries. Four main types, colour-coded for easy identification, make up two sets of complementary stereo pairs: D40 brown, 1A 6W, n-p-n; D41 black, 1A 6W, n-p-n; D42 red, 3A 12W, n-p-n; D43 green, 3A 12W, p-n-p. Each type is available with 30, 45 or 60V continuous rating, with a wide range of gains up to 30. The flat pins are easily formed to TO5 or TO66 configurations. 100 up prices range from 7s 8d to 21s.
Jermy Industries, Vestry Estate, Sevenoaks, Kent.
WW325 for further details.


Advance Electronics announce three low-drift versions of their ZEL 1 series operational amplifiers. They are designated ZEL 1/02, 1/03 and 1/04 and have drift characteristics of 2.5, 5 and 10µV/V·°C respectively. Other main features of the ZEL 1 range are: d.c. gain 5 × 10⁶ min; offset current 5nA max; slew rate 6V /µs min; c.m.r.r. 20,000 and input noise 2µV r.m.s. Prices £18 19s (02), £11 10s (03) and £8 10s (04). Advance Industrial Electronics, Raynham Road, Bishops Stortford, Herts.
WW314 for further details.

Subminiature Relays

Two miniature relays measuring only 20.3mm long by 14.2mm wide by 6.35mm high have been introduced by Bourns. These are models 3120 s.p.d.t. and 3121 d.p.d.t. Both have a 1A rating at 26V d.c. and an operating temperature range of -65 to +125°C. Coil resistance and sensitivity ranges for the 3120 and 3121 respectively are 50–2,000Ω, 100mA nominal, and 65–2,000Ω, 160mA nominal. Contact material is gold-plated semiprecious metal and a life of 100,000 cycles is claimed. Bourns (Triumph) Ltd, Hodford House, 17/27 High Street, Hounslow, Middx.
WW319 for further details.
ACTIVE DEVICES
We have received the following literature from Marconi-Elliot Microelectronics Ltd, Wilham, Essex, t.l.l. 9000 series applications handbook ... . price 30s: medium scale integrated circuits and memory elements product guide ... WW401reminder of the current steering logic data sheets: MB501 dual four-input gate with bias driver ... WW402MB502 dual four-input gate with bias driver and phantom NOR output WW403MB503 eight-input logic gate with bias driver ... WW404

Microwave Associates, Ltd, Luton, Beds., have sent us a folder containing the following:

Micronotes WW405 high-power varactors (two) data sheet ... WW406 bulletin 4058 p.i.n. switching diodes (low medium power) ... WW407 bulletin 4059 p.i.n. switching diodes (high power) ... WW408 bulletin 4060 35V tuning varactors ... WW409 bulletin 4061A avalanche oscillator diodes WW410 bulletin 4063 varactors, high-power ... WW411 bulletin 4065A snap varactors ... WW412 bulletin 4067A varactors, high-power ... WW413 bulletin 4073 X-band Schottky diodes ... WW414 bulletin 4074/5/6/7/8/9, snap varactor diodes WW415 bulletin 4081 90V tuning varactors ... WW416

A number of additions for the Microwave cathode-ray tube manual and display equipment manual may be obtained from Ferranti Ltd, Gem Mill, Chadderton, Oldham, Lancs WW417

“What is Thick Film?”, is the title of a leaflet which may be obtained from Reliance Controls Ltd, Drakes Way, Swindon, Wilts WW418

National Semiconductor Corporation, 2975 Ysidro Way, Santa Clara, California 95051, have published a data sheet on the LH101 operational amplifier, which is a variant of the LM101, and is now being manufactured in monolithic form WW419

Silicon General Inc., 7382 Bolsa Ave., Westminster, California 92683, U.S.A., have sent us the following data on the products: SG-1402, -2402, -3402 variable gain wideband amplifiers/multipliers ... WW420SG-710A, -710B differential voltage comparator ... WW421SG-710B, -710C differential voltage comparator ... WW422SG-711A, -711 voltage comparator ... WW423SG-711B, -711C voltage comparator ... WW424SG-105, -205, -305 voltage regulators ... WW425

Two more data sheets on d.l.l.t.l.t.l. compatible m.o.n.s. circuits from General Instrument Microelectronics, Stonefield Way, Ruislip, Middx, HA4 0JT, are available, SS-6-2004 dual 4-bit parallel access, reversible static shift register ... WW426SL-6-4025/32, quad 28/32-bit static shift register ... WW427

Leafl e No. 1, volume 1, of the Hivac Application Bulletin describes the use of glow diodes (cold cathode glow discharge tubes), in a number of circuits. Hivac Ltd, Stonefield Way, Ruislip, Middlesex WW428

A loose-leaf catalogue produced by Rastra Electronics Ltd, 275 King St, Hammersmith, London W6, lists integrated circuits, transistors, diodes and many other items ... WW429

Quardon Electronics (Semiconductors) Ltd, Slack Lane, Derby, DE3 3ED, who are distributors for Texas Instruments, S.G.S., Raytheon, Emibus and Sprague, have produced a comprehensive semiconductor catalogue, “Semicom 70”, which is now available WW430

The E.E.V. equivalents for nearly 2000 valves are listed in the “Equivalents Index-1970” which is published by the English Electric Valve Co. Ltd., Chelsford, Essex WW431

We have received a short-form catalogue from the Signetics Corporation, Trident House, Hayes, Middlesex, which lists linear and digital integrated circuits WW432

PASSIVE COMPONENTS
The 5th edition of “Components Applications Data”, may be obtained from Radiospares, P.O. Box 427, 13-17 Epworth St, London E.C.2 WW433

A leaflet, “Electrolyte Contact Lubricant”, is available from Electrolyte Corp, Oxford Avenue, Slough, Bucks WW434

Microwave waveguide filters manufactured by Ferranti Ltd, Components Division, Dunstable Avenue, Dunstable DD2 3PN, Scotland, are described in a leaflet WW435

“Military Specification Connector Manual”, lists the products of Elco Pacific, 2200 Park Avenue, CA WW436

Two additions have been received for the Erie Catalogue dealing with r.f. filter devices. Erie Electronics Ltd, South Denes, Great Yarmouth, Norfolk WW437

“Product Selector Guide”, from the Dialight Corporation, 60 Stewart Avenue, Brooklyn, N.Y.11237 lists illuminated哪怕是 dials, digital readouts and illuminated push-button switches WW438

The new range of “Control-Line” Modules, which operate high-current loads from low-level control systems without mechanical contacts, are described in a catalogue from FR Electronics, Flight Refuelling Ltd, Winborne, Dorset WW439

“Component Socket Guide”, from the Elco Corporation, Willow Grove, Pennsylvania 19090, U.S.A., lists valve, crystal, relay, transistor and d.t. sockets WW440

Reed relays are the subject of a new catalogue from: Kempton Electrical Co. Ltd, Shirley Rd, Rushden, Northants WW441

A catalogue listing the products distributed by the D-T-V Group, 126 Hamilton Rd, London S.E.27, is available WW442

A range of contactless switches is described in a catalogue from Cole Electronics Ltd, Landsdowne Rd, Croydon CR9 2BH WW443

Miniature switches, microphones, headphones, leads, plugs and sockets are the subject of a catalogue from Danavox (Great Britain) Ltd, “Broadlands”, Bagshot Rd, Sunninghill, Berks WW465

Two engineering bulletins received from Sprague (U.K.) Ltd, Sprague House, 159 High St, Yiewsley, West Drayton, Middlesex, describe capacitors: 2705A Metalized polyethene film capacitors WW466

3456A Aluminium capacitors, non-aqueous electrolyte WW467

An eight-page potentiometer selection guide is available from Reliance Controls Ltd, Drakes Way, Swindon, Wilts WW468

Details of a seven-day prototype illuminated pushbutton switch service are given in literature from Foster Graham Ltd., Pinecastle Hill, Kedalo, Roxborough. The service is based on a 4-pole change-over switch which may be supplied in banks with a variety of mechanical actions and contact configurations WW469

HARDWARE, ETC.
A data sheet from First Creekland Fastenings Ltd, Treforest, Pontypyll, Glamorgan, pictorially shows the uses of a range of Spire fasteners WW444


A modular connecting system called Hypertac is described in a leaflet S/294C from Smiths Industries, Industrial Instrument Division, Kelvin House, Wembley Park, Middd WW446

Applications data and technical information on Looite products for thread locking, retaining and sealing is given in a brochure from: Douglas Kane Group Ltd, Swallowfield, Welwyn Garden City, Herts WW444

EQUIPMENT
Over 200 power supply modules and about 50 measuring instruments are the subject of a leaflet from Lambda Electronics, 21 Aston Rd, Waterlooville, Portsmouth, Hants WW445

Performance details of the type TSA 663/6 counter timer are in a data sheet. Venner Electronics Ltd, Kingston By-Pass, New Malden, Surrey WW446

Helium-neon lasers are described in a leaflet from Ferrant Ltd, Dunstable Avenue, Dunstable DD2 3PN, Scotland WW447

A leaflet describing the digital voltmeter type LM 1867 may be obtained from the Solartron Electronic Group Ltd, Farnborough, Hants WW448

Lyons Instruments Ltd, Hoddesdon, Herts, have produced a leaflet which describes six pulse generators WW449

A Gunn-oscillator, type PM7015X is described in a leaflet from Sivers Lab, U.K. Office, Old Haverhill Rd, Little Wratting, Suffolk WW450

The following literature is available from Dana Electronics Ltd, Bilston Way, Dallow Rd, Luton, Beds: Series 5740 digital voltmeters WW451 Series 5700 digital voltmeters WW452

We have received the following literature from:

Wireless World, April 1970

www.americanradiohistory.com
Marconi Instruments Ltd, Longacres, St. Albans, Herts.

Automatic testing—the way ahead WW453
TF 2210, 100MHz oscilloscope WW454

Lyons Instruments (Hoddesdon, Herts), newsletter for January 1970 discusses a programmed pulse system for dynamic testing WW455

Thyristor controllers for use between 100 and 300A are the subject of a data sheet published by AEI Semiconductors Ltd, Carholme Rd, Lincoln. WW456

"Servoscribe" flat-bed chart recorders are described in a leaflet from the Industrial Instrument Division, Smiths Industries Ltd, Wembley, Middx WW457

The diverse applications of the SM.270/2/2D and "Measuretest" instrument application explains what S.W.I, Calibration Services have received of Sunbury-on-Thames, R.C.A. WW459

Radio telecommunications equipment and systems WW458

The following two brochures are obtainable from Racal Group Services Ltd., 26 Broad St, Wokingham, Berks.

Solid state h.f. Receivers WW459
Radio telecommunication equipment and systems WW459

V. N. Barrett & Co. Ltd, 1 Mayo Rd, Croydon, CRO 2QP. Surrey, have produced a new catalogue of used scientific and industrial equipment WW472

GENERAL INFORMATION


The Mullard Educational Service, Mullard House, Torrington Place, London W.C.I, have produced a leaflet listing all the publications available from them WW460

"Measuretest" instrumentation application notes (numbers 001 and 002), for colour television are available from Marconi Instruments Ltd, Longacres, St. Albans, Herts WW461

Tektronix U.K. Ltd, Beaverton House, P.O. Box 69, Harpenden, Herts, have three more books in their "Concept" series available; the price is 10s each including postage and packing. They are: Horizontal Amplifier Circuits WW462

Oscilloscope Probe Circuits
Probe Measurements

R.C.A. Great Britain Ltd, Lincoln Way, Windmill Rd, Sunbury-on-Thames, Middx, have available application note ICAN-4158 "Application of the CA 3059 zero-voltage switch in thyristor circuits"..... WW462

The Scientific Instrument Manufacturers' Association of Great Britain, SIMA House, 20 Peel St, London W.1, have produced a booklet called "Metrorating Guide" which is available from them price 50s.

Two new publications are available from the Mullard Educational Service, Mullard House, Torrington Place, London W.C.I.

"A simple f.c.t. voltmeter" WW473
"Introducing thyristors" WW474

We have received two publications from the British Calibration Service, Millbank Tower, London S.W.1, which are listed below. The first of these explains what the British Calibration Service is and how a laboratory may apply for approval. The second publication lists all the laboratories that have obtained approval so far together with the type of measurements they can carry out and the degree of accuracy guaranteed.

About the British Calibration Service WW475
Directory of Approved Laboratories WW476

THE CHOICE

OF CRITICS

BULGIN PRECISION

ELECTRONIC

COMPONENTS

COMPREHENSIVE RANGE OF MOULDED SWITCHES

NEW 4 CONTACT & 8 CONTACT MODELS

Illustrated right is one of a range of two NEW further types of Double Pole Moulded Insulation Switch with a higher rating than the Double Pole range above.

Two versions are available, both Toggle operated SM.277/2/2D is a D.P. Make-Break (4 contact) Switch (illustrated), rated at 4A at 250V A.C. and SM.301/2/2PD is a D.P. Change-Over B contact model, rated 3A at 250V A.C. for double pole alternative circuit switching.

In both cases the body is a polished Grey moulding, the internal contacts and solder tags are silver plated and the front of panel parts are chromed. Only one modification is available for this range as tabulated.

DOUBLE POLE ROTARY MODEL

Illustrated left is a semi-rotary shaft version of one of the above mentioned Double Pole Moulded Switches. The model is rated at 2A 250V A.C. N.1. with "φ" 0 shaft and head guide Make and Break action fine silver cleaning contacts and solder tag connections.

A wide range of different models are available. Operation can be Toggle (illustrated left), Biased Toggle, Biased Push, Push-Push (successional) Action. Push-Pull Action. Semi-Rotary Shaft or Key and the connection tags accept solder or 110 series push on tabs. Various modifications can be supplied, to agreed quantity orders. Send for the Moulded Switch Wall chart listed for the full list of modifications available.

SINGLE POLE RANGE

Illustrated right is one of the complete range of Single Pole Moulded Insulation Switches manufactured by the latest automatic methods, with constant testing ensuring that the highest standard of finish is always maintained. All front of panel parts are plated in brilliant chrome, except where moulded operators are used, which are black. Internal contacts and solder tags are heavily silver plated for the best possible connection whilst all other metal parts are suitably protected against corrosion, the polished Black moulded body gives excellent insulation.

A wide range of different models are available. Operation can be Toggle (illustrated left), Biased Toggle, Biased Push, Push-Push (successional) Action. Push-Pull, Slider, Key, and Semi-rotary Shaft (illustrated above right). Connection in all cases is to Solder Tags, with Screw Terminals available to order as an alternative on some models. A wide range of modifications can be supplied to agreed quantity orders, see the moulded switch wall chart.

