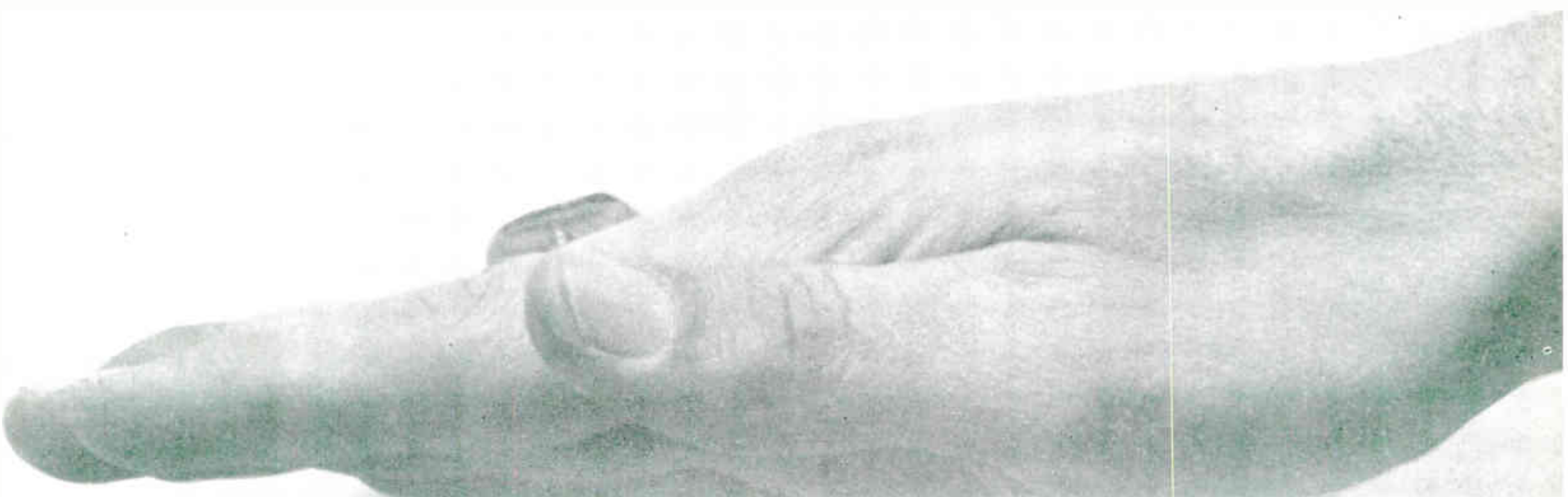
INDUSTRIAL ELECTRONICS

MARCH 1963 5s 0d



LOOK—NO CONTACTS!

NORBIT STATIC SWITCHES for automatic control systems NEVER NEED MAINTENANCE

No maintenance, no 'sneak circuits', operation in *any* position, constant speed and a life unaffected by the number of operations.

These are only some of the many reasons why electrical and electro-mechanical engineers, in increasing numbers, are using Norbit static switches instead of relays in a wide variety of automatic control and alarm applications, from lift systems to food processes.

Since they use no moving parts contactless Norbit switches need no adjustments, no cleaning and suffer no mechanical wear or variation in operating speed. Time wasting 'cut and try' methods are also eliminated during system design—using Norbits you can plan your complete system on paper and know that what you plan will work in practice.

Furthermore, one basic Norbit gives you any switching function you need. No contacts, no sparking, no heat to dissipate, unaffected by detrimental atmospheres—dust, abrasive particles, humidity, corrosive fumes, hazardous atmospheres—the reliability of Norbit static switches has been proven in practice and by exhaustive quality testing.

Here's all you need to know How does the Norbit switch if it uses no contacts? Just regard the Norbit as a switch which does not open or close, but one which either conducts or does not conduct. Furthermore, there's *no need* for you to know any electronic theory to understand Norbits and apply their many advantages.

Free to the practical engineer Write for a free copy of 'Static Switching Simply Explained'. This booklet gives you a completely non-mathematical explanation of Norbit static switches—what they can do and how they can be used. Write today for this practical guide to contactless switching using Norbits.

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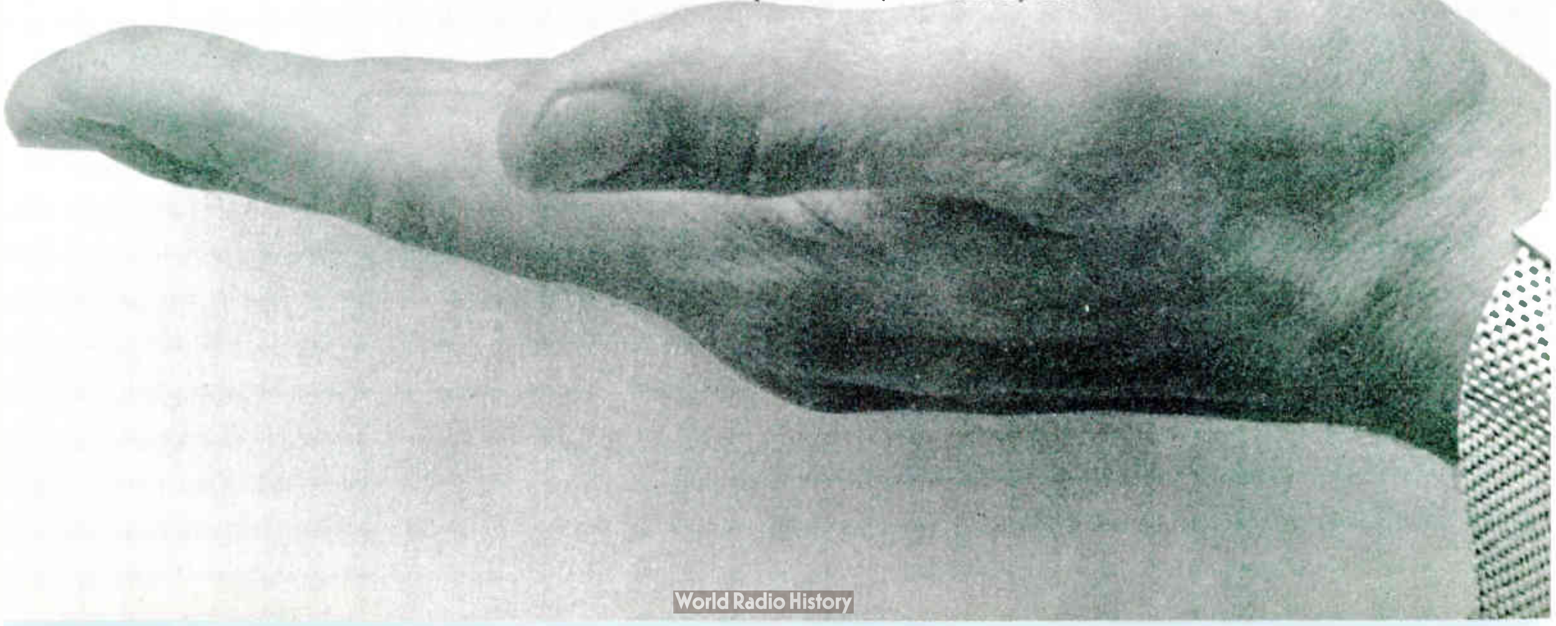
Telephone Crawley 28787



INDUSTRIAL ELECTRONICS

incorporating *ELECTRONIC TECHNOLOGY*

Volume 1 Number 6 March 1963

contents

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Assistant Editor **T. J. BURTON**

Advertisement Manager **G. H. GALLOWAY**

continued overleaf

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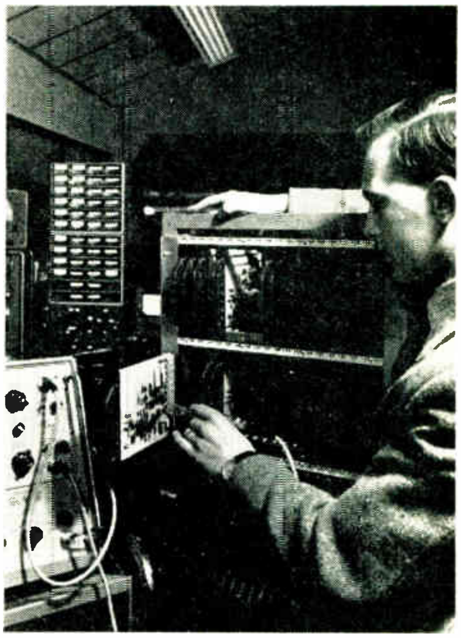
contents continued

FEATURES



OUR COVER

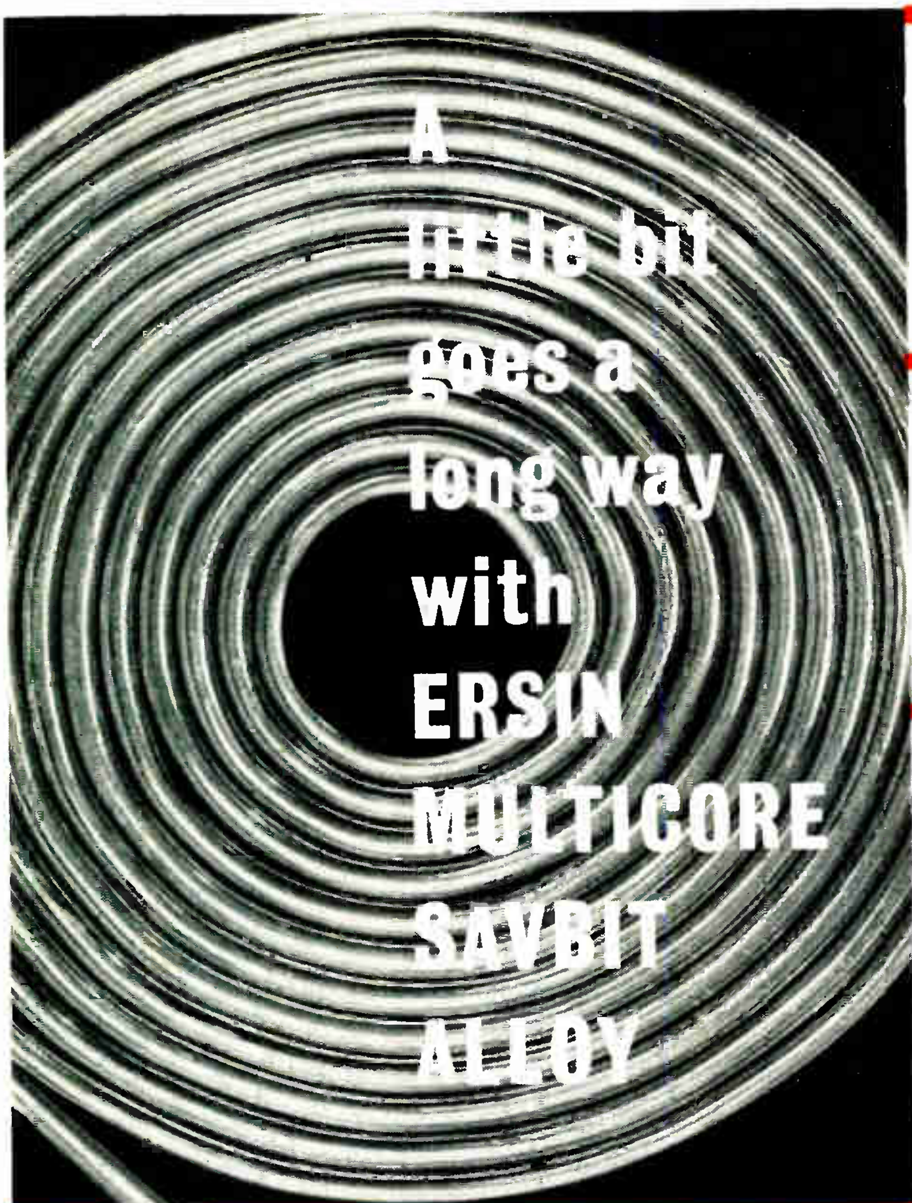
This picture shows high-speed digital storage apparatus under investigation at the Roke Manor Applied Research Laboratories of The Plessey Co. (U.K.) Ltd. An article in this issue describes the tunnel-diode storage elements employed.