Proof Test = 2K.V. at 50 C.S. I.R. <.
100MΩ dry or recovered at 500V.

SEND FOR COMPREHENSIVE MOULDED SWITCH/LAMINATED SWITCH EQUIVALENT LIST REF 1536/C

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D.A.M.

WWW.10? FOR FURTHER DETAILS

www.americanradiohistory.com
April Meetings

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

LONDON
1st. I.E.E.—Discussion on "Electrical measurement of surface wave devices" at 17.30 Savoy Pl., W.C.2.
2nd. I.E.R.E.—Discussion on "Direct digital measurement of physical quantities" at 18.00 at 9 Bedford Sq., W.C.1.
3rd. I.E.E.—Discussion on "Aeronautical communication by satellite" at 17.30 at Savoy Pl., W.C.2.
7th. I.E.E.—"Remote control system" by J. K. S. Jowett at 18.00 at Savoy Pl., W.C.2.
9th. R.T.S.—"Creating colour television titles" by M. J. Cox at 19.00 at I.A.A., 70 Brompton Road, S.W.3.
22nd. I.E.E.—"Telemcommunications support for the Apollo programme" by Lorne M. Robinson (N.A.S.A.) at 17.30 at Savoy Pl., W.C.2.
23rd. I.E.E.—"Quasar and radioisotopes" by Professors F. Hoyle at 17.30 at Savoy Pl., W.C.2.
23rd. Inst. Electronics—"Modern aspects of electronic instrument design" by G. F. Penner at 18.30 at West Ham College of Technology, Stratford, E.15.
29th. I.E.E.—"Ionospheric research by means of oblique incidence sounders" by P. Bradley at 17.30 at Savoy Pl., W.C.2.
29th. I.E.R.E.—"Scanning circuits for 110" colour tubes" by K. E. Martin at 18.00 at 9 Bedford Sq., W.C.1.
30th. R.T.S.—"An image analyser for medicine using colour television techniques" by M. B. Coyne, F. Paice & Prof. E. D. Williams at 19.00 at the Woffin Institute, Royal Postgraduate Medical School, Hammersmith Hospital, Ducane Road, W.12.

BARROW-IN-FURNESS
1st. Inst. Civ. and Memb.—Application of lasers" by Prof. E.D.R. Shearman at 19.30 at the Hotel Imperial, Carnavall St.

BELFAST
10th. I.E.R.E.—"Aerials" by H. V. Sims at 18.30 at the Ashby Inst., the Queen's University, Stranmillis Road.

BIRMINGHAM
8th. I.E.E.—"Thyristor drives" by M. F. Arnold at 19.00 at the Sunpear Bldg, the University of Aston, Gosta Green.
9th. I.E.R.E.—"Gramophone records—past and present" by G. M. Nathan at 19.30 at the University's Dept. of Electronic & Electrical Eng.'
15th. R.T.S.—"University of Birmingham television service" by Dr. Peter Whisker at 19.00 at the University.

BLENDY
21st. I.E.E.—"Lasers and their applications" at 19.15 at Harwood House College.

BRIGHTON
14th. I.E.E.—"On the future of world communication" by Prof. E. C. Cherry at 18.30 at the College of Technology, Lewes Rd, Moulsecoomb.

CARDIFF
6th. I.E.E.—"Digital filters" by Dr. R.C.V. Macario at 18.00 at U.W.I.S.T.
23rd. R.T.S.—"The E.V.R. system" by Sir Francis McLean at 19.00 at the B.B.C. Llandaff.

CARLISLE
8th. I.E.E.—"Application of thyristors to industrial control systems" by S. Denyser at 19.30 at the Technical College, Victoria Place.

CHATHAM
23rd. D.E.—"Automatic trains on the Victoria Line" by R. F. M. Arthurson at 19.00 at the Medway College of Technology.

CHELMSFORD
15th. I.E.E.—"Radio-astronomy, thirty-five years progress" by F. W. Hyde at 18.30 at the King Edward Grammar School.

DUBLIN
15th. I.E.E.—"Faraday Lecture—"People, communications & engineering" by J. H. H. Merriman at 20.00 at R.D.S. Hall.

DURHAM
22nd. I.E.E.T.—"Application of thyristors to industrial control systems" by S. Denyser at 19.30 at the University's Science Laboratories, South Road.

EVESHAM

LEEDS
16th. I.E.E.—"Thyristors into the home and industry" by R. Willis at 19.30 at the University's Dept. of Electronic and Electrical Eng.'
28th. I.E.E.—"Electronic measurement as a guide to archeological research" by E. T. Hall at 18.30 at the University.

LIVERPOOL
1st. I.E.E.—"Laser holography" by Dr. J. M. Burch at 18.30 at the University.
6th. I.E.E.—"The pulsars" by Prof. F. Graham Smith at 18.30 at the University.
22nd. I.E.R.E.—"Schools project technology" at 19.30 at the University's Dept. of Electrical Eng.'

MANCHESTER
8th. I.E.E.—"Communications hit by bit" by H. B. Law at 18.45 at U.M.I.S.T.
14th. I.E.E.—"History and development of time & frequency measurement" by C. R. Cordwell at 18.15 at U.M.I.S.T.
22nd. I.E.R.E.—"Radars data processing techniques with application to air traffic control" by Dr. P. J. C. Child at 18.15 at Revold Bldg, U.M.I.S.T.

NEWCASTLE-UPON-TYNE
8th. I.E.R.E.—"The symbolic integrated maintenance systems" by J. Hamilton at 18.00 at the Polytechnic (Rutherford College), Ellison Pl.

NORWICH
14th I.E.E.—"Electronic performance testing of motor vehicles" by E. Gamble at 19.30 at the Assembly Hall.

NOTTINGHAM
16th. R.T.S.—"Duplication of BBC-1 on u.h.f. & introduction of 3-channel colour" at 19.30 at the B.B.C. Studies, Wilson House, Derby Road.

PLYMOUTH

PORTSMOUTH
21st. I.E.E.—"Aids to all-weather landing of aircraft" by M. Catton at 18.30 at the Polytechnic, Angiess Rd.

READING
16th. I.E.E.—"The design of solid-state audio amplifiers" by P. J. Haxandall at 19.30 at the J. J. Thomson Lab., the University, Whiteknights Pl.

RUGLEY
2nd. I.E.E.—"Engineer to manager—effecting the transition" by M. W. Lauerman at 19.00 at the Shrewsbury Arms Hotel, Market St.

SALFORD
13th. I.E.E.—"Electronics, man & aerospace" by R. E. Young at 19.30 at the University.
14th. I.E.E.—"Electronics, man & aerospace" by R. E. Young at 14.30 (students) and 19.30 at the University.

SALISBURY
13th. I.E.E.—"Colour television" by L. G. Dive at 19.00 at the Salisbury & Wilts College of Further Education, the Friary.

STOKE-ON-TRENT
9th. I.E.E.—"Voltage and its measurement from 'A' to about 'Q'" by F. W. Senior at 19.15 at the North Staffs College of Technology.

SWANSEA
9th. I.E.E.—"M.O.S. integrated logic" by J. A. Roberts at 18.15 at University College, Singleton Pl.
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WW—108 FOR FURTHER DETAILS
McMurdo's new 0.10" Pitch Connector- "RL" Series

5 to 85 way single sided with solder and printed wiring tails.
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Another new product from:

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and agents in principal overseas countries.

WW—109 FOR FURTHER DETAILS
The Sinclair IC-10 is the world's first monolithic integrated circuit high fidelity power amplifier and pre-amplifier. The circuit itself, a chip of silicon only a twentieth of an inch square by one hundredth of an inch thick, has 5 watts R.M.S. output (10w. peak). It contains 13 transistors (including two power types), 2 diodes, 1 zener diode and 18 resistors, formed simultaneously in the silicon by a series of diffusions. The chip is encapsulated in a solid plastic package which holds the metal heat sink and connecting pins. This exciting device is not only more rugged and reliable than any previous amplifier, it also has considerable performance advantages. The most important are complete freedom from thermal runaway due to the close thermal coupling between the output transistors and the bias diodes and very low level of distortion.

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 full guarantee on every 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: 5mV.
- Input impedance: Adjustable externally up to 2.5 M ohms.

**CIRCUIT DESCRIPTION**
The first three transistors are used in the pre-amp and the remaining 10 in the power amplifier. Class 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 crossover distortion at all supply voltages, making battery operation eminently satisfactory.

**APPLICATIONS**
Each IC-10 is sold with a very comprehensive manual giving circuit and wiring diagrams for a large number of applications in addition to high fidelity. These include stabilised power supplies, oscillators, etc. The pre-amp section can be used as an R.F. or I.F. amplifier without any additional transistors.
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 foreseeable 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. Only holes have to be drilled into the wood of the plinth or cabinet to mount the Stereo 60 and any slight slips here will be covered completely by the aluminium front panel of the control unit. 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) POWER 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 A/B.

Frequency response: 30 to 300,000 Hz ± 1 dB.

Signal to noise ratio: better than 70dB unweighted.

Distortion: 0.02% total harmonic distortion at full output into 8 ohms and at all lower output levels.

Size: 3¾ x 2¾ x 4 inches.

Input sensitivity: 250mV into 100 Kohms.

Damping Factor: 500.

Loudspeaker impedances 3 to 15 ohms.

Power requirements: 8 to 35 V.d.c.

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—250mV.
- 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 100Hz.
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<td>100V</td>
<td>62/-</td>
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<td>14,000 μF</td>
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<td>42,000 μF</td>
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VOLTOMETER—Solartron VM 144D
Very suitable for the measurement of distorted or complex signals, noise or pulse voltages, employing thermocouples in a self-compensating bridge circuit. Reads true RMS values. High-frequency factors. Output up to 10 V/dec available as a drive speaker for a D.V. Frequency range 10 HZ - 10 MHz. Accuracy 1% of Full Scale Range; 0.05% rated. Dim. 14 x 5 x 20 in. Price £325.00.

PORTABLE AC/DC PEN RECORDER
A most versatile pen recorder. Primarily a time-on-a-event recorder. Two speeds 1 in. or 6 in. full scale. Limiting contacts to control gain, and limits the current when A. A. is removed. Range 0-100A D.C. Meter Full Scale Range AC: 500 mV Full Scale Range DC: 100 mV. Case with battery and 100 ft. extension leads £55.00. Price £105.00.

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25 characters per second.

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HOLLERTH 80 COLUMN CARD PUNCH TYPE H05 and VERIFY AVAILABLE

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COMPUTERS
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WEIGHT: 5.5kg.


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3 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 3 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

7 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 7 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

4 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 4 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

5 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 5 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

6 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 6 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

8 TRACK DIGITAL MAGNETIC TAPE STORAGE DECK
These machines originally ex-computer, are multi-track recording units, ideal for data storage. Record and Repay 8 tracks of 100 ft. each. Low recording head. Frequency response approximately 0 Hz to 40 KHz. Bit rate 577.2 K bit/s, 145 bit/s, Max 20° C to 30° C. A.C. 250 V. D.C. 300 V. Housed in a strong plastic case. Fully waterproofed to IPX 9. Price £52.10.0. Carriage extra.

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4/70

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**GUARANTEED**

**TRANSISTORS**

<table>
<thead>
<tr>
<th>Brand New Brands</th>
<th>Guaranteed</th>
<th>Various Models</th>
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<tbody>
<tr>
<td>Rs. 50 each</td>
<td>Rs. 40 each</td>
<td>Rs. 30 each</td>
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<tr>
<td>Rs. 25 each</td>
<td>Rs. 15 each</td>
<td>Rs. 6 each</td>
</tr>
</tbody>
</table>

**MOSFETs**

- 2N1131: Rs. 15 each
- 2N3134: Rs. 14 each
- 2N5354: Rs. 13 each

**JFETs**

- 2N1131: Rs. 15 each
- 2N3134: Rs. 14 each
- 2N5354: Rs. 13 each

**SILICON RECTIFIERS**

<table>
<thead>
<tr>
<th>Model</th>
<th>Quantity</th>
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<tr>
<td>2N5064</td>
<td>10 pc</td>
</tr>
<tr>
<td>2N5068</td>
<td>10 pc</td>
</tr>
</tbody>
</table>

**Ceramic Capacitors**

- 56pF: Rs. 4 each
- 1uF: Rs. 4 each

**Carbon Film Resistors**

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- 1M ohms: Rs. 4 each

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TE-310

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10 in. wide, 2,000 ft. £6.00
10 in. wide, 3,000 ft. £8.95
10 in. wide, 4,000 ft. £11.25
10 in. wide, 5,000 ft. £12.95
10 in. wide, 6,000 ft. £15.00
10 in. wide, 8,000 ft. £18.00
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Crinco 4 in. wide, 4 in. ft. £1.00
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Crinco 6 in. wide, 10 in. ft. £1.25
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Crinco 8 in. wide, 20 in. ft. £2.75

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Crinco 4 in. wide, 4 in. ft. £1.25
Crinco 5 in. wide, 5 in. ft. £1.75
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Crinco 7 in. wide, 7 in. ft. £2.75
Crinco 8 in. wide, 8 in. ft. £3.25
Crinco 9 in. wide, 9 in. ft. £3.75
Crinco 10 in. wide, 10 in. ft. £4.25
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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>
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</table>

Tick the values required:

- 13 ohms
- 22 ohms
- 33 ohms
- 47 ohms
- 91 ohms
- 220 ohms
- 470 ohms

**Total:**

### SILVER MICA/CERAMIC/POLYSTYRENE CONDENSERS.

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<td>22</td>
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2% discount lots of 100 per type.
5% discount lots of 1,000 per type.

**Total:**

### MULLARD POLYESTER CONDENSERS

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**Total:**

### LIGHT SENSITIVE DIODES

Can be used to control any transistorised device, 1 each.

**Total:**

### THYRISTORS

- 400 volt BTY 79 7/8d. each. SCR 51 (10 amp) £1 each.

**Total:**

### RECORD PLAYER CARTRIDGES

- ACOS GP97/2 15" (Mono) £49/4 190/6 (Stereo, ceramic)
- ACOS GP97/1 20/6 (Compatible) £39/3 with diamond needle 12/6d.
- ACOS GP98/1 25/6 (Stereo) £39/3 with diamond needle 27/6d.

**Total:**

### TRANSISTORISED FLOUORESCENT LIGHTS.

- 8 volt 12" tube, Reflector type 59/8 £13 with 18" tube, Batten type 79/8

**Total:**

### TRANSISTORED SIGNAL INJECTOR KIT

**Total:**

### VERO-BOARD

- Spot Face Cutter 79d. Pin Insert Tool 8/d. Terminal Pins 3/6d. for 36. Spot Face Cutter and 5 21/2" 1-Boards 89/d.

**Total:**

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 2/6.

G.F. MILLWARD, DRAYTON BASSETT, near TAMWORTH, STAFFS. Phone: TAMWORTH 2321

---

**SKELETON PRESETS.** Mixed. 6/- dozen.

**VOLUME CONTROLS.** 1 meg. 1 meg. with D.P. switch 5d. (No switch) all 2/-

**RECORD PLAYER AMPLIFIERS.** All transistor. Complete with screened input lead, volume control and speaker leads. This excellent unit also has built-in rectifier and smoothing components enabling same to be used direct on 6 to 9 volt A.C. supply. Small number only! Cannot be repeated at this price 30/- ea.

**TRANSISTOR RADIOS.** Fantastically bargain! Tremendous value! Superior quality sound from large speaker! Excellent sensitivity! Complete with earpiece, battery and plastic carrying case, all packed in a colourful presentation box. You would expect to pay £5—but our price due to huge purchase is only 37/6d.

**CO-AXIAL CABLE.** Semi-air spaced. 8d. yard. 50 yards rolls 30/- Postage 4/6d.

**CRYSTAL TAPE-RECORDER MIKES.** 12/- each. CRYSTAL EARPIECES WITH PLUG, 5/- each. Magnetic earpieces. No plug. 1/- each.

**THIN CONNECTING WIRE.** 10 yards 1/-, 100 yards 7s. 6d., 1,000 yards 50/-.

**RECORD PLAYER CARTRIDGES.**

- ACOS GP97/2 15" (Mono) £49/4 190/6 (Stereo, ceramic)
- ACOS GP97/1 20/6 (Compatible) £39/3 with diamond needle 12/6d.
- ACOS GP98/1 25/6 (Stereo) £39/3 with diamond needle 27/6d.

**Total:**

---

**Giant Silicon Solar Cells.** Last few to clear at half price.

- Circutaries, 67 mm. diameter, each 50 mm. × 37 mm. 3 for 10/-
- Tubes, 17" × 17/15 " 17" × 15/15 " 17" × 15/15 " 11/-

Spot Face Cutter 7/8d. Pin Insert Tool 8/d. Terminal Pins 3/6d. for 36. Spot Face Cutter and 5 21/2" 1-Boards 89/d.

**Total:**
We supply B.A. Screws, etc. in brass, steel, stainless, phosphor bronze and nylon to laboratories throughout the Commonwealth.

We can also offer early delivery for many sizes of screws, etc. with Metric Threads

Please send for List W2/69 (WW)

WALKER-SPENCER COMPONENTS LTD.
5, High Street, Kings Heath, Birmingham, 14.
Telephone: 021-444 3155 (Sales) and 5278

WW—124 FOR FURTHER DETAILS

---

**4-STATION INTERCOM**

Solve your communication problems with this new 4-Station Transistor Intercom system (1 master and 3 subs), in de luxé plastic cabinets for desk or wall mounting. Call/talk from Master to Subs and Subs to Master. Operates on one 9 v. battery. On/off switch. Volume control. Ideal for use in homes, Offices, factories, workshops, hospitals. Nothing else to buy. P. & P. 7/6 in U.K.

Our Price Only

£7/15/0

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**INTERCOM/BABY ALARM**

Solve your communication problems with this new 4-Station Transistor Intercom system (1 master and 3 subs), in de luxé plastic cabinets for desk or wall mounting. Call/talk from Master to Subs and Subs to Master. Operates on one 9 v. battery. On/off switch. Volume control. Ideal for use in homes, Offices, factories, workshops, hospitals. Nothing else to buy. P. & P. 7/6 in U.K.

Our Price Only

£7/15/0

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**Lasky's AUDIO TRONICS 1970**

The 1970 edition of Lasky's famous Audio Tronics catalogues is available—FREEm to receive! The 28 tabloid pages—equal to over 100 pages of our normal WW—contain—packed with 1,000's of items from the largest suppliers in Great Britain of everything for the Radio and Hi-Fi enthusiast. Electronics, Hi-Fi, Intercom, Communications, Shops, Stores, Home, and more.

Lasky's catalogue is available—FREEm to receive! The 28 tabloid pages—equal to over 100 pages of our normal WW—contain—packed with 1,000's of items from the largest suppliers in Great Britain of everything for the Radio and Hi-Fi enthusiast. Electronics, Hi-Fi, Intercom, Communications, Shops, Stores, Home, and more.

Send: Your name, address and 2/- to cover post only and the inclusion of your name on our regular mailing list.

Lasky's Radio Limited
**BI-PAK SEMICONDUCTORS**

**NEW BI-PAK TESTED SEMICONDUCTORS**

**QUALITY-TESTED PAKS**

- 5 Walflex Trons, OCA/OCB/OLD/CE/REF.
- 10-25 Red Spot AP Trons, PEP.
- 10-25 White Spot AP Trons, PEP.
- 5 Silicon Rects, 5-100-460 PIV.
- 5-100-460 PIV.
- 1 PEP Switching Trans. 12.10-240.
- 150-460 PIV.
- 200-120-240.
- 5 NPN Flop Trans., 1C01/1C02.
- 1200-240.
- 1200-240.
- 5-100-460.
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GLENSWANN CONTROLS KITS

Each kit comprises seven items—Choice, (5 tone tubes, starter, starter holder and 2 tube clips, with instructions. Suitable for crystal and for operated circuits of 150 grams. Choice items are not experimental, mostly new listed. Kit A-12.50. Kit B-36.50. Kit C-80.50. 32K. Kit H-50. 39K. We supply 6-7. 11K. 271. 2K. No. 20K. 8 for one or two kits 5.80. 12 or two kits 7.50. Kits C-80. 32K. Kit H-50. 39K. No. 20K. 8 for one or two kits 5.80. 12 or two kits 7.50. Ech kit 3.50. A RED SWITCHES

Glass-covered, switchable type, available in various guage winded contacts. We only offer 2 types:

- 10 Amp D.P.
- Small

TELESCOPIC AERIAL

For portable, car radio or television, a highly portable aerial. 150 ft. of 75 ohm coax conduct, can be 200 ft. high, 1.50 each 150 ft.

MINIATURE PIECE

As used with imported pocket radios. 1.50 each 150 ft.

15/32 AMP CONNECTORS

Supplementary 15/32-in. strip. 150 ft. 3.25 each 100 ft.

13 AMP FUSED SWITCH

Made by G.S.C. For connecting water heater or any other appliance. 150 ft. 3.25 each 100 ft.

SUPPRESSOR

5 cent. Moll, A.G. (A.A.C.) Metal cased 15/32-in. strip. 150 ft. 3.25 each 100 ft.

RELAY REED

Glass-encapsulated reed switch in 7/32-in. nominal, 150 ft. 3.25 each 100 ft.

SHEET PAX

Ideal for transceiver projects, paper 12, 16, 24. each 29-19. 1.70 each 19-1.00

G.E.C. MULTIPLE SWITCHES

Metal boxes (with cable extension) armoured with cover, with integral grid, 150 ft. 3.25 each 100 ft.

G.E.C. Chloride Variac

For the above boxes, 3 amp A.G. (A.G.C.) Metal 15/32-in. strip. 150 ft. 3.25 each 100 ft.

HERMOUTH

Continuous adjustable 20-90°C. Sensor bell controlled by 315s of flexible tubing. On operation a 1.50-in. dia. 36-in. dia. opal in addition to the full glass dome. 150 ft. 3.25 each 100 ft.

FILM HI F. BARGAIN

FILM HI F. BARGAIN.

This is undoubtedly one of the best bindings that we have ever offered, produced by one of the country's most experienced manufacturers. Mainly white metal frame and is strongly recommended for beginners and advanced constructors. 150 ft. 3.25 each 100 ft.

RING MAIN JUNCTION BOXES

Made by Rock. This won Designs award for making and indeed junction of 200 ft. and wider useful. Used for ring main circuit. Our price 1.60 each 1.50 each 100 ft.

FLUORESCENT CONTROL KITS

Each kit comprises seven items—Choice, (5 tone tubes, starter, starter holder and 2 tube clips, with instructions. Suitable for crystal and for operated circuits of 150 grams. Choice items are not experimental, mostly new listed. Kit A-12.50. Kit B-36.50. Kit C-80.50. 32K. Kit H-50. 39K. We supply 6-7. 11K. 271. 2K. No. 20K. 8 for one or two kits 5.80. 12 or two kits 7.50. Kits C-80. 32K. Kit H-50. 39K. No. 20K. 8 for one or two kits 5.80. 12 or two kits 7.50. Ech kit 3.50.
ISOLATING/STEP DOWN TRANSFORMER
Primary 0, 240v., Sec. 0, 115v. 240v. 10a. Ideal for workshop supply, only 6in. x 7in. x 7in. £8. carr. 20/-. 

STEP DOWN TRANSFORMER
Primary 0, 240v., Secondary 0, 115v. 300 Watts (conservatively rated) 4jin. x 4in. x 4in. 45/-. p. & p. 8/-. 

12v. 4a. POWER SUPPLY
Brand new: weighs 11lb. Constant voltage transformer, input 0-1125, 1310. 220-235v. produces 12v. 4a. capacitor smoothed output. £10.00 plus 10/- carr. 

EX-COMPUTER POWER SUPPLIES
Reconditioned, fully tested and guaranteed. These very compact units are fully smoothed with a ripple better than 10mv. and regulation better than 1%. Over voltage protection on all except 24v. units. 120v. - 130v. a.c. 50c/s input. Mains transformer to suit £3 extra if required. We offer the following types: 6v. 8a. £10 20v. 15a. £15 6v. 15a. £14 30v. 7a. £12 12v. 20a. £16 24v. 4a £14. Carryage 15/- per unit. 

PYE CAR RADIO
Push Button Tuning Heart
Manual Over-ride is an ideal basis for a quality AM car radio. Size 6jin. x 6in. x 2in. 25/- plus 3/- p. & b. 

RELAY OFFER
Single pole changeover. 2in. x 0.6in. x 0.75in. 50v. 2.5k coil, operates on 24v. 8 for 19/- 5000 available, p. & p. 1/6. 

MEMORY CORE STORE PLANES

EXTENSION TELEPHONES
Why get out of the bath when the phone rings. Install one in the bathroom. 19/6 each, p. & p. 5/-. 35/- for 2, p. & p. 6/-. These are extension phones and do not have bells. 

1,750 COMPONENTS
YES, QUITE TRUE. READ ON
BUMPER BARGAIN PARCEL
We guarantee that this parcel contains at least 1,750 components. Short-leaded on panels, including a minimum of 35 transistors (mainly NPN and PNP germanium, audio and switching types—data supplied). The rest of the parcel is made up with: Resistors 5% or better (including some 1% mainly metal oxide, carbon film, and composition types. Manly 1 and 2 watt... diodes, miniature silicon types OA80, OA91, OA95, 15130, etc... capacitors, including tantalum, electrolytics, ceramics and polysters... inductors, a selection of valves... also the odd transistor, trimpot, etc... These are all miniature, up to date, professional, top quality components. Don't miss this offer. One of our best offers yet!! Price 65/- post and packing 6/6 U.K., New Zealand 20/-., Limited stocks only. 

9 OAS, 30A10, 3 Pot Cores, 26 Resistors, 14 Capacitors, 3 GET 872, 3 GET 972B, 1 GET 875. All long leaded on panels 13in. x 4in. 2 for 10/-, p. & p. 3/6d. 4 for 28/-, post free. 

EX COMPUTER PRINTED CIRCUIT PANELS
2in. x 4in. packed with semi-conductors and top quality resistors, capacitors, diodes, etc. Our price, 10 boards 10/-, p. & p. 2/-. With a guaranteed minimum of 35 transistors. 25 boards for £1, p. & p. 3/6. With a guaranteed minimum of 65 transistors. Transistor data included. 

COMPONENT PACKS
200 capacitors, electrolytics, paper, silver mica, etc 10/- Postage on this pack 2/6. 250 mixed resistors 10/-, post and packing 2/-. 40 wirewound resistors, mixed types and values. 10/-, postage 1/6. 

QUANTITIES AVAILABLE
EXTRACTOR/BLOWER FANS (Papst)
100 c.f.m. 43 x 43 x 2in. 2,600 r.p.m., 240v. A.C. Precision made in West Germany by Papst. These fans are the best available. Genuine bargain at 50/- each. 

KEYTRONICS
52 Earls Court Road, London, W.8. Tel. 01-478 8499 
MAIL ORDER ONLY. Retail and Trade supplied. Export enquiries particularly welcome. S.A.E. FOR LIST 

LATEST RELEASE OF 
RCA COMMUNICATION RECEIVERS AR88

BRAND NEW and in original cases—A.C. mains input. 110v or 250v. Freq. in 6 bands 535 Kc/s to 32 Mc/s. Output impedance 2.5-600 ohms. Complete with crystal filter, noise limiter, B.F.O., H.F. tone control, R.F. & A.F. variable controls. Price £87/10/- each, carr. £2. 

Same model as above in secondhand cond. (guaranteed working order), from £45 to £60, carr. £2. 

*SECONDS: VALVES: new, £3/10/- a set, post 7/6. SPEAKERS: new, £3 each, post 10/-. 'HEADPHONES: new, £1/5/- a pair, 600 ohms impedance. Post 5/-.

AR88 SPARES. Antenna Coils L5 and 6 and L7 and 8. Oscillator coil L35. Price 10/- each, post 2/6. RF Coils L13 & 14; 17.6 in. x 4 in. x 4 in. 25/-. 18.4 in. x 22 in., and 27 and 28. Price 12/6 each, 2/6 post. By-pass Capacitor K-98034-1, 3 x 0.05 mfd. and M, 980344, 3 x 0.01 mfd., 3 for 10/-, post 2/6. Trimmers 95534-502, 2-20 p.f. Box of 3, 10/- post 2/6. Black Condensers, 3 x 4 mfd., 600 v., £2 each, 4/- post. Output transformers 901666-501 27/6 each, 4/- post. 

*Available with Receiver only. 

S.A.E. for all enquiries. If wishing to call at Stores, please telephone for appointment. 