Next Month

The April issue will include an article on the use of electronics for testing internal combustion engines. Designed for garage use the apparatus greatly simplifies fault-finding in car engines. Other articles will deal with the use of nucleonics for friction and wear measurement and with control systems for heating and air-conditioning.

TO SAVE YOUR TIME

We will assist you to obtain further information on any products or processes described or advertised in this issue. Just use the enquiry cards to be found in the front and back of the journal.



A little bit goes a long way with ERSIN MULTICORE SAVBIT ALLOY

SAVBIT for factories

Supplied to factories as standard, in 7 lb. or 1 lb. reels of 14, 16 and 18 s.w.g., packed in easy-to-handle 28 lb. cases.

SAVBIT fine gauges

Ersin Multicore Savbit alloy is also available in 19, 20 and 22 s.w.g. for fine precision soldering.

SAVBIT

Approx. No. of feet per lb.

S.w.g.	Ft.
10	24
12	36
13	46.2
14	60.8
16	96.2
18	170
19	244
20	307
22	508

A soldering bit goes ten times as far . . . does ten times as much work . . . when it is used only with Ersin Multicore Savbit Alloy. Replacement of bits can be a heavy, recurring, maintenance cost. The small percentage of copper in Ersin Multicore Savbit Alloy reduces bit wear and prolongs the working life of bits as much as ten times.

Send for this interesting booklet

Laboratory engineers and technicians are invited to write on their Company's letterheading for the latest edition of Modern Solders. It contains technical and background information, tables of data on alloys, gauges and temperatures.

Ersin Multicore Savbit Alloy is manufactured under the sole British Licence of Patent No. [illegible]—by

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ERSIN Multicore SOLDER

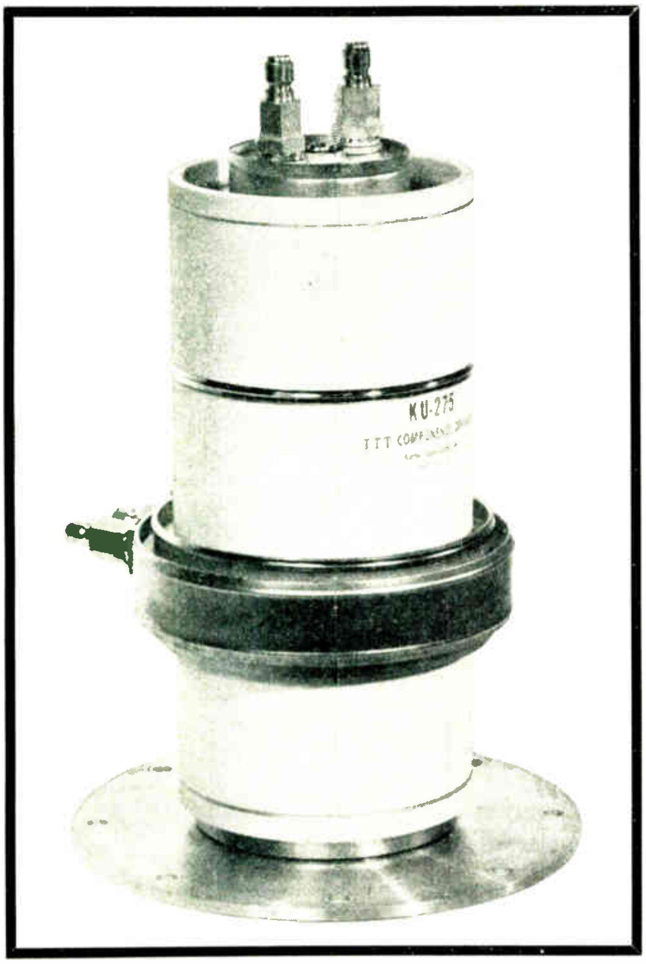
STC COMPONENTS REVIEW
MARCH, 1963

PULSE MODULATOR VALVES

HYDROGEN THYRATRONS

A complete range of hydrogen-filled thyratrons of the world-renowned Kuthe manufacture is now available in Great Britain from STC Valve Division.

The hydrogen thyratron is now the accepted pulse modulator device for the higher kilowatt and megawatt peak power applications.



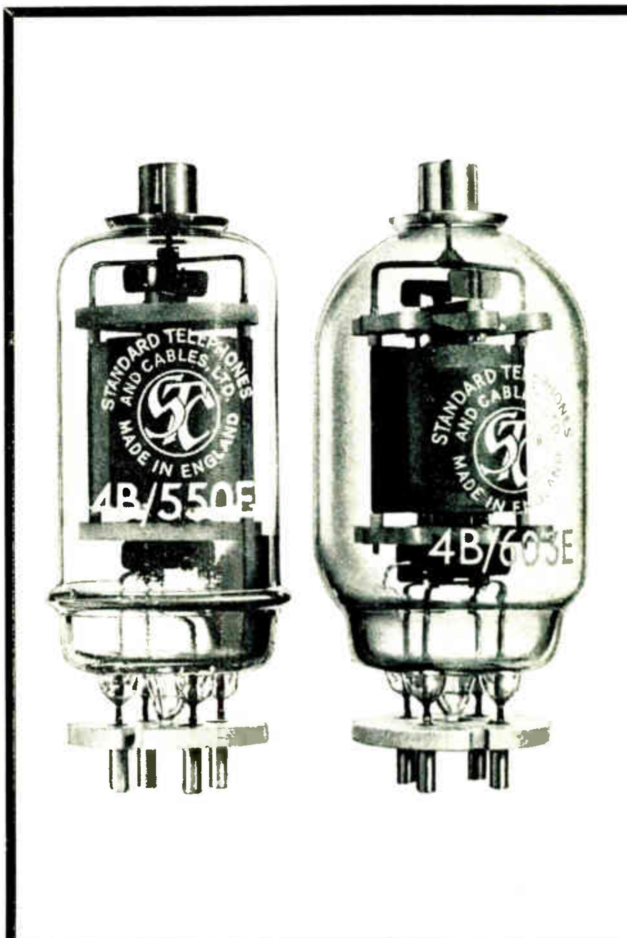
Illustrated is the new super power KU-275. The ceramic construction permits operation at very high power levels relative to the physical size of the valve.

THYRATRONS	KU 70	KU 71	KU 72	KU 73	KU 74	KU 274	KU 275
Performance Factor (x 10⁹)	2.7	4.0	7 0	20.0	40.0	55.0	400 0
Peak Power Output, Megawatts	0.4	1.0	3.5	12.0	33.0	60.0	100.0
Forward Anode Voltage, Kilovolts	8.0	12.0	20.0	25.0	33.0	50.0	50.0
Peak Anode Current, Amperes	100	200	350	1000	2000	2000	4000
Average Anode Current, Amperes	0.100	0.200	0.300	1.5	4.0	4.0	8.0
Seated Height, Inches	1.5	1.8	2.3	5.2	10.0	12.0	16.0
Diameter, Inches	1.0	1.4	1.8	3.0	4.5	4.5	8.5

Write, 'phone or Telex for information on the complete range of hydrogen thyratrons and diodes.

VACUUM TETRODES

The STC range of Vacuum Pulse Amplifier Tetrodes grows steadily as does their reputation for reliable service. The latest valve to be added to the range is type 4B/550E which is a smaller version of the now very popular 4B/603E.



Code	3D21A	4B/550E	4B/603E	4B/602E
V_h (V)	6.3 or 12.6	26	26	26
I (A)	1.7 or 0 .85	1 2	2	2
[illegible] (kV)	3.5	12	15	20
I peak (A)	7	10	15	15
V_{g2} (kV)	0.8	0.8	1.25	1.25
V_{g1} bias (V) Typical	150	—500	800	800
V_{g1} pulse (V) Typical	300	700	1025	1025
Equivalent Codes	CV2659		CV398	CV427

Write, 'phone or Telex for full data sheets.

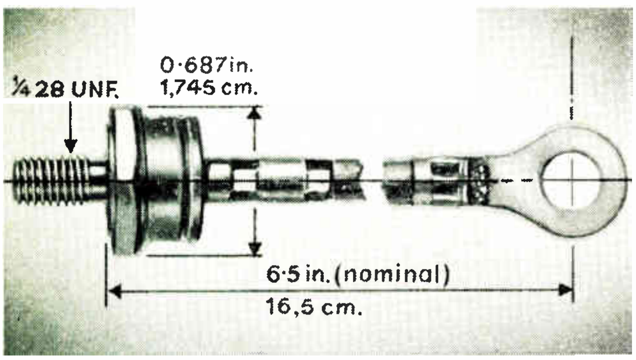
STC Valve Division, Brixham Road, Paignton, Devon, or London Sales Office, Footscray, Kent. Telephone FOOtscray 3333. Telex 21836

25 AMPERES SILICON RECTIFIERS with dual polarity

Available from Stock

STC RS600 Series silicon rectifiers are rated at 25 amperes at 125 C stud temperature with crest working voltages from 100 to 600V. They are available with a choice of stud polarities to facilitate the assembly of diodes with heat sinks.

RS600 diodes conform to VASCA outline SO.32A and are flexible lead versions of VASCA outline SO.13, JEDEC DO-5 and IEC 1-104.