W. MILLS 3-B TRULOCK ROAD, TOTTENHAM, N.17 Phone: 01-808-9213

MARCONI SIGNAL GENERATORS

TYPE TF-144G
Freq. 85Kc/15Mc/s in 8 ranges. Incremental: +1/- 1% at 1 Mc/s. Output: continuously variable 1 microvolt to 1 volt. Output Impedance: 1 microvolt to 10 millivolts, 10 ohms 100mV-1 volt-52.5 ohms. Internal Modulation: 400 c/s sine wave 75% depth. External Modulation: Direct or via internal amplifier. A.C. mains 200/250V, 40-100 c/s. Consumption approx. 40 watts. Measurements: 191 x 121 x 10 in. The above come complete with Mains Leads, Dummy Aerial with screened lead, and plugs. As New, in Manufacturer's cases, £40 each. Carr. 30/- DISCOUNT OF 10% FOR SCHOOLS, TECHNICAL COLLEGES, etc. 

www.americanradiohistory.com
**NIFE BATTERIES:** 4 v. 160 amps, new, in cases, £20 each, £1 10/- carr.

**FUEL INDICATOR** Type 113R: 24 v. complete with 2 magnetic counters 0-9999, with locking and reset controls mounted in a 3 in. diameter case. Price £1 10/-.

**FREQUENCY METERS:** Type BC-221, meter only £30 each, BC-221 complete with stabilised power supply £35 each, carr. 15/-, LM13, 125-20,000 Kc/s, £25 each, carr. 15/-, LM175, £75 each (as new); Type AC-227 consists of a first reading and the results are presented directly in digital form. Counting rate: 0-100,000 events per sec. Time Base Crystal Freq. 100 Kc/s per sec. Power supply: 115 v., 50/60 c/s, £100 each, carr. £1.

**AUDIO OSCILLATOR** Type 3E2: Input 15 v. A.C., 50 c/s, 20-200,000 c/s per sec. 4 range Controls. Output 0-6 v. in 10 ranges. Power output 100 mw. Output impedance 1,000 Ohms. £170 each, carr. 15/-.

**RACK CABINETS** (totally enclosed) for std. 19in. panels. Size: 6ft. high x 23in. wide, and 50/60 Mc/s., £100 each. 4ft. high x 23in. wide x 19in. deep. Power end output £80 each, £2 carr.

**CATHODE RAY TUBE UNIT:** With 3in. tube. Type 3E21C (CV1252) colour green, medium persistence complete with mu-metal screen, £310 each, carr. 7/6.

**APNI ALTIMETER TRANS/REC.** suitable for conversion 420 Mca., complete with all valves 28 v. D.C. 7 relays, 11 valves, price £3 each. carr. 10/-.

**TEST EQUIPMENT**

**MARCONI**

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<tr>
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<tr>
<td>TF-1274</td>
<td>VHF Bridge Oscillator</td>
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<tr>
<td>TF-1275</td>
<td>VHF Bridge Detector</td>
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<td>TF-1007</td>
<td>Heterodyne Frequency Meter</td>
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<td>TF-899</td>
<td>A.C. Millivoltmeter</td>
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<td>TF-978</td>
<td>VHF Admittance Bridge</td>
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<td>TF-4684</td>
<td>Audio Tester</td>
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<td>TF-329Q</td>
<td>Circuit Magnification Meter</td>
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<td>TF-414</td>
<td>A.C. Milliammeter</td>
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<td>TF-4281</td>
<td>Valve Voltmeter</td>
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<td>TF-1282</td>
<td>A.C. Gain Bridge</td>
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<td>TF-934</td>
<td>Deviation Test Meter</td>
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<td>TF-975A</td>
<td>Resistance Test Meter</td>
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<td>TF-1097</td>
<td>Noise Generator</td>
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<td>TF-956</td>
<td>(CT-4A) A.P. Absorption Wattmeter</td>
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**F18 HILL**

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<td>V200</td>
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**SOLATRON**

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<td>CD-513-2</td>
<td>Oscilloscope</td>
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<td>AW-253</td>
<td>Power Amplifier</td>
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**AIRMEC**

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<td>Type GM-6008 Valve Voltmeter</td>
<td>£35 each</td>
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**DAWE**

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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Type 402C Megohm Meter</td>
<td>£12 each</td>
</tr>
</tbody>
</table>

**CANADIAN 25C TRANS/REC.:** Freq. 1-756 Mc/s on 3 bands. R.T., M.C.W. and C.W. Crystal stabilized etc., power input 12 V.D.C. four valves, complete set £56. Carr. £35. Power Unit for Rec., new £35. Carr. 10/-.

**DECAD RESISTOR SWITCH:** 0.1 ohm per step. 10 positions. 3 Gang, each 0-100 ohms. Tolerance ±1% £3 each, 5/- post. 90 ohms per step. 10 positions, total value 900 ohms. 3 Gang. Tolerance ±1% £2/10/- each, 5/- post.

**TELESCOPIC ANTENNA:** In 4 sections, adjustable to any height up to 20 ft. Diameter 2 in. up to 1 in. £2 each £1 10/- carr. or £9 for two £1 carr. (brand new condition).

**COAXIAL TEST EQUIPMENT:** COAX/WHITCH—Mfrs. Rind Electronic Corp. Model 72R; two-circuit reversing switch, 75 ohms, type "A" female connectors fitted to receive U.S. coaxial type. New in cases, £60 each, carr. 7/6. CO-AXIAL SWITCH—Mfrs. 3EG1 (CV1526) colour green, (New) £60 each, carr. 5/-. TYPE 115ST—(as new) £150 each, carr. 7/6.

**PRD Electronic Inc. Equipment: FREQUENCY METER:** Type 587-A, 0.2-30.0 KMc/S/Sec. (New) £75 each, carr. 12/-.

**FOR EXPORT ONLY**

**BRITISH & CANADIAN COMMUNICATION EQUIPMENT**

Type B.44 2 Tx/Rx, Crystal controlled, 60-95 Mc/s, 12 v. o.c. operation. W.S. Type 3004, 0.1-10 Mc/s, complete set £25, carr. 12/-.

**M1600-22, 2 pole, 2 band. (New) £160/6/- each, 4/6 post. 1 pole, 4 throat, Model M16040-1. (New) £160/6/- each, 4/6 post.

**3E21C TRANS/REC.:** 600 Line Automatic Telephone Exchange. Complete system with full test Manuall. Mobile Communications Power Amplifier mounted in a trailer with pneumatic tyres. Consisting of 3E21C-27 Tx/Rx with all associated equipment (as new).

**ALL GOODS OFFERED WHILE STOCKS LAST IN "AS IS" CONDITION UNLESS OTHERWISE STATED**

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THE ENGLEFIELD SYSTEM

The Peak Sound Englefield system assemblies from laboratory designed modules to provide a cost-performance ratio which has never been bettered in high fidelity. Here is top-flight circuitry housed in a cabinet of elegantly original design which is both beautiful and completely practical back and front. By assembling these Peak Sound units, you can own one of the best high fidelity instruments you have ever heard or seen and all for a cost of about £38 (about £33 if assembled from kit of parts). The assembly is supplied complete down to the necessary connecting wires supplied colour coded, cut to length and stripped at the ends for soldering. You can use the Englefield Cabinet design to house either the 12 + 12 system as published in Practical Wireless, or the 25 + 25 watt system as approved for the Hi-Fi News Twin Twenty by Reg Williamson. The modules are all obtainable separately and are recommended for highest quality work. Go to your stockist and ask to see and hear Peak Sound equipment now. Leaflets on request.

Matching F.M. Tuners will be available very shortly.

THE SPECIFICATION

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 B.D. (see spec. guarantee).

Frequency bandwidth: 10Hz to 45 KHz for 1% and 1%.

Distortion: Total Harmonic Distortion at 1 KHz at 10 watts into 15Ω 0.1%.

Input sensitivities: Mag. PU 3.5 mV, imp. R.L.A. equalized into 68 KΩ Tape: 100mV linear into 100 KΩ.

Load factor: 29 dB on all input channels.


Power bandwidth: 1 dB at 20 watts R.M.S. into 3Ω at 15Ω at less than 0.25% distortion is 20 Hz to 20 KHz.

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Peak Sound can supply the parts necessary to build the famous Baxendall Speaker described originally in 'Wireless World'. All to designer-approved spec. Details on request. Also available built in top finished cabinet 18" x 12" x 10" - 18½ lbs.

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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.

peak sound

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ROOMS 231
AND 236

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To Peak Sound, 32 St. Jude's Rd., Englefield Green, Egham, Surrey.

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RESISTORS

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<td>20W</td>
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<tr>
<td>WW</td>
<td>5W</td>
<td>10%</td>
<td></td>
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PE NOV. 49 STEREO AMPLIFIER KITS
less metalwork £1/11-# - NET complete.

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<tr>
<th>Code Range</th>
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CRAIN SPECIFICATION

PE FOUR WIRE 100W WIRE WOUND POTENTIOMETERS

<table>
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<tr>
<td>B</td>
<td>1W</td>
<td>25%</td>
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ELECTROVALUE

DEPT. WW.704, 28 ST. JUDES ROAD, ENGLEFIELD GREEN, EGHAM, SURREY
Hours: 9-5.30 daily; 1-6 p.m. Saturdays.
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This remarkable monolithic integrated circuit amplifier and pre-amp is now available for dispatch from stock. It is equivalent to 13 transistor/18 resistor circuit plus 3 diodes and the first of its kind ever. It is d.c. coupled and applicable to an unusually wide range of uses all of which are detailed in the manual provided with it.

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B80 8 MULLIARD GLASS TYPE
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B84 100 HIGH QUALITY GERM. DIODES MIN. GLASS TYPE.
B86 50 GERMANIUM TRANS. EQUIV. TO OC44, OC45, OC61, 62.
B88 100 SIL TRANS. NPN, PNP. EQUIV. TO OC202V. 2N706A, 8595A, ETC.
B88 50 7 WATT ZENER DIODES.
B86 10 7 WATT ZENER DIODES.
H5 16 1 AMP. PLASTIC DIODES 50-1000 VOLTS
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B77 2 10/-
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B91 8 SILICON & GERMANIUM TO-18.
B92 4 NPN SIL. TRANS. TO-18 92.
B95 5 TRANS. EQUIV. TO AD17-21 PNP GERM.
B96 5 2N316 PN PNP TRANS. TO-18.
B97 5 HPE100-300 C, 600mA 200 MHz.
B98 10 CAPACITORS. ELECTROLYTICS. PAPER. SILVER NICA. ETC.
B99 300 POSTAGE ON THIS PAK 2/6.
H4 2500 MIXED RESISTORS POST & PACKING 10/.
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VARIOUS CONTACTS AND COIL RESISTANCES.
INDIVIDUAL SELECTION.
POST & PACKING 5/-
NEW HYSTERESIS MOTORS BY WALTER JONES. Type I4050/12, 240v. 50 c/s 1500 RPM cont. rating: output, 2.0 c/s, 60 HP. Sizes: Length (less spindle) 3½". Width 3½" x 1½", Spindle (superior) 1⅛" x 1½", 3 lb. Maker's price in region of £22.10.0. Our price £10.10.0 each.

"Parvalux" Reversible 100 RPM Geared Motor Type S.D.14, 230/250v. reversible motors. Choice of mounted, variable 100 plates (banks Plus 240v. length 16.10.0 each.) JONES. NEW 123 COILS CHOKES/Duty coils of 0.028 pf. (12). Which gives 2.5 ohm, 240v. output 48 basic de V, 651b. CR4.8LZ 651b.

Wireless final Type S.D.14, 230/250v. reversible motors. Choice of mounted, variable 100 plates (banks Plus 240v. length 16.10.0 each.) JONES. NEW 123 COILS CHOKES/Duty coils of 0.028 pf. (12). Which gives 2.5 ohm, 240v. output 48 basic de V, 651b. CR4.8LZ 651b.

K.G.L. Sealed Terminals, Type TSL1 AA, overall length 11½", box of 100, 25s. Type TSL1 B, overall length 1" box of 100, 35s.

THORN DIGITAL INDICATOR designed as a modular unit for easy mounting where 1st class numerical readout is required. Easily read through a wide angle of view and without ambient light, 12 characters, 0 to 9, decimal point and minus sign. Chars 136x144 thick engravings on acrylic slides and individually index by 1 watt, minder/midial. Large overall size of front panel 10¾" high x 15½" overall depth 1.2 mm is finished in matt black supplied with 12 lamps, choice of viewing ratings: 4V. January 13-14. 0.6A. £4.15 per doz., spare lamps 44½ per cent. 84½ per cent.

ATLAS MINIATURE LAMPS type k121 123.5V, 1/2W. 120/250 volt. Light source with excellent light-output and few power input. 1.5 W. 2.5 W. 3.5 W. 4.5 W. 5.5 W. 6.5 W. each. 240 v. 24v. per doz. or boxes of 50 x 64 per box. INDICATOR LAMP HOLDERS AND CAPS for MINIATURE MIDGET PANELS (as above) available red, green, blue, white each (formed) minimum order 4 units.

NEW "CRYODYO" 240V. A.C. reversible motors. Choice of 1½th Output 1200 rpm, 1/10th hp, 750 RPM (independent in appearance). Size 3½" high x 5½" long plus 11½" flat distance of motor at less than half maker's original price. £6.15 each.

English Electric 1 hp. Motors, 240v. single-phasers, standard size mounted, 1,425 r.p.m., continuous rating. £6.15 each. Carriage £3.00.

Isolation Transformers, 1 to 1 ratio. 240v. input, 240v. centre tapped out, at K.V.A., mounted in metal case measuring 8½" x 6½" x 11" high. Weight 65½. £10.15. £10.15. Carriage £3.00.

SCHRAK ROTARY STEPPING RELAY RT04 40-500 ohm. The relay has 48 basic segments shunted in step by the 4 sweep contacts to 12 groups of plates (banks of 12). There are 2 secondary switches: (1) one c/s H/Duty contact set which changes over and back with each step; (2) two H/Duty changeover contacts which changeover on each 150 step and return on the following pulse. Size: Base 3½"x1⅛"x4⅛" high. New in maker's stock. Also, as above, but 1501 (2,000 amp coil). £6.15 each.

Welwyn high value Resistors Type GA 36951. Weights 0.9 to 9-4 and 10-9 kilo-meg ± 1%, class encapsulated 15. Victoria "Hi-Meg" Resistors. One value only 50,000 meg ± 2%, class encapsulated 15.£.

VICTORIAN "Hi-Meg" Resistors. One value only 50,000 meg ± 2%, class encapsulated 15.£.

SYLVANIA MAGNETIC SWITCH—a magnetically activated switch operating in a vacuum. Switch speed—4ms. temperature −54 to −200° C. Silver contacts normally closed rated 3 amps at 120v, 1.5 amp at 240v. 10½ each. £4.15 per doz. Special quotations for 100 or over. Reference Magnets available 1½ each.

SYLVANIA CIRCUIT BREAKERS gas filled providing excellent thermal response between 80 and 100°C. Will withstand pressures up to 2,000 lb. sq.in. rated 10 amp at 240v. continuous. Fuse currents of 38 amps at 120v, or 13 amp at 240v. silver contacts. Supplied in any of the following opening temperatures (deg. cent.) 80, 85, 90, 100, 105, 110, 120, 135, 130, 135, 140, 150, 155, 160, 170, 180, 190-220 each. £4.15 per doz.

MINIATURE "LATCH-MASTER" RELAY 6, 12, or 24v. D.C. operation. One make one break, contacts rated 5 amps, at 30v. Once current required to close relay remains latched until input polarity is reversed. Manufactured for high acceleration requirements by Sperry Gyroscope Co. Size: Length 2¼, dia. 9/16 (including mounting). Please state vertical or horizontal mount and voltage. £2.60 each.

New 75-75 Micro-ammeter by Sifam. 750 ohm movement, dial reading, 5 amp divisions x 1, 1/10th, 1/100th of a, 0-10 micro ammeters. £2.15 each. £2.15 each.

Ernest Turner 5" x 4" 0-1 Ma. calibrated 0-10 in 5 divisions mirrored scale, handsome chrome escutcheon for flush mounting. A quality instrument. £6.15. £6.15.


"AUTOMATIC ELECTRIC" ENCLOSED RELAYS 6v. 5051 £2/case, 12/ each. 24v. 4705 £2/case, 13/6 48v. 77062 £2/case, 13/6 £2.50 each.

New "Magnetic Devices" solenoid 240v. A.C. Type 4217, 1 to 3 lb., pull, frame size 1¼" x 1¼", 75. £1.00 each.

Motor Driven Variable Voltage Transformers by Ohmite (U.S.A.). Input 120v/240v, 50/60c. Output 0-380v, 12.5 amp. A reversible 115v, a.c. geared motor drives the contact arm which can be moved in either direction. A micro switch mounted at each end of the track which is cam-operated and intended to provide an ideal safety-stop. First class condition. £10.15. Carriage £3.50.

We have a considerable range of glassware, many grades of stepping resistors, microamperes, vacuum, pumps, etc., etc., for personal callers.

WHERE NO CARRIAGE CHARGE IS IMPOSED PLEASURE IN IEEE, INCLUSIVE, PERSONAL CALLERS WELCOME.
**Samson's**

( ELECTRONICS ) LTD.

9 & 10 CHAPEL ST., LONDON, N.W.1

01-723-7851 01-262-5125

**NEWMARK SYNCHRONOUS MOTORS**

220-240v. 50 cycles. 4/4 horse power... 

**VENNER SYNCHRONOUS BIO-DIRECTIONAL MOTORS**

220-240v. 50 cycles. 4/4 horse power... 

**LONDON 330-360v. A.C. RELAYS**

Open frame type 12 heavy make contact.

**CROUZEY SHAPED POLE MOTORS**

A.C. 240v. 50 cycles. 220 watt. 230 volt input...

**INGRA SynchrOnous GEARED MOTORS**

220-240v. 50 cycles. 3 watts. 6 inch per hour. Overall size 2 1/4 x 2 1/4. Spindle length 1 1/2. 220-240v. Overall size 2 1/4, dia. depth...

**6200 SERIES SWINGING CHORE**

240v. 60 H.P. 70H. 325A. 36 18. D.C. W. 325b. P & P. 6-

PARTRIDGE TOTALLY ENCLOSED CHORES


**GARDNER'S H.T. TRANSFORMERS**

C core Pri. 120. Pri. 1,2, 3, 4, 5 & 6. Ampl. size 31 x 3 x 3. 120, P & P. 8-

**LOW VOLTAGE ISOLATION TRANSFORMERS**

Sec. 68. Sec. 20. 48. W. 48c. C" core potted type... 176b. P & P. 8-

**SPECIAL OFFER OF SLIDING RESISTORS**


**CULVERT INSY POTS**

2000 0.25x1. 8H. 15. 1A. 15%. P & P. 8-In. 1500 0.1-500. 0.15A. 8-In. 15. 1A. 15%. P & P. 8-In.

**SINCH ROUND PANEL METERS**

0.50 D.C. 140 1-4A. 15%. P & P. 3/2. 400 D.C. volts. 1500 0.1A. P & P. 3/2. 3 inch sq.

**AIR MINISTRY HEAVY DUTY CUT-OFFS**

Type E 2248. Cast in base cases 8 3/8 x 8 3/8 x 2 1/2. 1500 0.1A. 5/2. 15. 1A. 15%. P & P. 8-In.

**PELSLEY A.C. 250-350V. SOLENOIDS**

Powerful very small size 21 x 2 x 2. Full line 1964. P & P. 8-In.

**DIGITAL HOUR METERS**

A. C. input. 2 3/4 x 2 3/4 x 2. 8 1/4 x 8 1/4. 5/2. 15. 1A. 15%. P & P. 8-In.

**HEINEMANN MAGNETIC CIRCUIT BREAKS**

3 phase 600. 3 poles 3-5 amp panel mounting. 3x20. P & P. 5-

**WEYRAD**

COILS AND I.F. TRANSFORMERS IN LARGE SCALE PRODUCTION

FOR RECEIVER MANUFACTURERS

**P.11 SERIES**

10 mm. x 10 mm. x 14 mm. Ferrite cores 3 mm. 472 kc/s operation. Single-tuned I.F.s and Oscillator Coils.

**P.55 SERIES**

12 mm. x 12 mm. x 20 mm. Ferrite cores 4 mm. 472 kc/s operation. Single-tuned I.F.s and Oscillator Coils.

**T.41 SERIES**

25 mm. x 12 mm. x 20 mm. Ferrite cores 4 mm. 472 kc/s operation. Double-tuned 1st and 2nd I.F.s and Single-tuned 3rd I.F. complete with diode and by-pass capacitor.

These ranges are available to manufacturers in versions suitable for most of the popular types of Transistors. The Oscillator coils can be modified to enable specific tuning capacitors to be used provided that bulk quantities are required.

**OUR WINDING CAPACITY NOW EXCEEDS 50,000 ITEMS PER WEEK**

On the most up-to-date and efficient machines backed by a skilled assembly labour force for all types of coils and assemblies.

WEYRAD (ELECTRONICS) LIMITED, SCHOOL ST., WEYMOUTH, DORSET
**R + TV**

**Complete stereo system £29 10s.**

The new Duo general-purpose 2-way speaker system is beautifully finished in polished teak veneer, with matching crystal grille; it is ideal for wall orabinet mounting or horizontal or upright installation.

**Type 1 SPECIFICATION:**
- 6½" + 2½" speaker and 2½" tweeter. Teak finish 12" x 6½" x 11½". 4-way passive crossovers. 5½" p. 5½. 7 circuits and 8 parts are used, Supply 15/20 Volt direct to mains or via transformer.
- Sensitivities: 13 dB at 15 KHz. 12½ dB at 100 KHz.
- Treble lift and cut at each setting.

**THE RELIANT MK.II Solid State Complete Purpose Amplifier**

**SPECIFICATION**
- Inputs: 6 positions rotary selector switch (3 mono, 2 mono and 2 mono stereo).
- Outputs: 3 mono, 2 mono, stereo.
- Tone Controls: Separate treble and bass controls. TREBLE 13dB lift and cut at 15KHz.
- TONE CONTROL: Treble lift and cut. Separately adjustable.
- Power Output: 60 watts per channel into 3 to 4 ohms speakers (20 watt minimum).
- INPUT SENSITIVITIES: Suitable for medium amplifiers costing £20-£200.
- FREQUENCY RESPONSE: 40Hz-20KHz ±2dB.
- INPUT IMPEDANCE: 47k. Equalised from 20 Hz to 20KHz. Mains 200-250v. Size 10½" x 6½" x 11½". Weight 21lbs.

**ELEGANT SEVEN MK. III**

**SPECIFICATION**
- Input: 15mV at 1 kHz.
- Output: 60 watts.
- Frequency Response: 30 Hz to 30KHz.
- Power Output: 60 watts.

**SPECIAL OFFER**

Complete stereo systems comprising BALFOUR 4 speed audio player with stereo head 2 DUO (1 mono, 1 stereo). Windows - £29 10s. 1 stereo. £31 10s. 2 stereo.

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**NEW COMPLETE HI-FI STEREO SYSTEM £41**

DORSET (600W Output) £5.50

Special: £5 7½p. p. 3½ Extra.

Hi-Fi amplifier, built-in, 7 transistors, 100 watts. Sensitivity (the rated output): Tool box size. Protective circuit board—back printed for foolproof construction.

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**THE CLASSIC**

**TEAK FINISHED CASE**


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**TUNE-UP**

INTEGRATED HIGH FIDELITY TRANSISTOR STEREO AMPLIFIER £15 6s. £7 6d. p. 6½.

£15 6s. £7 6d. p. 6½.

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**X101 10W. SOLID-STATE HI-FI AMP**

With Integral Pre-amp.

£10 15s. £5 10d. 8½ Extra.

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**50 WATTS AMPLIFIER**

£28 10s. £12 10d. p. 8½.

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**TECHNICAL SPECIFICATIONS**

1. Electrolytic filter capacitors with 2 watts items, ensures the use of 4 separate transformers at the same time. The volume control for each channel is located directly above the corresponding input socket. SENSITIVITIES AND INPUT IMPEDANCES: Channel 1 & 2 15mV at 470k. Two 10mV inputs are available for applications at greater power. Channel 3 & 4 300mV at 1m. Suitable for high output inputs (magnets, outputs, etc., input sensitivity relates to input across. TONE CONTROLS ARE COMMON TO ALL INPUTS. Stereophonic input - 60 Hz. Tune Control - 150Hz at 60 Hz. Tuned Control - 150Hz at 60 Hz. Tuned Control - 150Hz at 60 Hz. Tuned Control - 150Hz at 60 Hz.

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**69/6 Line £5 6d. p. 6½**

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**MAINS VOLTAGE**

Available from £200-250v. AC 110v 60Hz. A protective fuse is located at the cost of unit. Details: impedance 3 ohms or 15 ohms.
A WIDE SELECTION OF SERVOMOTORS NOW AVAILABLE INCLUDES THE FOLLOWING TYPES:

- A.T.N. (All-Temperature, All-Purpose) Servomotors 1 in. w.d. x 1.5 in. l, 30 lbs. output, 1300 rpm, 12-220 VAC, 500 VDC, 400 Hz., continuous duty, with integral brake. Presently available standard sizes are 0.5 in. w.d., 1 in. w.d., 1.5 in. w.d., and 2 in. w.d. Sizes up to 2 in. w.d. are available on special order. Servo-motor performance details are available. Servo-motor performance details are available. Servo-motor performance details are available.

- MIL-STD-1553B Servo-motors. These motors are designed for use in hostile environments where high reliability and long life are essential. They are available in a variety of sizes and can be customized to meet specific application requirements.

- Servo-motor accessories. A wide range of accessories is available to complement the performance of MIL-STD-1553B Servo-motors. These accessories include mounting hardware, encoders, and other components necessary for integration into complex systems.
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LARGE DIGIT 12-18v. D.C. MAGNETIC COUNTER
4in. drum, calibrated 0.9 Figures 1½ high, wide. Set of 1m, 1b, 1c, constant output by drum cam. May be used in multiple sets. Watt-hour units which can be used in multiples are ideally suited for each lab requiring or for the many purposes where large scale readouts are desired. Price 18½, 2½ P. 

VEEDER ROOT COUNTER
220 x A.C. 50 cycle 5 figure counter (from reliable). 16½, 2½ P. & 1/2 T.

REGULAR TRANSFORMER
Functional Veritable Educational
This multi-purpose Auto Transformer, with large centre aperture, can be used as a Double wound output Transformer, Auto Transformer, H.T. or L.T. Transformer, by simply hand winding. It may be used for taking Current, Volt & Watt Readings. Use the 67.5 KVA--V.A. Model. It could be used in any or all of the following experiments.

1. E.G. energy in a given time
2. JK or CK system
3. D.C. and A.C. Inductive charging and discharging
4. Induction heating of ferrous and non ferrous metals.
5. Transformer theory
6. Transformer losses
7. Transformer magnetism
8. Transformer efficiency
9. Transformer core overheating
10. Transformer exciting power
11. Transformer rating

DISTRIBUTOR TRANSFORMER (STENZYL TYPE)
Two removable coils are tapped at 40, 180, 360 volts, and 6, 12, 36 volts respectively. A movable tap apparatus designed for class demonstration. Electro magnetic induction, jumping ring, induction losses, operating characteristics. Induction coil apparatus is just a few of the possible experiments. New modelled 14/10. P. & 1/2 T.

L.T. TRANSFORMERS
All primaries 220-240 volts. Price Car. 36½ P.
12 x 4...at 5 A. 17 6 5/6
30 x 40...at 5 x 5 A. 66 6 6/6
60 x 48...at 5 x 6 A. 66 6 6/6
90 x 72...at 5 x 8 A. 66 6 6/6
120 x 100...at 5 x 10 A. 66 6 6/6
180 x 150...at 5 x 18 A. 66 6 6/6
220 x 200...at 5 x 17 A. 66 6 6/6
270 x 120...at 20 x 20 A. 66 6 6/6
300 x 220...at 30 x 20 A. 66 6 6/6
400 x 300...at 40 x 20 A. 66 6 6/6
400 x 600...at 40 x 30 A. 66 6 6/6
500 x 1500...at 50 x 30 A. 66 6 6/6

AUTO TRANSFORMERS
Step up, step down. (1000 220 to 110 and 220.) New modelled 6x12 volt. 4½ P. 5½, 6½ 5/6, 500 volt 6x12/6/12 each, P. 4½, 5½, 6½ 5/6

LATEST TYPE SOLID STATE DEVICES
R.C.A. plastic Triac 400-68 amp. Price 25. P. & 1/2 T.
R.C.A. Diac for above, price 6½ P. & 1/2 T.

G.E. P.U.T., D13, T1, D2. Texas F.E.T.
40319Y, 7½ P. & 1/2 T.

ALL prices above plus 1½, 2½ P. & 1/2 T.

INСULATED TERMINALS
Available in black, red, white, blue and green. New 2½ each.

A.C. CONTACTOR
2 make and 2 break or 2 (2 and 2) 15 amp. contacts. 230/240 V. A.C. operation. Brand new. 21½ plus 1½, 2½ P. & 1/2 T.