RS600 MAXIMUM RATINGS
(125°C stud temperature)

Average forward current	25A
Surge current (5 milliseconds)	500A
Crest working reverse voltage	up to 600V
Non-repetitive peak reverse voltage (one cycle)	up to 800V
Storage temperature range	−60°C to +150°C
Mean dissipation	30W

RS600 ELECTRICAL CHARACTERISTICS
(max. values)

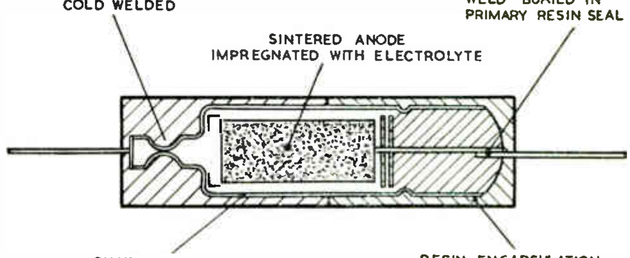
Average reverse current at 125°C stud temperature and at rated voltage and current	1·5 mA
Forward voltage drop at 25 A d.c.	1·1 V

Diodes and heat sinks, assembled into stacks, are available in all circuit configurations.

Write, 'phone or Telex for Data Sheets and prices to STC Rectifier Division, Edinburgh Way, Harlow, Essex. Telephone Harlow 26811. Telex 81146.

NEW TANTALUM CAPACITORS

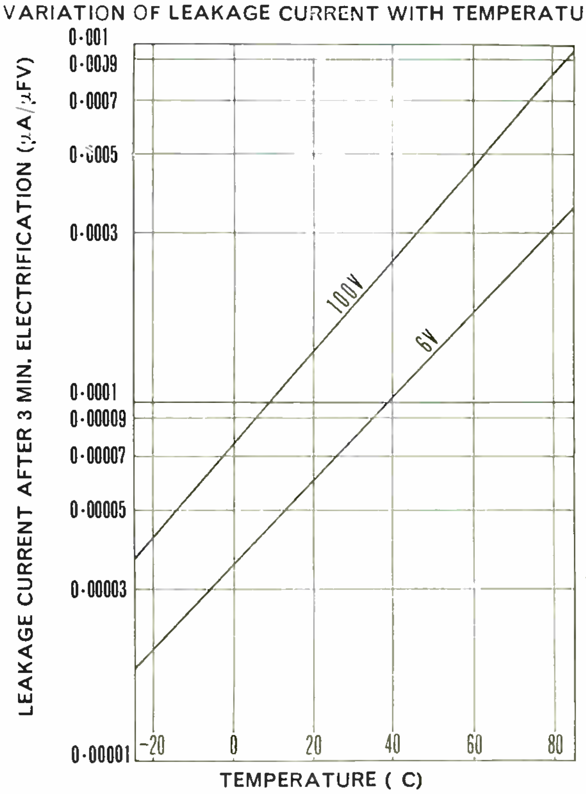
STC announce the introduction of a range of wet—electrolyte Sintered Anode Tantalum Capacitors. They combine the high space factor resulting from the use of a porous sintered body with working voltages up to 100V d.c.



An exceptional feature is the low leakage current which has a highly stable performance on life test.

TYPICAL CHARACTERISTICS

VARIATION OF LEAKAGE CURRENT WITH TEMPERATURE



39 μF @ 6V to 2·7 μF @ 100V   68 μF @ 6V to 4·7 μF @ 100V

Write, 'phone or Telex for Data Sheets to STC Capacitor Division, Brixham Road, Paignton, Devon or London Sales Office, Footscray, Kent. Telephone FOOtscray 3333 Telex 21836.

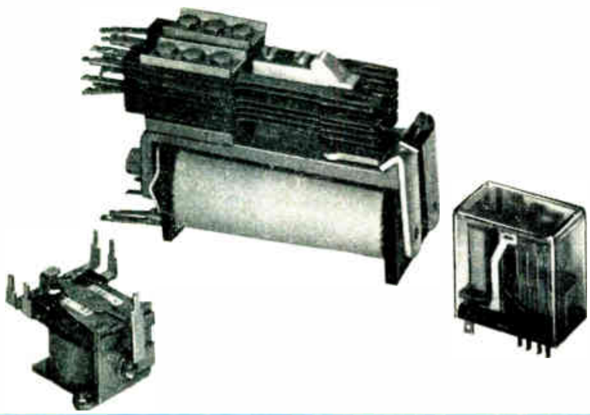
COMPONENTS REVIEW

THREE NEW RELAYS

TYPES 24 AND 25

These miniature industrial relays and sockets are now available to industry. They are interchangeable in form, fit and function with well-known continental types. For maximum economy, the preferred configuration is 2-changeover contacts (Type 24) or 4-changeover contacts (Type 25), with coil voltages as required.

To ensure optimum reliability of performance, silver/gold contacts are used together with a cover formed from non-gassing plastic. For a.c. operation, suitable STC quality rectifiers are available; voltages should be specified with order.



TYPE 11200 TWIN RELAY

These are, basically, 2 × PO 3000 Type relays, but special flat coils are fitted, together with two special armatures each operating one springset. One or two windings can be supplied for each core. For 50 V d.c. working, 1 000–2 000 ohms coils are used but they are available from 5–3 000 ohms if required. The Type 11200 twin relay is recommended where price and space-saving are important considerations.

TYPE 11301 'DOLLAR' RELAY

A d.c. relay for general use where space and cost are important and where high current capacity is not required. 'Dollar' relays are available for 6, 12, 24, 48 or 60 volts working with coil resistances from 100–6 000 ohms. They have one changeover contact which will switch either 0·3 A at 50 V d.c. or 1·0 A at 50 V d.c. depending on contact material.

OTHER TYPES

Other types in the STC ranges include reed switches and relays, PO 3000 Types and PO 600 Types. PO 3000 Types are available in quantity with ten days delivery.

Write, 'phone or Telex for STC relay literature and prices to STC Electro-mechanical Division, West Road, Harlow, Essex. Telephone Harlow 21341. Telex 81184.

NEW SILICON EPITAXIAL PLANAR DIODES FOR FAST SWITCHING

UP TO 30V PIV

The BAY31 and BAY36 are new silicon epitaxial planar high performance diodes. They are specially designed for use in logic circuits working at frequencies of up to 10 Mc/s. Exceptional ruggedness and standardized dimensions make these diodes eminently suitable for use on printed circuit boards.

- LOW COST
- HIGH SPEED
- HIGH FORWARD CONDUCTANCE
- LOW REVERSE LEAKAGE CURRENT
- PLANAR EPITAXIAL CONSTRUCTION
- RUGGED DESIGN
- DO-7 OUTLINE

Actual Size

CHARACTERISTICS (AT 25°C)

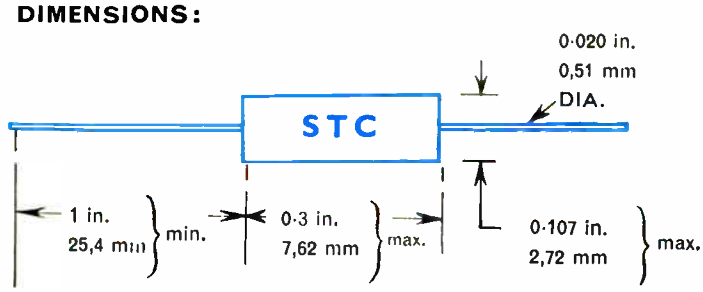
I_R	(Max) at	−10V	100nA
V_F	(Max) at	30mA	1·0V
$*t_{rr}$	(Max) to	1mA	5·0ns

*(I_F = 10mA, V_R = 6V, R_L = 100 Ω)

MAX. RATINGS

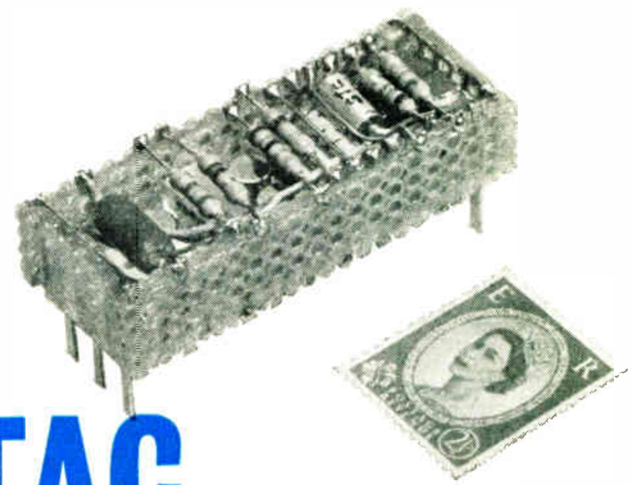
V_R	(mean, peak or transient)	15V	(BAY 31)
V_R	(mean, peak or transient)	30V	(BAY 36)
I_F	(mean)	100mA	
I_F	(peak)	200mA	
P_{tot}		200mW	
T	(operating)	100°C	

DIMENSIONS:



Write, 'phone or Telex for advance Data Sheet to STC Transistor Division, Footscray, Sidcup, Kent. Telephone FOOtscray 3333. Telex 21836.

COMPONENTS REVIEW



A NEW CONCEPT IN MODULAR CONSTRUCTION

THE MINISTAC

AN STC SERVICE FOR CIRCUIT AND EQUIPMENT DESIGNERS

STC will design *your* circuit into a Ministac to provide the most compact and economic module. Ministac modular assemblies provide a reliable and flexible system suitable for use with standard size conventional components, the packing density being at least twice as great as that possible with printed circuits at comparable prices. The design permits manufacturing methods which bring the small production run within the same price range.

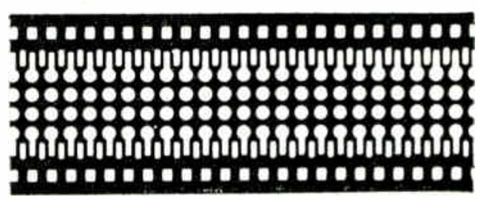
Ministacs are designed and manufactured from equipment designer's circuit schematics. Prototypes can be made available at short notice.

The salient feature of the design is its flexibility. It is capable of accommodating all components in the small power field and of embodying any normal circuit without difficulty. The design is equally suited to miniaturized conventional components and thin film circuits all of which can be removed and replaced without danger of damage to connecting points or other components. Access to adjustable items such as potentiometers and variable capacitors can be provided on the upper or lower face of the module. For components which cannot be supported adequately by their lead out wires a sub-plate is provided.

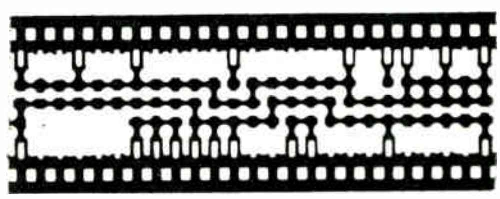
The composing of Ministac circuitry is a simple and effective operation which is standard for long or short runs. The operation is merely the pressing-out of unwanted circuitry from nickel silver pre-formed circuit paths.

MINISTAC ADVANTAGES:

- Complete flexibility in design
- Uses standard components
- Improved packing density
- Short runs at low cost
- Can be used with miniaturized components and thin film circuits
- Easy access to components for servicing
- Suitable for potting
- Terminals suitable for printed circuit or solderless wrapped wiring connections



Stock material from which Ministac circuitry is punched



Wiring pattern cropped from stock material, but still supported by matrix side pieces

Write, 'phone or Telex for Advance Information Leaflet to STC Rectifier Division, Edinburgh Way, Harlow, Essex. Telephone: Harlow 26811. Telex: 81146

Send us your circuit schematics; we will provide components and produce *MINISTAC* modules to meet your specifications

Standard Telephones and Cables Limited

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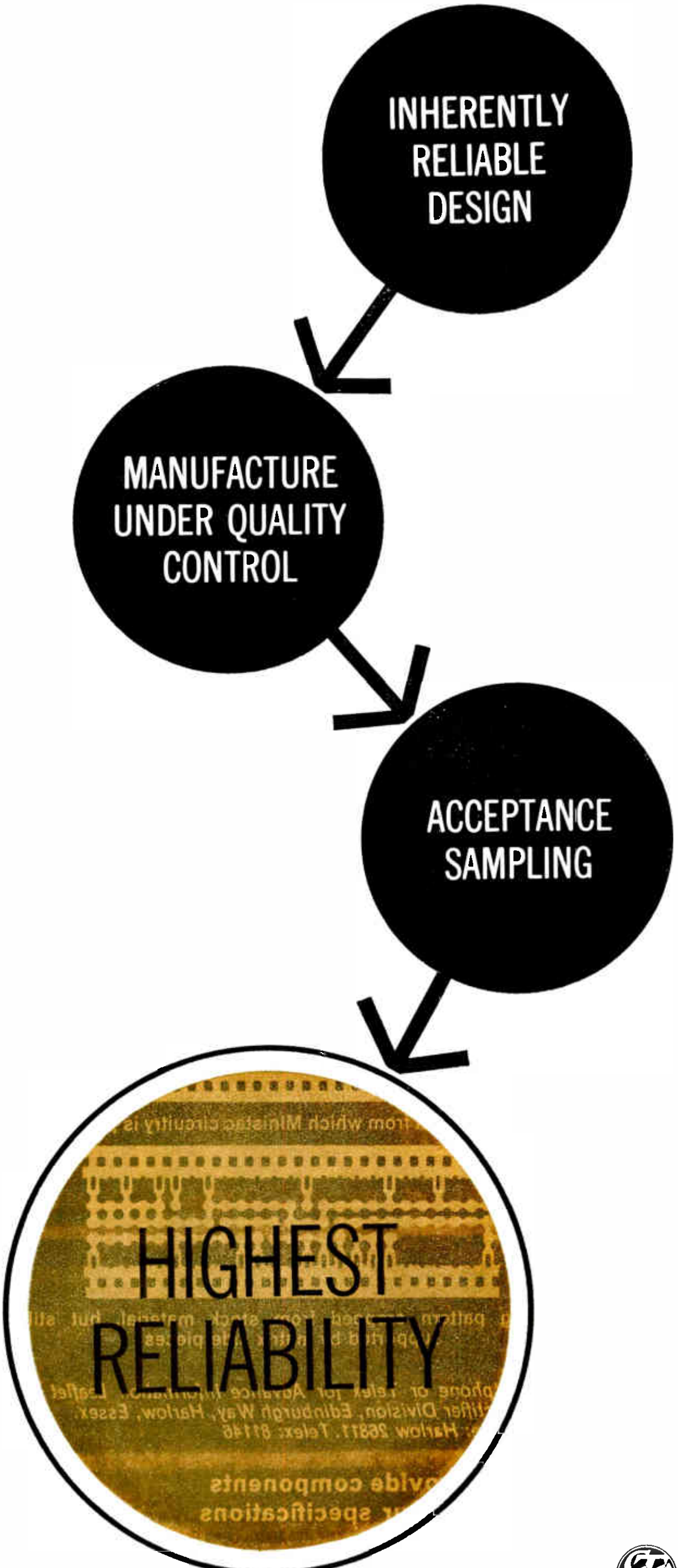
For further information circle 212 on Service Card

STC introduce SPECIAL QUALITY tantalum capacitors



For equipments demanding components of the highest quality, STC produces a range of SPECIAL QUALITY tantalum foil capacitors. These are based on the STC High Temperature tantalum range which is known, from life test data and field experience, to be inherently capable of high reliability.

Using established statistical control techniques, variations in manufacturing processes and raw materials are tightly controlled—and the full intrinsic reliability of the product realized.

STC SPECIAL QUALITY tantalum capacitors are manufactured on a batch basis under full Quality Control. They are then formed into lots which are released only on the successful completion of extensive Quality Assurance (destructive) tests carried out on a statistically chosen percentage. These Acceptance Sampling tests extend up to 1 000 hours.

63/8MC

For full information write, 'phone or Telex

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Reliability
High conductance
Low leakage
Fast recovery characteristics
Rugged, sub-miniature all-glass construction
Operation up to 90°C
Low cost

point-contact general purpose diodes

HG10

High forward conductance
Max. average power dissipation 80mW
Nominal capacitance at -10V 0.2pF
Operating and Storage temperature range -60°C to 90°C

Type	P.I.V.	Max. D.C. or Mean Forward Current (mA at 25°C)	Min. Forward Current at 1V (mA)	Max. Reverse Current at —50V (μA at 25°C)
*HG1005	100	45	5	50
†HG1006	100	45	5	100
HG1012	75	45	5	100

TYPE APPROVED *CV 7041 †CV 448 & †CV 7130

gold-bonded computer diodes

HG50

Extremely high forward conductance
Stored charge at 10mA 400pC
Nominal capacitance at -10V 0.4pF
Max. average power dissipation 80mW

TYPE APPROVED *CV 7127

Type	Min. Breakdown Voltage	Max. D.C. or Mean Forward Current (mA @ 25°C)	Max. Forward Voltage at 100mA	Max. Reverse Current at 25°C μA @ V
HG5003	100	100	0.8	25 -50
*HG5004	70	100	0.8	25 -50
HG5008	40	100	0.8	25 -30
HG5085	Transistor base protection diode	V_f at 100 mA (25°C) ....1.0V max. I_b at -1.0V (45°C) ....5μA max. P.I.V. ....5V Max. DC Current (25°C) ....100 mA		

fast recovery computer diodes

HD18

High forward conductance
6 Nanosec typical recovery time
Nominal capacitance at -1V 1.5pF

Type	P.I.V.	Max. Forward Voltage		Max. Reverse Current @ -10V (25°C)
		@ 10 mA	@ 100 mA	
HD1810	50	0.45	0.75	5μA
HD1840	30	0.45	0.70	10μA
HD1841	20	0.45	0.70	20μA
HD1870	15	0.42	0.70	15μA
HD1871	10	0.42	0.70	20μA (@ -5v)

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actual size

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Accurate forecasting of the performance of control systems in the prototype stage can be an enormous saver of time and money. This Control System Analyser has become standard equipment in the aircraft and missile industries, in light and heavy engineering, and in chemical, nuclear and marine engineering.

As well as its use in design, it is also a valuable means of quality control in the production of control systems. It is built by the Precision Engineering Division of Short Brothers & Harland Limited—Europe's leading manufacturers of analogue computers.

Outstanding features include:

- Ease of operation
- Low frequency operation
- Steady meter readings even at the lowest frequency
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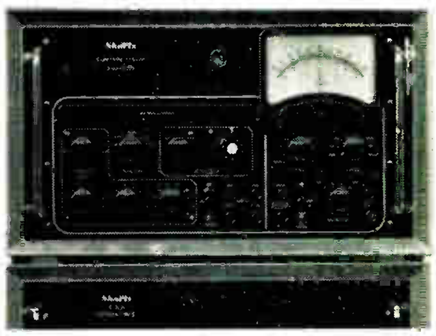
- Very low D.C. level
- Competitive price



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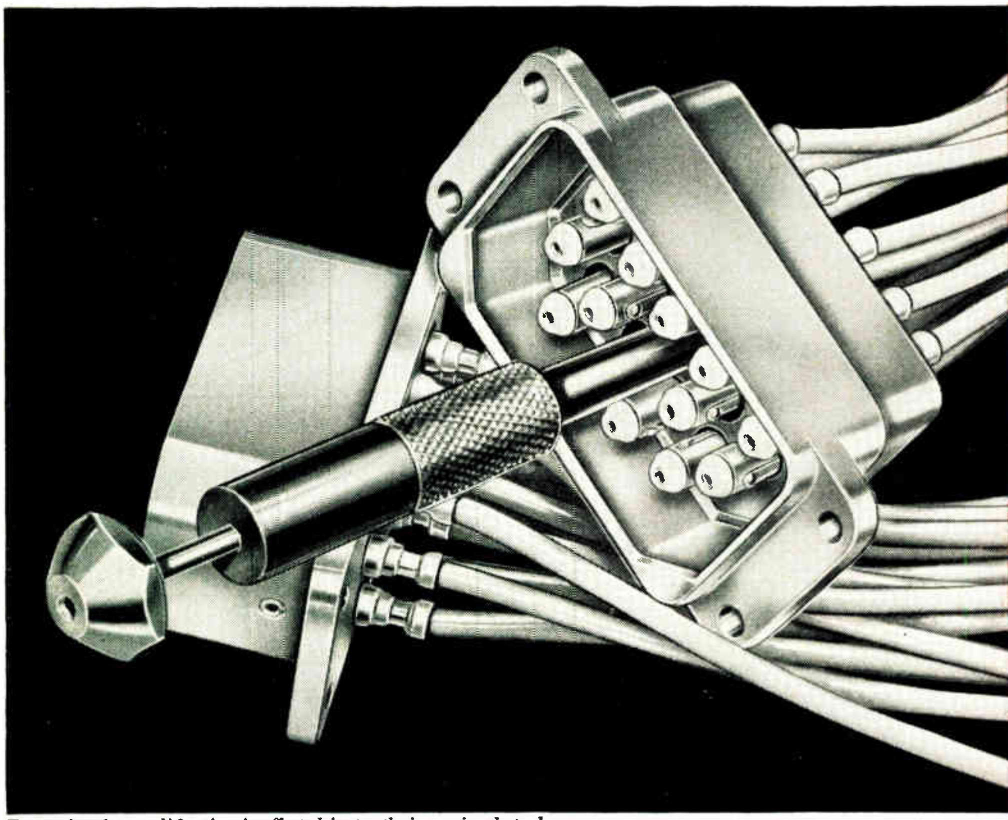