LIGHT SENSITIVE SWITCHES
Kit of parts including ORP.12 Cadmium Sulphide Photo Cell, Relay Transformer and Circuit. Now supplied with new Siemens Switching Tubes, ideal for different experiments. Price 25½, plus 2½ P. & 1/2 T.

220/240 A.C. MAINS MODEL
Incorporates Siemens Switching Transformer rectifier and special relay with 2 x 5 amp. mains c/o contacts. Price inc. tax 55½, plus 1½, 2½ P. & 1/2 T.

"LIGHT SOURCE AND PHOTO CELL" MOUNTING
Precision engineered light source with adjustable lens assembly and standard back housing to take M.S.C. bulb. Stepped photographic mounting assembly for ORP.12 or similar cell with optical window. Both units shipped in similar units. Price per pair 21½ plus 1½ P. & 1/2 T. 

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New at a fraction of the old prices:
2.500 mfd. 100...at 1½ 24½ P. & 1½ T.
4.000 mfd. 25...at 1½ 45½ P. & 1½ T.
10,000 mfd. 1½...at 45½ 25 P. & 1½ T.
15,000 mfd. 1½...at 50½ 30 P. & 1½ T.

BELLMULTIWAYPLUGS
10 way plug and socket. (Socket chassis mounted.) 7½ way rectified plug and socket. (Plug chassis mounted.) Price: either type 3½ p. 6/-. P. & 1/2 T.

BURGES MICRO SWITCH
Lever operated c/o contacts. Price 4½ plus 9d. P. & 10 in maker's carton plus post paid. 6/-. P. & 1/2 T.

MOTORISED SWITCHING UNIT (EX.W.D.)
Powerful, precision-made, e.g., W.V.13 D.C., reversing motor, driven by 500 Volt, 10 amp. train with outputs approx. 4 r.p.m. and 5 r.p.m. Price 25½, 2½ P. & 4½ P. & 4½ T.

Ex.W.D. MINIATURE MOUNTING
18-24v. D.C. operation, overall length 23 x 23 x 20 in. 2½ P. & 4½ P. & 4½ T.

POWER RHEOSTATS
(New) Ceramic construction, windings and terminals, High quality, Heavy duty brush assembly designed for continuos operation. New. Price 35½, 5½ P. & 1/2 T.

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BELL MULTICYCLEPLUG
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BUTTRESS MICRO SWITCH
Lever operated c/o contacts. Price 4½ plus 9d. P. & 10 in maker's carton plus post paid. 6/-. P. & 1/2 T.

MOTORISED SWITCHING UNIT (EX.W.D.)
Powerful, precision-made, e.g., W.V.13 D.C., reversing motor, driven by 500 Volt, 10 amp. train with outputs approx. 4 r.p.m. and 5 r.p.m. Price 25½, 2½ P. & 4½ P. & 4½ T.

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BUTTRESS MICRO SWITCH
Lever operated c/o contacts. Price 4½ plus 9d. P. & 10 in maker's carton plus post paid. 6/-. P. & 1/2 T.
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P. C. RADIO LTD.

170 GOLDHAWK RD., W.12

01-743 4966

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MARCONI TEST EQUIPMENT

Wireless World, April 1970

SIGNAL GENERATOR TF 801A, 10-500 MHz, in 4 bands, Internal as 400, c/s 1 kHz, External 50 c/s to 1 kHz. Output 0-100 dB below 200 mV at 75 ohm source. $25. $1997.01 reissue with additional high level output. Both P. & P. 30c., including necessary connectors, plugs, and instruction manual.

HEWLETT-PACKARD TEST EQUIPMENT

MODEL 2548 ELECTRONIC LEAK TESTER TF 801. PLUG IN UNIT. Basic counter measuring range 10mHz to 10kHz, input range from 0 to 10 kHz. Automatic positioning of decimal point, eight place registration. Full self check facility from built in standards. Plug in unit extends range 2 of basic counter to 100 to 220MHz. Full specification and price on request.

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INTEGRATED CIRCUITS MANY OTHERS IN STOCK

RCA CA 3505, wide band 8F Ampl 300mW output, $11.50.
CA 3012 wide band amp 150mV diss. 25c.
CA 3016 Audio pre-amp $4.90.
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MITE 70/11C Linear operational amp. $2.
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CIRCUIT MAGNIFICATION GENERATOR TF 927. Input range: 50Hz to 50MHz. Magnification 1 to 5000. $25.00.
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LIMITED QUANTITY ONLY SIGNAL GENERATOR TF 97. ICT 2100 units. Range 35-5kHz-50MHz. 50 Hz. Frequency scale. 200 kHz to 2MHz. Built-in crystal calibration sine Wave. M.F. M. Out.

Pulse: D.I.Y.V. Price on application.

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Model 7X with leads, $15.00. Model 47A complete with multiplier bridge, etc., in special fitted case, $12.
Model 46A equipped as 47A, $14.10. Carriage for each of above 7c.

WEB MEGGER 500v., $14.10. 25-0.25mA range. Model 607325, ordered unchecked but in very good con.

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LAB. AMP AWS 151A, Frequency: 15Hz to 30MHz. Metered output, 62.
Scope viewing, etc. $14.10. Carriage 20c.

RECO and stabilised P''U. SRS 151A, 20 to 500V positive at 300mA in two ranges. $35.00. 62.
Negative output, $35.00. Carriage 20c.

CGI 0.57 10V, $3.06. Complete in- stock.

FIELD TELEPHONE TYPE "M". Houseable in portable wooden case. Excellent for communication in and out doors for up to 10 miles. Pair including batteries, fully tested, $6.10, or with 220yd field cable in drum, $6.70.

END OF RANGE ITEMS in 'as seen' condition. H.R.O.—410; Coils at 15c.—Furthall VYMP 305.

PANEL METERS

Just a few from our ample stock:

25A round M.C. 2c. $13.00
25A round M.C. 2c. $1250
100A round M.C. 2c. $11.50
200A round M.C. 2c. $12.50
5000-0-5000A round M.C. 2c. $12.50
500ufA round M.C. 2c. $13.00
10mA round M.C. 2c. $12.50
50mA round M.C. 2c. $12.00
100mA round M.C. 2c. $12.50
200mA round M.C. 2c. $12.00
500mA round M.C. 2c. $13.00
1A round M.C. 2c. $13.00
5mA round M.C. 2c. $13.00
10mA round M.C. 2c. $13.00
20mA round M.C. 2c. $13.00
50mA round M.C. 2c. $14.00
100mA round M.C. 2c. $14.00
200mA round M.C. 2c. $14.00
500mA round M.C. 2c. $15.00
1A round M.C. 2c. $15.00

PLEASE NOTE

Unless offered as "as seen" all equipment ordered from us is completely overhauled mechanically and electrically and, thus ensuring that our equipment is in "connect and use" condition.

TRANSISTORS, ZENER DIODES

1206 and 1207, $2.50 each.

P. C. RADIO LTD.

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01-743 4966

All overseas enquiries & orders please address to:

COLOMOR (ELECTRONICS)

170 Goldhawk Rd., London, W.12

Tel: 01-743 0899
INTEGRATED CIRCUIT AMPLIFIERS

CA3050 B.F. Amplifier with 100mA peak/peak. Max. distortion 0.5%. For use as B.F. amplifier, balanced mixer, product detector or for pre-amplifier.

CA3012 Wide Band Amplifier (up to 20mHz), suitable as IF Amplifier for VHF/FM receivers.

CA2050 General Purpose Audio Amplifier of 50mW output. 30-

CA4066 Buffer Amplifier consisting of two "super-alpha" units of transistors suitable for stereo plug-in systems.

The above four IC's are in TO92 encapsulation.

PA302 Audio Amplifier providing a max. output of 1.5 watts. 90-

PA404 Audio Amplifier providing a max. output of 1 watt. 27.8-

PA507 2 watts Audio Amplifier. The above three IC's are in socket moulded double foot-in-line package.

MC17093G General Purpose operational amplifier in TO99 case.

TA2060 2-stage direct coupled amplifier for use from DC to 100Hz, 50mW dissipation. Output 10mW into 10k load. 1.5-

TA2080 3-stage amplifier with connection brought out to the individual leads. Bandwidth 600kHz. 100mW dissipation. Output 10mW into 10k load. 1.5-

TA4109 MOST input stage followed by a bi-polar transistor stage. 200mW dissipation.

TA1100 All active components required for an A110 Receiver comprising mixer, exciter, I.F. Amplifier, a.g.c and pre-amplifier stages. To build complete receiver only coils, capacitors and resistors are required and output stage for which one of the above described IC's can be used. Dual seven-lead-in-package. 1.5-

Data sheet available for all the above IC's—free with IC's or $1 per data sheet if ordered separately.

TRANSMITTERS

<table>
<thead>
<tr>
<th>Device</th>
<th>Frequency</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>SY-101</td>
<td>101 MHz</td>
<td>5W</td>
</tr>
<tr>
<td>SY-102</td>
<td>102 MHz</td>
<td>5W</td>
</tr>
<tr>
<td>SY-103</td>
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<tr>
<td>SY-104</td>
<td>104 MHz</td>
<td>5W</td>
</tr>
<tr>
<td>SY-105</td>
<td>105 MHz</td>
<td>5W</td>
</tr>
</tbody>
</table>

PLESEY SL408A INTEGRATED CIRCUIT AUDIO AMPLIFIER


SILICON MATCHED DIODE PAIRS

IN5312 Two diodes in a common TO92 epoxy case. Separate anode leads and joint cathode. Diodes are radially and individually balanced. Max. reverse voltage 50V. Max. dissipation 100mW. Suitable for TV horizontal phase distributors and similar applications. Price $0.25. Considerable discount for quantities.

ZENER DIODES

BZV68 series, from 0.7V to 31V ± 5%, 500mW 3/8 each

BZV69 series, from 3.3V to 31V ± 5%, 500mW 3/8 each

BZV70 series, from 7.5V to 31V ± 5%, 500mW 3/8 each

BZV71 series, from 15V to 31V ± 5%, 500mW 3/8 each

BZV72 series, from 25V to 31V ± 5%, 500mW 3/8 each

Please state voltage required—nearest standard voltage will be supplied.

WHEN ORDERING BY POST PLEASE ADD 2/6 IN £ FOR HANDLING AND POSTAGE.

NO C.O.D. ORDERS ACCEPTED.

ALL PRODUCT MUST BE SENT TO HEAD OFFICE AND NOT TO RETAIL SHOP.

FULLY GUARANTEED

FIRST QUALITY VALVES

A.R.B. Approved for Inspection and also for electronic valves, tubes, klystrons, etc.

WE WANT TO BUY:

SPECIAL PURPOSE VALVES, PLEASE OFFER US YOUR SURPLUS STOCK. MUST BE UNSED.

Foox 20, Foox 20, Foox 20, Foox 20

PSEW 20, PSEW 20, PSEW 20, PSEW 20

Telex 241320

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A.R.B. Approved for Inspection and other electronic valves, tubes, klystrons, etc.

OUR NEW 1970-71 CATALOGUE IS NOW READY—PLEASE SEND QUARTO S.A.E. FOR YOUR FREE COPY
SALES ENGINEERS

Ether Engineering Ltd

are expanding in the TRANSUDER MARKET and require additional sales effort. If you are successfully selling quality transducers or associated equipment to professional users, you may wish to consider this excellent opportunity to join a rapidly expanding member of the Pye Group.

Modern marketing methods are employed and the company offers excellent working conditions, including:

- Company Car
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Ether Engineering Ltd

also have an interesting new development line in AUTOMATIC TEST EQUIPMENT. Sales Engineers at present qualified in this field are invited to join an expanding division of this company.

Applicants will receive immediate response and a quick decision. Apply in writing, giving brief details of career to date, to:

Personnel Manager
Ether Engineering Ltd.
Park Avenue, Bushey, Herts.

A Special Project R & D team is being set up by Control Systems Ltd. at Uxbridge to provide group facilities for subsidiary companies manufacturing and marketing internationally-known electronic equipment of advanced concept. New staff are required as follows:—

ELECTRONIC ENGINEERS

at graduate and qualified level with an interest in the application or design of M.O.S. integrated circuits in Mini Computer equipment with an emphasis on office mechanisation.

GRADUATES in computer science or mathematics seeking a first appointment in industry who will carry out original work on the development and programming side of the new equipment.

Members of the Research and Development team enjoy first-class conditions of employment including the opportunity of four weeks holiday and a very good Life Assurance and Pension Scheme. The modern R & D building is in pleasant surroundings overlooking the Buckinghamshire countryside.

Apply, with relevant particulars of experience to:

Group Personnel Manager,
Control Systems Ltd.
The Island,
Uxbridge, Middx.
There is scope, variety and responsibility as a **RADIO TECHNICIAN** in Air Traffic Control

Join the National Air Traffic Control Service of the Board of Trade as a Radio Technician and you have the prospect of a steadily developing career in a demanding and ever-expanding field.

**Entrance qualifications**: you should be 19 or over, with at least one year’s practical experience in telecommunications. Preference will be given to those having ONC or qualifications in Telecommunications.

Once appointed and given familiarisation training, you will be doing varied and vital work on some of the world’s most advanced equipment including computers, radar and data extraction, automatic landing systems, communications and closed-circuit television. Work is based on Civil Airports, Air Traffic Control Centres, Radar Stations and specialist establishments. Vacancies exist in various parts of the United Kingdom.

**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.

Promotion prospects are excellent and ample opportunity and assistance is given to study for higher qualifications. The annual leave allowance is good and there is a non-contributory pension scheme for established staff.

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**NATCS**
National Air Traffic Control Service

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**SERVICE ENGINEERS**

Our Instruments Company is currently expanding its activities and range of products.

Senior and Intermediate vacancies exist at the Service Department situated in Reading Berks.

The Department is furnished with modern test and fault finding equipment and the work is varied and interesting. Equipments are modern analogue and digital devices incorporating the latest techniques in instrumentation.

Previous servicing experience is desirable but our main requirement calls for an enthusiastic sound approach to the servicing of our wide range of products.

Applications in writing please to:

Mr. L. A. Jemmett,
Racal Instruments Ltd.,
Bennet Road,
Reading,
Berks.

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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 quoting publication and month of issue.

Plan your future with **NCR**
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 Mulafax 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 installation, 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 M2K/690413/WF.

Opportunities with Redifon in Radio Communications

Experienced Test Engineers are invited to write to Redifon with regard to vacancies in our Test Department at Wandsworth.