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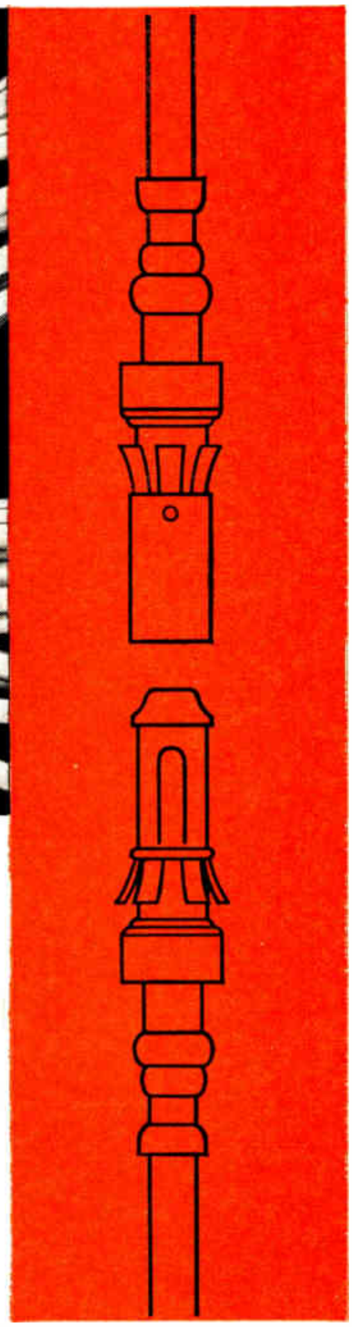

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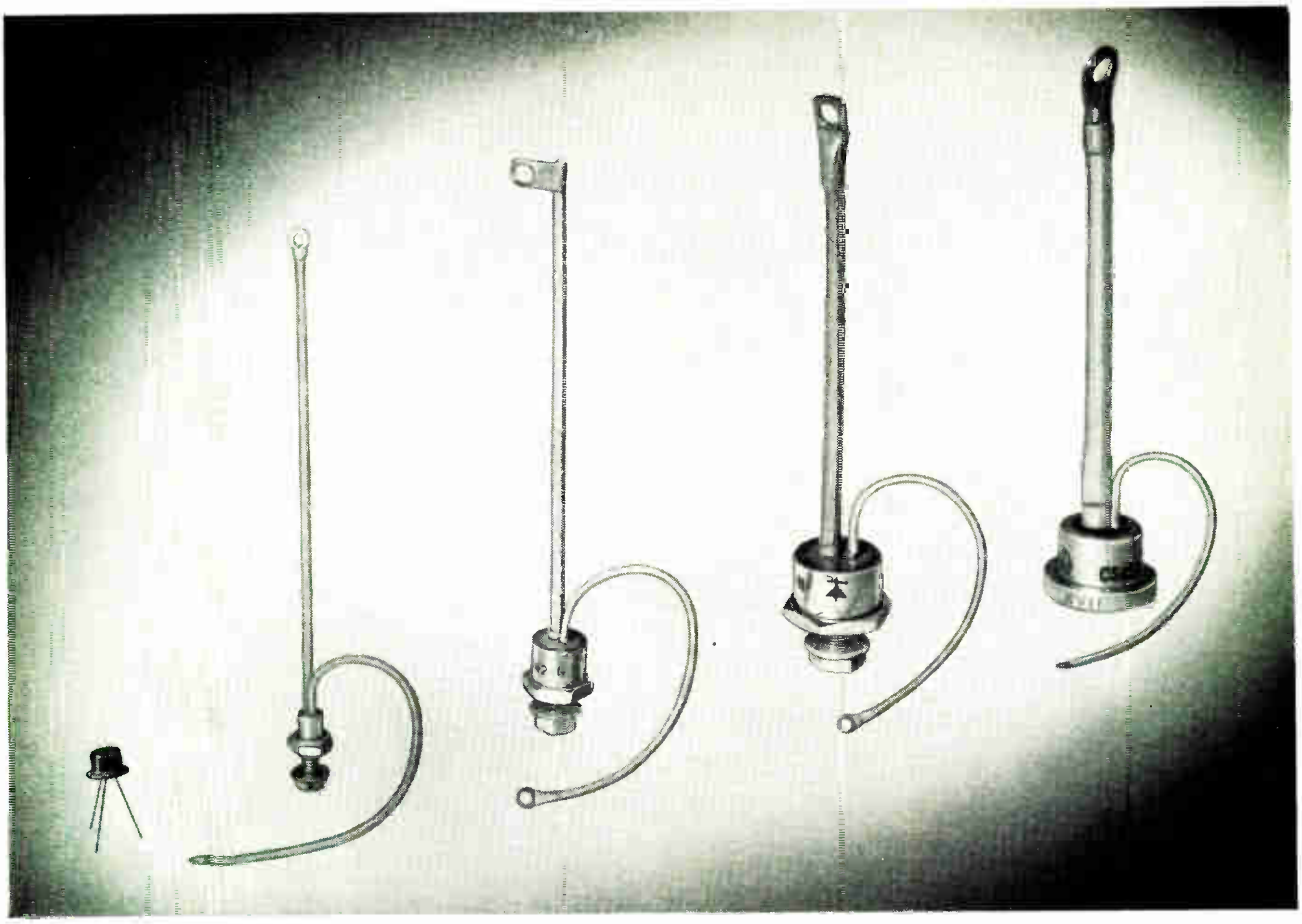

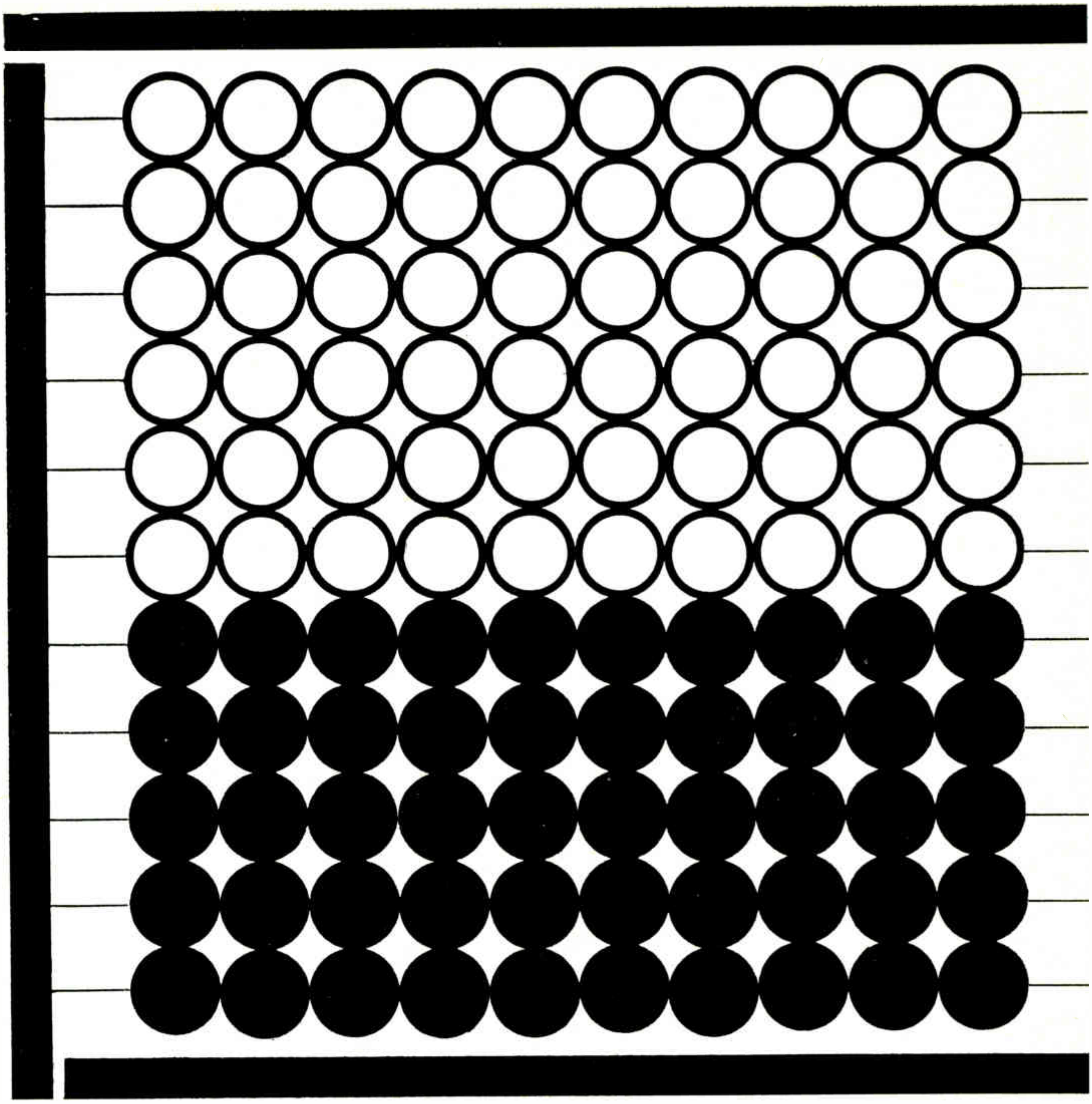

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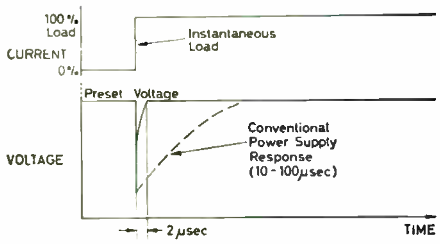

Fig.1. TRANSIENT RECOVERY

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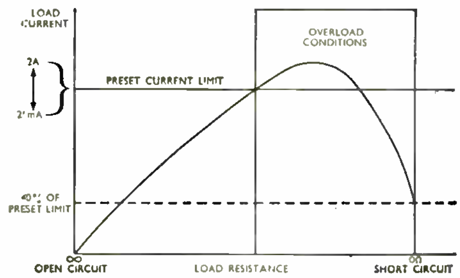