The Company is engaged in the design and manufacture of a wide range of radio communications and allied equipment from military pack-set to broadcast transmitter, including communications receivers, M.F. beacons, teletypewriter terminals, complete radio office installations for the Merchant Marine and mobile H.F. S.S.B. Stations. Our Test Engineers have sound technical knowledge coupled with good practical experience in the alignment and test of H.F. and V.H.F. Communications equipment. The work is varied and interesting and offers excellent opportunity to broaden experience in semiconductors, S.S.B. and Frequency synthesis.

Limited vacancies also exist for engineers experienced in Test gear maintenance.

Please write in the first instance to: The Personnel Officer, REDIFON LTD., Broomhill Road, Wandsworth, S.W.18.

REDIFON

A Member Company of the Rediffusion Organization.

Suppliers of Radio Communications equipment to Home, Commonwealth, and foreign governments. Contractors to B.B.C., G.P.O., Crown Agents, Cable and Wireless, leading shipping companies of the world, etc.
Work as a RADIO TECHNICIAN attached to Scotland Yard

You'd be based at one of the Metropolitan Police Wireless Stations. Your job would be to maintain the portable VHF 2-way radios, tape recorders, radio transmitters and other electronic equipment, which the Metropolitan Police must use to do their work efficiently.

We require a technical qualification such as the City & Guilds Intermediate (telecommunications) or equivalent.

Salary scale: £1,095 (age 21), rising by increases to £1,500 plus a London Weighting Allowance. Promotion to Telecommunication Technical Officer will bring you more.

For full details of this worthwhile and unusual job, write to: Metropolitan Police, Room 733 (RT), New Scotland Yard, Broadway, London, S.W.1.
Government of ZAMBIA

Police Department

requires

RADIO SPECIALIST

on contract for one tour of 36 months in the first instance. Salary according to experience in the Scale Kwacha 2460 to 3000 (Approx. £ Sgr.1435–Sgr.1750) plus an Inducement Allowance of £ Sgr 684 a year which is payable direct to the Officer’s bank in the U.K. Gratuity of 25% of total salary drawn. Both gratuity and Inducement Allowance are normally TAX FREE. Liberal leave on full salary or terminal payment in lieu. Free passage. Accommodation at moderate rental. Education Allowances. Outfit and plain clothes allowances. Contributory pension scheme available in certain circumstances.

Candidates, who will serve in the rank of Inspector of Police, must have completed a five year apprenticeship or hold a Service Trade Certificate or equivalent qualification and have had at least six years post-qualification experience in the Installation and maintenance of modern low and medium power H.F. equipment, S.S.B. and I.S.B. equipment, and of V.H.F. equipment including multiplex links. Knowledge of maintenance of teleprinters, diesel and petrol generators preferred.

The Officer will be required to maintain and install police radio equipment throughout Zambia, travelling by road and air, and to train Zambian Officers for City and Guilds examinations.

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/61274/WF.

Borough of Lowestoft Committee
for Education

LOWESTOFT COLLEGE OF
FURTHER EDUCATION

Engineering and Science Department
Principal: A. E. Roddy, B.Sc.(Econ.) F.R.G.S.

LECTURER

LECTURER GRADE I required for teaching radio, electronics and other subjects associated with the General Certificate for the Radio Officer (Merchant Navy) Course.

Salary in accordance with the Burnham Scale, at present £1,110 to £1,850, plus allowances for approved qualifications. Starting point within the scale determined by past teaching and/or appropriate industrial experience.

The post is vacant as from the 1st of May, 1970. Applicants preferably with teaching experience, suitable qualifications and industrial experience should apply to the Secretary, The Lowestoft College of Further Education, St. Peter’s Street, Lowestoft, Suffolk, for further particulars and application form.

SKILLED MEN are required for the repair and overhaul of aircraft instruments and flight control units at BEA’s Workshops at Heathrow Airport – London. Applicants should preferably be apprentice trained in one of the following trades—Electrical Instruments (Fine mechanical) Radio Electronics and can expect a certain amount of ‘on-the-job’ training.

Commencing rate £27.4.6. rising within 6 months to £28.16.0. and ultimately to £32.16.6. according to qualifications and responsibility. Avionics supplement of £2.10.0. pw may later be earned by qualified staff.

* Good promotion prospects
* Generous shift payments when applicable
* Opportunities for holiday air travel.

Write or phone for an application form to Personnel Officer Engineering (Employment) (W.W) BEA, Engineering Base, Heathrow Airport – London, Hounslow, Middlesex.

SKYport 3131 Exts. 4302, 4185 or 4692

www.americanradiohistory.com
Electronics Maintenance Engineers

There are excellent opportunities in the Installation and Maintenance Division of U.K. Electronics and Industrial Operations of E.M.I. Ltd., at Hayes, Middlesex, for engineers to carry out maintenance work on a wide variety of electronic equipments including laboratory test gear and transceivers.

Candidates should be between 21 and 45 years of age and have some experience in this type of work. Consideration will be given to experienced Radio and Television servicing technicians and to ex service personnel.

Commencing salaries of up to £1,500 per annum will be paid and staff conditions include contributory pension scheme and free life assurance.

Please apply in writing giving brief personal and career details to:
Tel: 01-573 3888, Ext. 411.

There are excellent opportunities for engineers to work at Basildon we are looking for experienced Radio and Television servicing techniques who are keen to help develop our new town.

At Basildon we have a number of vacancies for technical staff to work on the design and manufacture of specialised electronic test equipment and also on the repair and maintenance of general electronic test apparatus.

Applications, including details of qualifications and experience, should be addressed to Mr. R. McLachlan, Personnel Officer, The Personnel Dept., The Marconi Company Limited, Christopher Martin Road, Basildon, Essex. Phone: Basildon 22822.

A GEC-Marconi Electronics Company
**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 Shg. 31,120-27,780 (£Shg. 1,232-1,820) a year, plus an Inducement Allowance, normally tax free, of £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. Outil 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 high power M.F. 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 M2K/690995/WF.**

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**METROSOUND**

**ELECTRO-MECHANICAL ENGINEER**

A vacancy exists for a skilled Electro-mechanical Engineer who will be required to service and maintain a production unit of high speed tape duplicating equipments.

The applicants must be thoroughly conversant with the latest transistorised circuitry as applied to professional tape recorders and ideally should have had some experience with studio equipments.

The successful applicant who will be laboratory based will be paid a minimum salary of £1,600 p.a. which could be considerably increased in the case of an exceptionally experienced or qualified applicant.

Please write or telephone in the first instance to:
Mr. R. Bishop,
Audio Works, Cartersfield Road,
Waltham Abbey, Essex.
Waltham Cross 31933.

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**OMRON PRECISION CONTROLS**

**SUPPLIERS OF**

**PROCESS TIMERS**

**MICRO & LIMIT SWITCHES**

are still expanding and require experienced

**FIELD SALES ENGINEERS**

**also**

**SALES OFFICE MANAGER**

to co-ordinate operations

Apply: P. A. LEIGH,
Tel. 01-723 2231

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**RADIOLOGICAL PROTECTION SERVICE**

(Department of Health and Social Security and Medical Research Council)

Clifton Avenue, Belmont, Sutton, Surrey

requires

**Junior Technician and Technician**

**POST 1. JUNIOR TECHNICIAN** required for duties in the Department of Electronics to assist in the construction of nucleonic instruments. Preference will be given to those candidates with aptitude and interest in electronic and mechanical practice. Salary according to experience at a point on the scale £467 (~922) plus London Weighting. M.R.C. conditions of employment. Applications with the names and addresses of two referees to the Administrative Officer at the above address, quoting reference 70/3/4/17.

**POST 2. TECHNICIAN** required for duties in the Department of Electronics to maintain nucleonic instruments and systems. Previous experience of testing and "fault-finding" on Electronic equipment is essential. Two 'A' level G.C.E.'s desirable but not essential. Salary according to qualifications and experience at a point on the scale £982 (~1255) plus London Weighting. M.R.C. conditions of employment. Applications with the names and addresses of two referees to the Administrative Officer at the above address, quoting reference 70/3/4/9.

Closing Date: 19.3.70

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www.americanradiohistory.com
Vacancies exist in our AYLESBURY and CRAWLEY factories for:

**SERVICE ENGINEERS**

**Our Product.** Flight Simulators

**Requirements.** A complete theoretical knowledge coupled with at least 2 years practical experience in one or more of the following:—Digital computing techniques, hardware, software & computer peripherals. We are prepared to train suitable applicants who have considerable experience in transistorised and integrated circuits. A knowledge of analogue computing techniques and principles of hydraulics systems would be advantageous. ONC or City & Guilds Electronics.

**Travel.** Must be prepared to travel anywhere in the U.K. and Overseas.

**Salary.** Negotiable but we are prepared to go as high as £1,800. for the right persons.

**Applications to:** Personnel Manager, Redifon Air Trainers Limited, Bicester Road, Aylesbury, Bucks. Personnel Manager, Redifon Limited, Flight Simulation Division, Gatwick Road, Crawley, Sussex.

The big Burroughs challenge!

Burroughs large on-line systems dominate the U.K. market. A wide variety of concepts, a rapidly expanding market and a policy of promotion from within – all mean exciting opportunities for trained computer engineers to develop their skills in the large, on-line systems field or into the supervisory grades and beyond. Join the Burroughs boom – and grow with us.

We want experienced computer engineers to work on our B5000 and B6000 installations in the Greater London area With Burroughs, you can find the freedom to enlarge your talents, open fresh horizons, learn new skills - on the largest third generation systems in the world - these are the exciting prospects at Burroughs. In return we are offering you three weeks' paid holiday, free life assurance and a contributory pension scheme.

If you have an electronics qualification and experience with computer systems, then take a big step now into one of today's development industries – fill in the coupon and send it off for one of our application forms. The address is:

The address is: Geoff Lewis, Burroughs Machines Ltd. (2), Heathrow House, Bath Road, Cranford, Hounslow, Middlesex.

NAME
ADDRESS

**BP** requires an

**ASSISTANT TECHNICIAN**

to undertake maintenance and development work in the Communications Division of their LONDON OFFICE. The maintenance element involves a sound knowledge of Teleprinters and associated telegraph equipment, and the development work requires a good working knowledge of Electronics and/or Audio systems.

Candidates, aged 25 to 30 years, should possess a minimum qualification of ONC and have at least 2 years' relevant practical experience. Preference will be given to applicants continuing their studies to HNC. We offer three weeks' holiday, subsidised lunches, non-contributory pension and other benefits.


**ANTARCTIC EXPEDITION** require

**Wireless Operator/Mechanics**

With current speed of 20 w.p.m. PHC Certificate, teleprinter experience essential. Salary from £1,003 according to qualifications and experience with all living and messing free.

For further details apply to:

BRITISH ANTARCTIC SURVEY
30 Gillingham Street, London, S.W.1
CONTINUOUS EXPANSION

Installation Engineers Technicians & Testers
Ref. 25720
To test and commission Multiplex, Co-axial Line and Microwave Radio Systems.
Ideal candidates will be less than 45 years of age with practical experience on some of the above equipment. These challenging posts call for drive, initiative and common sense. It is necessary for applicants to be prepared to work anywhere in the U.K.

Applications should be addressed to
The Personnel Officer,
STC Chester Hall Lane,
Basildon, Essex.

Test Technicians
Ref. 27221
The diversity of products manufactured at the Basildon Plant demands experienced testing staff for work on complex transmission systems. Candidates should hold an ONC in electrical engineering and be able to offer considerable practical experience in the field of testing and fault clearing all types of land-unit, PCM and microwave equipment.

UNIVERSITY OF LIVERPOOL
Institute of Child Health
Alder Hey Children's Hospital
Applications are invited for the post of ELECTRONICS TECHNICIAN to assist with research. Applicants should be suitably qualified and have experience in general instrumentation and pulse techniques. The successful applicant will be expected to be able to assist in the design and development of medical electronic Instruments. Initial salary, according to age, qualifications and experience. Application forms may be obtained from the Registrar, The University, P.O. Box 147, Liverpool L69 3BX. Quote ref. RV/5643/W.W.

JUNIOR ELECTRONICS TECHNICIAN
required for construction and repair of electronic instruments and maintenance of a Linear Accelerator. G.C.E. "O" level in Physics and Maths required; "A" levels or O.N.C. an advantage. Day release for further study is possible. Salary according to age and experience.
Apply with full details to The Director, Medical Research Council Cyclotron Unit, Hammersmith Hospital, London, W.12.

MALE TECHNICIAN
BRISTOL POLICE require a Technician to service and maintain facsimile and dictation equipment.
38 hour week. Salary £965-£1,130 according to qualifications. The post is superannuable. Applications to:
The Chief Constable
Bristol Police Headquarters, Bristol 1

CRAFTSMEN and SEMI-SKILLED MEN
are required for interesting work in the Signal Engineering Department of London Transport at FULHAM

The workshop in which these vacancies exist undertakes a considerable variety of work which includes the manufacture of prototype mechanical and electronic equipment for Signalling, Automatic Trains and Automatic Fare Collection projects together with the overhaul of electro-pneumatic equipment, ticket machines, clocks, telephones and allied apparatus and fault finding on electronic components.

- **GOOD RATES OF PAY AND PROSPECTS OF PROMOTION**
- **ADDITIONAL PAYMENT FOR OVERTIME**
- **EXCELLENT WORKING CONDITIONS**
- **FREE TRAVEL ON AND OFF DUTY**
- **PENSION AND SICK SCHEMES**

This is an opportunity for a secure, absorbing and worthwhile occupation. Please apply to a London Transport Recruitment Centre:—

Griffith House,
280 Old Marylebone Road,
London, N.W.1

Chiswick Works,
566 High Road,
Chiswick,
London, W.4

RADIO & TELEVISION SERVICING
RADAR THEORY & MAINTENANCE
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, Earls Court, London, S.W.5. Tel.: 01-373 8721.
Electronic Test Engineers

Pye Telecommunications of Cambridge has immediate vacancies for Production Test Engineers. The work entails checking to an exacting specification VHF/UHF and SSB radio telephone equipment before customer delivery; applicants must therefore have experience of fault finding and testing electronic equipment, preferably communications equipment. Formal qualifications, while desirable, are not as important as practical proficiency. Armed Service experience of such work would be perfectly acceptable.

Pye Telecom is the world's largest exporter of radio telephone equipment and is engaged in a major expansion programme designed to double present turnover during the next 5 years. There are therefore excellent opportunities for promotion within the Company. Pye also encourages its staff to take higher technical and professional qualifications. These are genuine career opportunities in an expansionist company so write, or telephone, for an application form without delay. Interviews can be arranged anywhere in the country at locations to suit the majority of applicants.

Mrs A. E. Darkin, Pye Telecommunications Ltd., Cambridge Works, Haig Road, Cambridge.
Telephone: Cambridge 51351.

Pye Telecommunications Ltd

MOBILE COMMUNICATION ENGINEERS
SOUTHERN GERMANY

Design engineers are required for interesting projects in an attractive area of Southern Germany. Engineers are required for a contract of two years' duration and should be qualified to a minimum standard of H.N.C. and some years' experience in either of the following fields:

(a) Mobile V.H.F. or U.H.F. solid state transmitter output stage design. Preferably at outputs of 20 W or more.
(b) Vehicle aerials and matching network design for wideband V.H.F.

The remuneration will be in the range of £3,000-£4,000 p.a., depending upon qualifications and experience. Write in confidence to:

INTERNATIONAL SCIENTIFIC CONSULTANTS LTD.
P.O. BOX 75, NORMANDY HOUSE, ST. HELIER, JERSEY, C.I. Quote Ref: EG 34

GUY'S HOSPITAL MEDICAL SCHOOL Department of Physics

ELECTRONICS ENGINEER or TECHNICIAN required to join Blood Flow Research Group for three-year project. Applicants should possess specialist experience/interest in construction/development of analogue solid state circuitry and Grad.I.E.E.E., H.N.D., H.N.C., D.N.C., or equivalent qualifications. Salary according to qualifications and experience, with superannuation.

For further details of work telephone Dr. Gaskell or Mr. King, 01-407 7600 Ext. 546. Applications giving full particulars and quoting ref. PH.2, to The Secretary, Guy's Hospital Medical School, London Bridge, S.E.I.

LANCAISHIRE CONSTABULARY HUTTON wanted RADIO TECHNICIANS

Must have experience in Radio/Television servicing and have obtained CGLITREB in Television Final Servicing Certificate or equivalent.

Pay £985 to £1,500. Starting point according to age and experience.

Apply to: The Chief Constable, P.O. Box 77, Lancaster Constabulary, Hutton, Preston, PR4 5SB

An immediate vacancy occurs at THE WIRELESS COLLEGE, COLWYN BAY, NORTH WALES

for a SENIOR INSTRUCTOR to take overall charge of the preparation of students for P.H.D., M.I.T. examinations, and to be directly responsible for telegraphy instruction. Applicants must hold a P.H.D. First Class Degree and operational and teaching experience is desirable but not essential. Write in the first instance to the Principal.

ENGINEERS

Have you considered a career in Technical Author-ship? If you have sound experience in electronics and ability to write clear concise English we can offer positions as Technical Authors. The salary range is £1300-£2000 plus with excellent prospects and rewards. Box No. W.W.364, Wireless World.

Wireless World, April 1970
RADIO OPERATORS

There will be a number of vacancies in the Composite Signallers Organisation for experienced Radio Operators in 1970 and in subsequent years.

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:

- Age 21: £865 per annum
- 22: £890
- 23: £925
- 25 and over: £965

Free accommodation will be provided at the Training School.

After successful completion of the course, operators will be paid on the Grade I scale:

- Age 21: £965 per annum
- 22: £1025
- 23: £1085
- 24: £1145
- 25 (highest age point): £1215

then by six annual increments to a maximum of £1650 per annum.

Excellent conditions and good prospects of promotion. Opportunities for service abroad.

Applicants must normally be under 35 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.

Interviews will be arranged throughout 1970.

Application forms and further particulars from:

Recruitment Officer, (R.O.3) Government Communications Headquarters, Oakley, Priors Road, CHELTENHAM, Glos., GL52 9AJ

Telephone No. Cheltenham 21491, Ext. 2270

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THE UNIVERSITY OF MANCHESTER

TELEVISION SERVICE

Applications are invited for the post of ASSISTANT STUDIO ENGINEER, to assist with the maintenance and operation of television equipment used in the University studios and Mobile Unit.

Applicants should possess a Higher National Certificate or equivalent and have a good knowledge of basic electronics with particular emphasis on transistor circuitry. They should have experience in maintenance of electronic equipment, radar, television or similar field.

Initial salary range £1050-£1300 per annum.

Applications, giving full details of age, qualifications and previous experience and giving the names of two persons to whom reference may be made, should be sent as soon as possible to The Director of Television Services, The University, Manchester M13 9PL.

NORFOLK EDUCATION COMMITTEE

The County Technical College, King's Lynn

LECTURER GRADE I in RADIO and TELEVISION SERVICING to teach electronics, radio and TV Servicing (including Colour) to C & G Final. Applicants should have considerable relevant practical experience and hold a C & G Final Certificate.

Salary £1100-£1900 p.a. point of entry depending upon qualifications and experience. Details and forms from the Registrar at the College.

County Hall, Martineau Lane, F. LINCOLN RALPHS,
Norwich, Chief Education Officer NOR 49A

NORFOLK

TV MECHANICS FOR NEW ZEALAND

RADIO and TV MECHANICS—are you dissatisfied with your present working conditions, high taxation and lack of progress? Why not shift to the sunny South Pacific and join the friendly team at TISCO, New Zealand's largest Service Company! Being purely in Television Service, our mechanics are important people, not just numbers on a time sheet.

All 30 of our Branch Managers are mechanics. You can be with us in 3 months if you write now. Requirements: 5 years' experience and £20 towards the family's fare, remainder of which will be paid.

Mr. R. I. Wells, Tech. Supervisor, TISCO Ltd., Private Bag, Royal Oak, Auckland, NEW ZEALAND.
Handsomely remunerated positions are available for experienced Mfr./Working Jewellers who have spare capacity to diversify with Electronics manufacturer. Five/soft soldering-Rhodium Plating of small component parts.

Strictest confidence.
Box No. WW392

NOTTINGHAMSHIRE
BEESTON COLLEGE OF FURTHER EDUCATION

Radio, TV and Electronics Technologies, Part I
Course No. C & G 434
A one-year, full-time and/or block release course will commence in September, 1970. The course will be open to students already engaged in the industry and to students leaving school who possess a good standard in mathematics and science. Minimum age of entry is 16 years.

Radio, TV and Electronics Mechanics, Part II
Course No. C & G 433
A two-year block release course will be offered in September, 1970, Part I of 15 weeks and Part II of 22 weeks. Minimum age of entry is 15 years.

Radio and Television Servicing, Part I
Course No. C & G 48
This one-year, full-time course will be offered next session for the last time after which it will be replaced by the Technicianics and Mechanices courses. Students already in industry and those leaving school this year who possess a good standard in mathematics and science will be accepted on this course.

For further particulars and entry forms for the above courses write to: The Principal, Beeston College of Further Education, High Road, Beeston, Nottingham, NGS 4AH.

SITUATIONS VACANT


ARE YOU INTERESTED IN HI Pay IT so, and you have some experience of selling in the Retail Radio trade, an excellent opportunity awaits you at Tunco Ltd., 243 Buxton Road, London, N.W.1. Tel. 01-387-7407.

DEPARTMENT of Nuclear Physics, University of Oxford, has a vacancy in the experimental electron- engineering for a technician to assist in the establish- ament, building and maintenance of modern nuclear electronics equipment. Salaries, as for the range of £580-£1,116 depending on age, qualifications and experience. Five-day week, good pay leave. Write to T. L. Green, Nuclear Physics Laboratory, Keble Road, Oxford, mentioning reference A12. (£86)

ELECTRONICS OFFICER required to run C.C.T.V. and Audio Section of the Department of Audio-Visual Communication, British Medical Association. He will be required to give information and advice on equipment. Excellent opportunities for promotion to medical teachers. His responsibilities will include establishing contact with manufacturers, ordering equipment and materials, maintaining and operating equipment for demonstration and experimental purposes. Appointments should be able to present written English to a good standard. A good knowledge of electronics and experience will be essential. The starting salary will be up to £1,500 p.a. according to qualifications and experience. Write briefly, in the first instance, stating age, education, qualifications and experience for appointment.


RADIO TEST ENGINEERS. Production testing and fault finding on Transistorised Audio Amplifiers & PM Receivers. 5-day week. Apply, Chief Engineer, Rogers Developments (Electronics) Ltd., 4-14 Harnaston Road (off Bromley Road), Catford, S.W.18. Tel. 01-388 7424/426. (£23)

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<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
</tr>
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<tbody>
<tr>
<td>KEP Onconerto QUAD Electroacoustic</td>
<td>£54 10</td>
<td>£29 10</td>
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<tr>
<td>WHARFEDALE Super</td>
<td>£58 10</td>
<td>£29 10</td>
</tr>
<tr>
<td>WHARFEDALE UNIT 3</td>
<td>£60 10</td>
<td>£32 10</td>
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PLAYING DECKS

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<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
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<tr>
<td>GARRARD 401</td>
<td>£61 10</td>
<td>£29 10</td>
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<td>GARRARD W40 Mark II</td>
<td>£64 10</td>
<td>£32 10</td>
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<td>GARRARD T75</td>
<td>£65 10</td>
<td>£32 10</td>
</tr>
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<td>GOLDERING G16</td>
<td>£65 10</td>
<td>£32 10</td>
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<tr>
<td>GOLDERING G160</td>
<td>£69 10</td>
<td>£32 10</td>
</tr>
<tr>
<td>THORENS TD100</td>
<td>£70 10</td>
<td>£32 10</td>
</tr>
<tr>
<td>THORENS TD100/80 M with ring unit</td>
<td>£79 10</td>
<td>£39 10</td>
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STEREO CARTRIDGES

<table>
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<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
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<tr>
<td>SHURE M101M</td>
<td>£50 0</td>
<td>£25 0</td>
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<td>SHURE M71</td>
<td>£49 0</td>
<td>£24 0</td>
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<td>SHURE M80</td>
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<td>SHURE M10</td>
<td>£29 0</td>
<td>£14 0</td>
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<td>GOLDERING C800</td>
<td>£45 0</td>
<td>£21 0</td>
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<tr>
<td>GOLDERING C900</td>
<td>£50 0</td>
<td>£25 0</td>
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STEREO TAPE DECKS

<table>
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<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
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</thead>
<tbody>
<tr>
<td>AKAI AD600 3-band stereo tape deck</td>
<td>£150 0</td>
<td>£75 0</td>
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<tr>
<td>AKAI X150M Stereo tape deck, cassette, hand held</td>
<td>£150 0</td>
<td>£75 0</td>
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<tr>
<td>AIWA PT1101, professional stereo b band deck</td>
<td>£130 0</td>
<td>£65 0</td>
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<tr>
<td>SANYO MD100 stereo tape recorder</td>
<td>£79 10</td>
<td>£39 10</td>
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<tr>
<td>SANYO MD150 stereo tape recorder</td>
<td>£79 10</td>
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<tr>
<td>REVOX model 1104 4 -track tape recorder</td>
<td>£160 10</td>
<td>£79 10</td>
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<tr>
<td>PHILIPS 8935 4 -track tape recorder</td>
<td>£160 10</td>
<td>£79 10</td>
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MONO/MAIN S TAPE RECORDER

<table>
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<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>GARRARD SP125, separate 2 -8 &quot;x 12 -8 &quot;x 12 -8 &quot;amplifier 1</td>
<td>£57 10</td>
<td>£23 10</td>
</tr>
<tr>
<td>GARRARD SP125, separate 2 -8 &quot;x 12 -8 &quot;x 12 -8 &quot;amplifier 2</td>
<td>£57 10</td>
<td>£23 10</td>
</tr>
</tbody>
</table>

COMPUTER HI-FI SYSTEMS

<table>
<thead>
<tr>
<th>Model</th>
<th>Rec. Retail Price</th>
<th>Discount Price</th>
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</thead>
<tbody>
<tr>
<td>GARRARD SP100, separate 2 -8 &quot;x 12 -8 &quot;x 12 -8 &quot;amplifier 1</td>
<td>£57 10</td>
<td>£23 10</td>
</tr>
<tr>
<td>GARRARD SP100, separate 2 -8 &quot;x 12 -8 &quot;x 12 -8 &quot;amplifier 2</td>
<td>£57 10</td>
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Applications
A useful application of H.M.P. is the soldering of joints close to each other in such a way that the connections made first are not re-melted while later joints are made, with for example, a standard 60/40 alloy, melting point 183°C. Essential for use where high operating temperatures are experienced, for instance, electrical motors, car radiators, high temperature lamps. H.M.P. is also ideal for equipment, which is being operated in low temperatures, as it reduces the chance of the joint becoming brittle.

Specification
Multicore H.M.P. alloy complies with BS.219 Grade 5S. Supplied in a form of Ersin Multicore 5 core solder wire on 1lb. or 7lb. reels, incorporating Ersin 362 rosin based flux. This non-corrosive flux-cored solder wire complies with BS 441 and is available from 10 to 26 s.w.g., and in Multicore Solder Preforms. Ask for Technical Bulletin No. 1369.

Low Melting Point

A low melting point solder for soldering silver plated and gold plated surfaces. Melting point 179°C (354°F).

Applications
L.M.P. reduces the absorption of silver or gold into the solder alloy whilst soldering, and therefore, preserving the silver or gold plated surfaces. Also reduces the chance of a brittle joint being made.

NOTE
a) The solution of gold into tin rises rapidly with temperature and so the use of L.M.P. Low Melting Point Solder is preferable.

b) The solution rate of gold into tin is also reduced because L.M.P. is a ternary alloy comprising tin, lead and silver.

Specifications
L.M.P. is normally supplied in the form of Ersin Multicore 5 core solder wire, incorporating Ersin 362 rosin based flux, which complies with Min. Tech. specification D.T.D. 59A. It is available from 10 to 34 s.w.g. in 1lb. or 7lb. reels and Multicore Solder Preforms. Ask for Technical Bulletin 1469.

Extra Low Melting Point

Extra low melting point solder. Melting point 145°C (295°F).

Applications
T.L.C. alloy can be used whenever a soldered joint should be made with the minimum heat input. This would include heat sensitive transistors, flexible printed circuits and gold plated surfaces. The melting point of T.L.C. alloy is 38°C lower than any tin/lead alloy. Because of its low temperature application it is considered completely non-toxic in use unlike the high temperature cadmium-bearing brazing alloys.

Specification
T.L.C. alloy is normally supplied in the form of Ersin Multicore 5 core solder wire, incorporating Ersin 362 rosin based flux, which complies with Min. Tech. specification D.T.D. 59A. T.L.C. alloy can also be supplied in the form of Multicore precision made solid solder wire, Extrusol extruded solid solder bars for solderbaths and Multicore Solder Preforms. Available from 10 to 34 s.w.g. on 1lb. or 7lb. reels. Ask for Technical Bulletin No. 1569.