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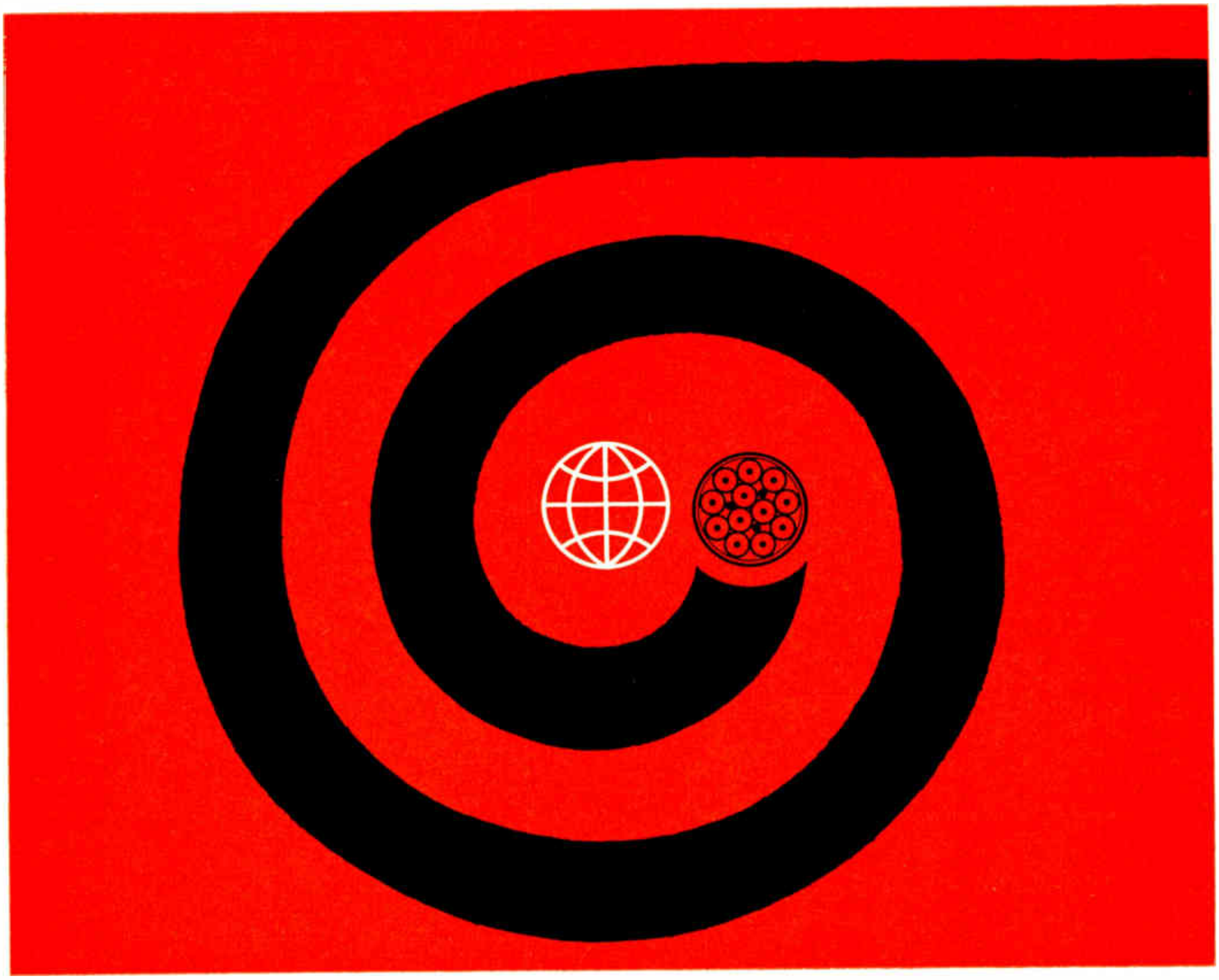


INDUSTRIAL ELECTRONICS

Comment

Being largely concerned with the applications of electronics we do not deal very much with fundamental research. We recognize its importance and we ourselves like to know what is going on. Some of it is quite curious. It is well known that electronics is widely used by biologists as an aid to understanding. For instance, circuits capable of 'learning' are constructed to help in understanding how the brain works ('Memory and Learning Circuits', *Industrial Electronics*, November and December 1962).

There is now reported just the reverse of this. Biological research is being undertaken with a view to finding out how to improve electronic apparatus! It is usually considered that the eye is somewhat analogous to a mosaic of photocells whose outputs are passed to the brain, the real process of seeing being carried out in the brain which acts as a data processor to sort out the information passed to it from the eye. It now appears that this is not wholly true. In some cases, at least, the eye itself seems to do some of the processing and this not only relieves the brain of work but reduces the number of communication channels necessary between eye and brain (*Frontier*, Autumn 1962).

The frog's eye is one example of this. Behind the retina there is a neural structure which is connected to the brain by four types of fibres. Each type responds to different sorts of stimulus on different parts of the eye. One is stimulated if the sharp edge of an object moves into the field of vision. Another responds to a small object passing through the field, a third mainly to moving objects, and the fourth to changes of light intensity.

The frog seems to have found a way of reducing its communication network load by doing some of the data processing in the eye instead of the brain. Something similar might be possible in electronic equipment by providing the sensory devices with built-in elementary data processors. A very crude illustration consists of two concentric rings of photo-conductive material. A battery is connected from the centre to the outside and an output taken from their junction. A constant output is obtained whenever the device is uniformly illuminated, but the output changes if the device is only partially illuminated.

Although we doubt if all this will have much immediate effect on electronics, the ideas which the research is generating may well have their effect in time to come. This may be in enabling new things to be done or perhaps only in simplifying the hardware needed to carry out what we can do already.

Standard Frequencies

When we were *Electronic Technology* we published regularly the daily deviations of certain standard-frequency radio transmissions so that users of them could make any necessary corrections to their measurements. We ceased to publish them when we became *Industrial Electronics* because their inclusion no longer seemed appropriate.

Of these transmissions one of the more important is Droitwich. Although not officially a standard-frequency transmission the carrier frequency of the B.B.C.'s Light Programme transmission on 200 kc/s is so accurately controlled that it forms a useful standard frequency. It is widely used as such because it is readily received almost anywhere in the U.K. and because it transmits for long periods every day.

It has recently been announced that

the frequency stability has been improved and is now maintained within 5 parts in 10^9. The diurnal rate of frequency change is not more than 1 part in 10^{10} and the resultant error is corrected on the first Sunday of each month. During 1963 the transmission time will be increased to 20½ hours each weekday.

The Droitwich transmissions will thus be more useful than ever in the future and they will be accurate enough for many purposes without any correction. Where a knowledge of the deviations is needed for very accurate work, however, details of them can be obtained on a monthly basis from the National Physical Laboratory, Teddington, Middlesex.

Mending Telstar

We talked last month a little facetiously about the repairs to Telstar. At that time we had only a report that equipment in the satellite had failed and been mended by action from the ground.

Details of the fault and how it was remedied have now come to hand, and the engineers concerned have certainly been clever. The fault lay in the command decoders and developed somewhat gradually; it was suspected that some of the transistors in these circuits had become damaged by high intensity radiation.

The deterioration of transistors under radiation is greatest under reverse bias conditions, a normal condition in Telstar, but they tend to recover towards more normal operation if the reverse bias is reduced or removed. It was noted that the command function would fail during the first few passes of a series and then begin to operate again, and this led to the deduction that the first few command signals, which affect the reverse bias, were enabling the transistors to recover a little.

The engineers then set to work to devise a command signal which would set the transistors into operation in spite of their deterioration, in the hope that they would then recover. A command decoder was irradiated in the laboratory to find out which parts of the circuit were the most sensitive to radiation. A command signal which would operate the circuit in spite of the damage was then devised.

A zero gate was found to be the most likely part of the circuit to be at fault. This is operated by a short pulse, a long pulse being used for 'ones' in the code. However, it was found in the laboratory that a long pulse with a notch in the middle would operate the zero gate of the irradiated decoder.

It was tried on Telstar and worked! New command codes were devised and as the transistors began to recover it at length proved possible to operate the switch disconnecting the batteries so that the transistors could be given a lengthy period without reverse bias. In this period they recovered so well that the circuits now respond to normal command signals.

All this breaks completely new ground in repairing electronic apparatus. In a sense the people concerned were lucky in that the fault was one which it was possible to treat from the ground. Nevertheless the success of the attempt reflects great credit on the engineers concerned.

Ultrasonic Rotator

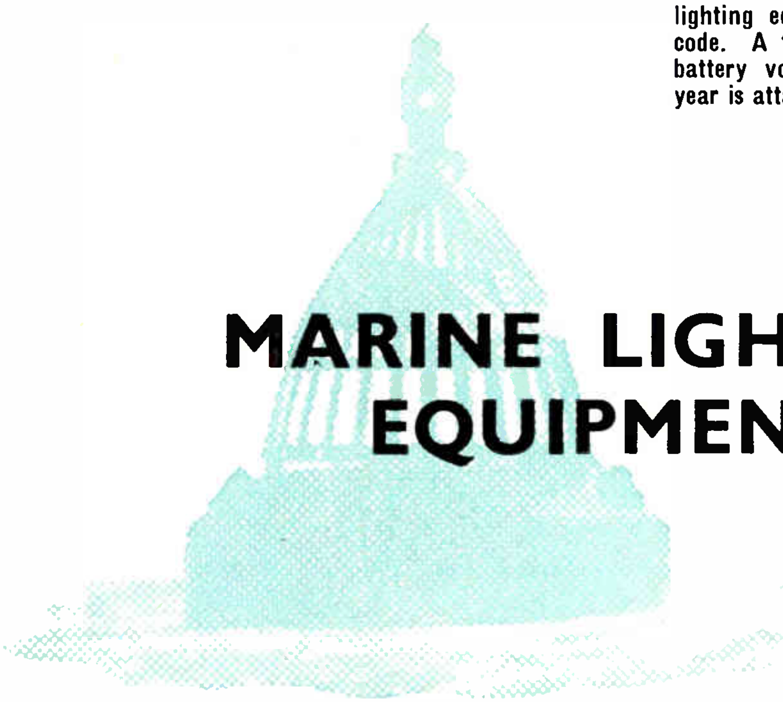
One thing which makes the electronics field so interesting is the way in which new developments keep occurring. With the enormous increase in knowledge in the last twenty years or so one might reasonably expect that we should by now be entering a period of relative calm, a period of consolidation or even of stagnation. But there are no signs of it. New things keep on cropping up and the difficulty is to keep abreast of them all.

There is now news of a device which will rotate the plane of polarization of an ultrasonic wave. It is analogous to a ferrite rotator for electromagnetic waves and as the direction of rotation is similarly independent of the direction of travel of the wave an ultrasonic isolator becomes possible. This might be very useful in ultrasonic delay lines since it would make it possible to eliminate the effects of reflections at the terminations.

Bell Laboratories have developed the device, which comprises a single crystal yttrium iron garnet in cylindrical form with a quartz disc bonded to each end. An axial d.c. magnetic field is applied. In the tests, a pulsed r.f. field was applied to one quartz plate which developed a plane-polarized ultrasonic wave pulse of 500 Mc/s. The second quartz disc, of course, is set in vibration by the wave which has travelled through the garnet and produces an electrical output; it is, of course, sensitive to the polarization of the wave. The plane of polarization of the wave propagated through the garnet is rotated by an amount which depends on the length of the garnet and upon the strength of the magnetic field applied to it.

The planes of the transmitting and receiving crystals must be at an angle to each other and then the magnetic field can be adjusted for maximum output. A wave reflected from the receiving crystal has its plane of polarization further rotated in passing back through the garnet and so excites the transmitting crystal but little.

A transistor circuit is described for the control of marine lighting equipment which must flash in a predetermined code. A feature is the low power consumption and wide battery voltage permissible. Some 15 ampere-hours per year is attained with voltages from 4·5 to 18.



MARINE LIGHTING EQUIPMENT

By W. J. MARKWICK*

BATTERY-OPERATED marine lighting equipment has been in use over the past 25 years, particularly in the U.S.A., and, in general, the primary and secondary batteries, fittings and lamps have proved very satisfactory in service. The majority of small lights, however, must be switched to a recurrent character for identification and economy of battery consumption, and experience has shown that switching mechanisms based on cam-operated contacts require more frequent attention than other components of the system. As a battery life of two years is obtainable at the present time, unattended operation for at least the same period is desirable for the character switch. This requirement in combination with the further requirement of extremely low power consumption indicates contactless switching and timing using solid-state circuits.

Several arrangements are available using various forms of bistable circuits to control a power transistor as the current switch, but the base input power required to hold a high-current transistor saturated is quite appreciable. In this respect, silicon-controlled rectifiers controlled by complementary transistor circuits have outstanding advantages, viz:—

(1) the d.c. coupled complementary bistable circuit has as its two stable states—(a) the condition where both devices are cut-off, and (b) the condition where both devices are conducting.

(2) the silicon-controlled rectifier used as a switch requires no power input to hold it in its conducting state.

Therefore, it can be seen that if the non-conducting state of the control circuit can be arranged to occur during the load-off periods, the total power consumption of the circuit can be negligible.

As the character of the light flash is an identification, a very wide range of timed switching facilities must be readily available in a standard unit, which should also be able to control any lamp size at both 6 and 12 volts. In practice, a time range from 0·15 sec to 90 sec for any event, and lamp sizes from 2 watts to 60 watts, will meet almost all needs.

* Stone-Chance Ltd.

The block diagram, Fig. 1, illustrates a system meeting these requirements, where independent control is available over the following variables:—

(1) Duration of 'load-on' periods
(2) Recurrence rate of 'load-on' periods
(3) The number of periods in a group
(4) Recurrence rate of complete group

(1), (2) and (4) are controlled by the value of a single resistor in each case, and (3) is determined by the position of a link in the circuit. These control points are brought out to the front panel of the unit, where an interchangeable plug can be used to determine the character and mode of operation of a particular installation.

The basic circuit of each of the timing elements is shown

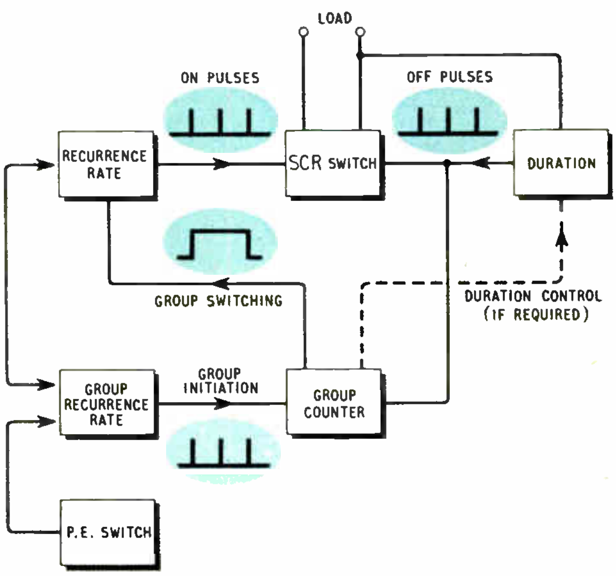


Fig. 1. Block diagram of control equipment

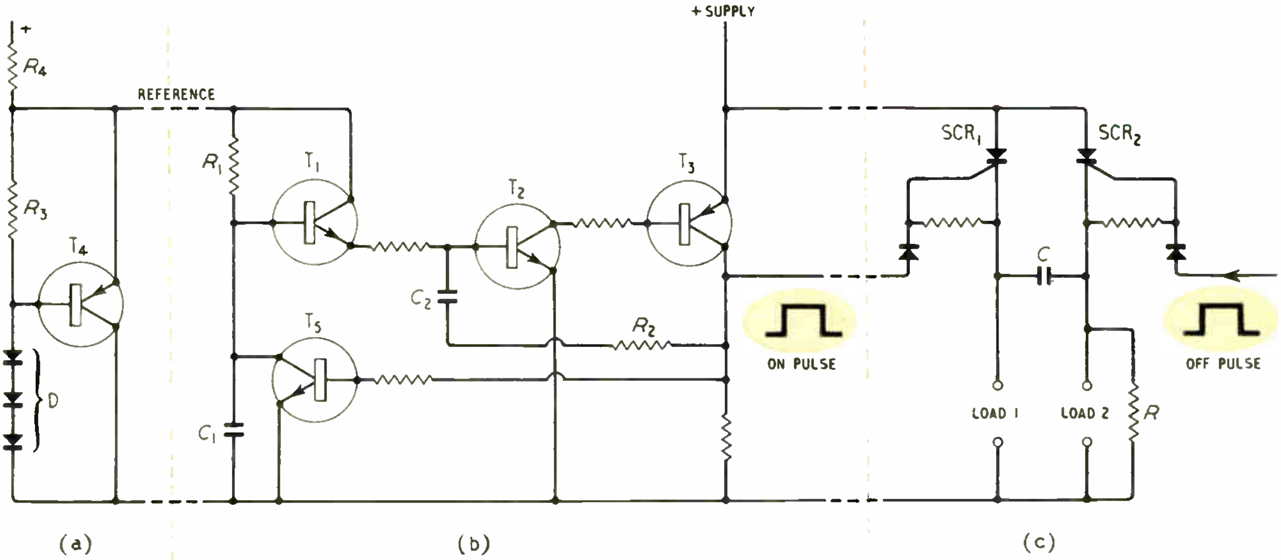
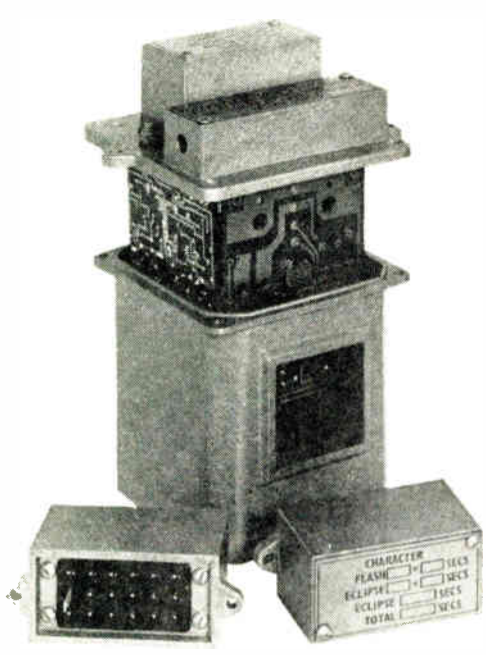


Fig. 2. Timing and switching circuit. The stabilized power supply is at (a), the timing circuit at (b) and the silicon-controlled rectifiers for load switching are at (c)

in Fig. 2(b). This is an n-p-n/p-n-p complementary-pair trigger circuit, controlled by a resistance-capacitor charging circuit R_1 C_1. The trigger circuit is normally stable with both transistors at cut-off. When the positive reference supply is applied C_1 will commence to charge and this rising positive potential is applied via the emitter-follower T_1 to the base of T_2.

At some point up the charge curve of C_1, sufficient base current will flow in T_2 to initiate regenerative action, the positive feedback for this being via R_2 and C_2 from the collector of T_3. Up to this time C_2 has been uncharged, as T_3 collector has been at supply common potential and the base of T_2 will not have been above approx. 0·5 volt. Therefore, the full supply voltage is available initially as a source to drive T_2 'on'. Immediately this occurs, C_2 will commence to charge via R_2 and the base–emitter junction of T_2; at the same instant, the main timing capacitor C_1 will be clamped by the discharge transistor to the common supply. Therefore, the holding base current of T_2 is only the charging current of C_2, and the duration of holding is determined almost entirely by the time constant C_2 R_2 of about 1 msec. Eventually, as C_2 charging current falls, T_2 will come out of saturation and immediately a reverse regenerative action takes place, as T_3 collector returns to the common supply potential. The T_2 base side of C_2 is driven negative to the emitter to the extent of the charge during the pulse. In this application, the recovery time of the circuit is of no importance, as the recurrence time is always many times longer than the pulse action.



Here the Omniflasher is partially removed from its case. Plug-in units which enable the coding to be changed are also shown

Therefore the circuit will produce at the collector of T_3, 1-msec wide pulses at a rate controlled by R_1 C_1. The emitter follower T_1 is used to enable a very wide range of control to be obtained by varying R_1 only. The output pulse available is almost the full supply voltage and as T_3 is fully saturated, it is from a source impedance approaching that of the supply. This pulse is suitable for driving the gate electrode of a silicon-controlled rectifier.

Two points of importance should be noted in this circuit:—

(1) The loop gain of T_2, T_3 is very high and the trigger current is approximately 5 μA. Therefore, the circuit can be considered to be triggered at a voltage level fixed by the base–emitter junction voltage drop, which is independent of supply voltage over wide limits.

(2) In the absence of the positive reference potential, the whole circuit is cut-off. Therefore, switching the positive reference at very low current levels can control the entire operation up to the load.

The latter feature is used to control the operation of the duration timing circuit. The reference is derived from the load circuit and timing is initiated by the switching on of the load. It is obvious that the charging time is dependent on the reference voltage, and while the free-running pulse generators have a stabilized reference (see below), in the case of the 'on' period some modification of the timing is required when the load is a filament lamp. The heating time of the filament is a function of the lamp power rating, and to obtain the same duration of light output, power must be applied for a longer period as the lamp size increases.

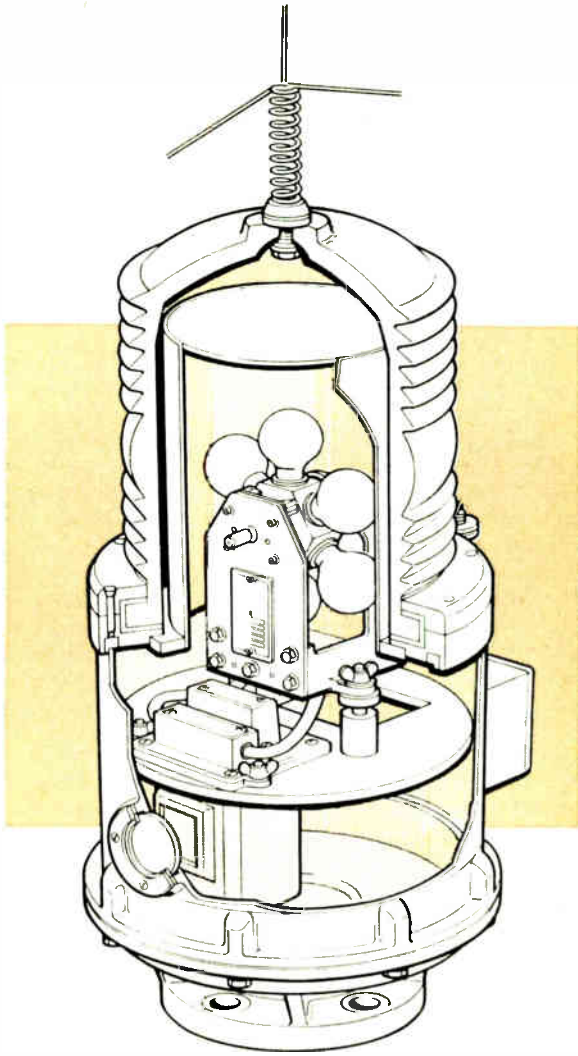
During the current surge in a cold filament the voltage across the filament is low due to the supply internal resistance and, therefore, if some part of this is used as the reference, the timed duration is extended in a manner which is dependent on filament size, but independent of the timed duration setting.

The free-running pulse generators require a stable reference voltage for the resistance-capacitance timing circuit. In order to be of the maximum use, it is necessary for this equipment to operate normally on battery supplies which may be as low as 4·5 volts. It is, therefore, necessary to use reference voltages below this and obtain stability over the range 4·5 volts to 18 volts. In practice, a reference potential of 2 volts is convenient, but difficult to obtain with devices such as Zener diodes.

The temperature coefficient of the reference potential must also be considered. As described above, the voltage level at which the trigger circuit operates depends on the base-emitter potential of a silicon transistor. This potential has the usual temperature coefficient of a silicon junction and correction is necessary to obtain high stability over a wide temperature range. This can conveniently be obtained by deriving the charging reference potential from silicon junction diodes, which have a similar temperature coefficient. This coefficient varies slightly with current through the diode and, therefore, a control of the temperature coefficient matching can be obtained by controlling the current in the reference.

A circuit to obtain the reference potential is shown in Fig. 2(a). The current in diode D is controlled by the value of R_3, and due to the negative feedback from the emitter-follower T_4 is held virtually constant over a wide range of input voltages. The current is chosen to give a temperature coefficient in the diode chain, which will correct for emitter-base voltage variation in the trigger circuit. To obtain a low source resistance for the charging circuit, the reference is taken from the emitter of T_4.

The repetitive pulse generator and the duration timing circuits are used to control an s.c.r. switch as shown in Fig. 2(c) which can be an on/off control for load 1, or a changeover of supply between loads 1 and 2. The positive pulses from the recurrence rate generator, when applied to the gate electrode



Stone-Chance Zenithal Beacon fitted with the Omniflasher and a 6-lamp exchanger unit

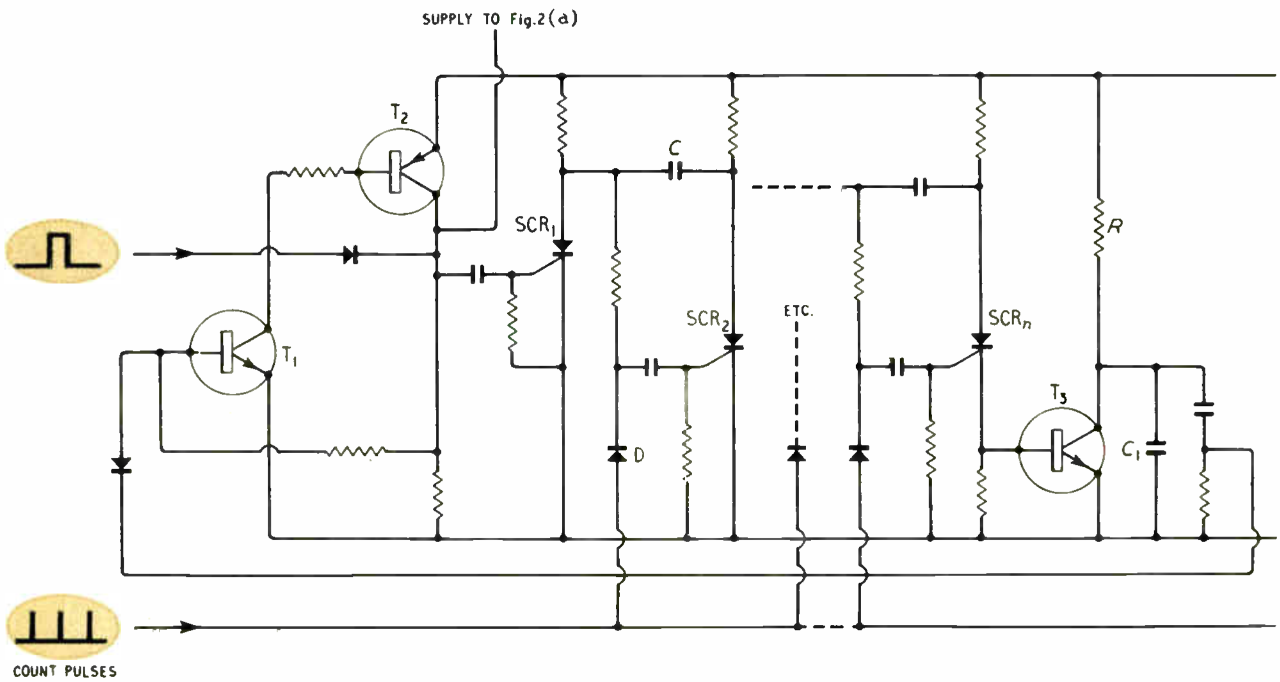


Fig. 3. Group control circuit

of SCR_1, switch the supply to load 1 and initiate the timed 'on' period. At the end of the period, a positive pulse from the duration circuit switches SCR_2 and by the commutating capacitor C, returns SCR_1 to the non-conducting state. When used as an on/off switch, SCR_2 is made self-extinguishing by a value of resistor R, which limits the current in SCR_2 to less than the hold-on value. As a change-over switch, SCR_2 controls load 2.

The foregoing circuits comprise a timed on/off mechanism where the operation can be controlled by a positive voltage applied to the input of Fig. 2. At this point the current to be switched is of the order of 1 mA and can, therefore, be switched by small-signal transistors.

This point of control is used to obtain groups of on/off signals. A free-running pulse generator of the same design is used to provide the timing of the group recurrence, but in this case the pulse is used to initiate a bistable switch of the complementary type, which provides the supply to the reference circuit. Thereupon, the recurrence circuit can operate at its preset rate, and a count of the pulses from the duration circuit ('off' signals) is used to control the time of operation of the recurrence circuit.

The circuit is shown in simplified form in Fig. 3. T_1 and T_2 form the bistable switch, n-p-n/p-n-p complementary, which is switched to its stable 'on' state by a positive pulse to the collector of T_2 and thence the base of T_1. This positive pulse, supplied by the group rate generator, also sets the counter by firing SCR_1. The anode of SCR_1 is, therefore, low in potential and, as a result, diode D on the gate of SCR_2 is near the conduction point. Then if a positive pulse is applied on the count input, the only s.c.r. that can be fired is SCR_2; i.e., count pulses are 'steered' to the next s.c.r. down the counting chain. Each in turn extinguishes the preceding s.c.r. via the commutating capacitor C. The operation continues down the chain and it should be noted that the state of the count is indicated by which s.c.r. is conducting at any instant.

The last s.c.r., n in the chain, is arranged to self-extinguish by a high anode resistor, and the output consists of a positive pulse (the discharge of the commutating capacitor) from its cathode. The pulse is inverted and lengthened by T_3, R and C_1, and used to trigger the bistable circuit back to its cut-off state. This, in turn, switches off the recurrence generator and the cycle ceases until the next initiation pulse from the group generator.

A change of count is obtained by linking SCR_1 (the 'priming' s.c.r.) to the desired count number from the end of the chain. The fact that the state of count is indicated by the s.c.r. which is conducting can be used, if necessary, to modify the operation of the duration timing circuit. The conducting s.c.r. can be considered a short circuit for practical purposes and, therefore, can be used to change time constant values in the duration timing, and obtain a change in time for any pulse in a group.

The reference voltage switching to control the operation of the entire circuit is carried further by using a photo-electric control of the single or group rate generator when this is desired. A cadmium sulphide photo-conductive cell is used in a resistance bridge where unbalance will trigger a d.c. coupled complementary pair to provide snap action switching of the reference voltage. The on/off differential is arranged to be in the region of 1 : 1·5 to avoid 'flutter' on a slowly changing light level.

The illustration shows the construction of a complete unit, which will switch loads up to 15 amps with an annual battery consumption (excluding lamp) in the region of 15 a.h. The stability of character is $\pm 3\%$ for supply voltages from 4·5 volts to 18 volts at temperatures from -20 °C to $+70$ °C.

The author wishes to thank the directors of Stone-Chance Ltd. for initiating this development and for permission to publish a general description. Some of the circuit arrangements described are the subject of a patent application, No. 33744/62. Stone-Chance is a member of the Stone-Platt Group.

New Gyroscopes

Everyone knows that the basis of a gyroscope is a spinning wheel. It comes as something of a shock, therefore, to find that it is possible to make a gyroscope which does not embody such a wheel. Strictly, of course, these new devices are not gyroscopes but ones which exhibit similar properties. The word gyroscope is, in fact, defined in terms of a spinning wheel and should thus be applied only when a wheel is involved.

One of the new devices was exhibited at the 1963 I.P.P.S. Exhibition by R.A.E. It is based on a tuning fork maintained in oscillation by an amplifier. When the fork is rotated with its base as axis, the rate of rotation causes oscillatory reaction forces to be developed by the tines. They are proportional to the Coriolis acceleration of the tines and act to form an oscillatory couple about the base of the fork.

The fork is mounted on a torsion stem having a natural frequency of torsional vibration which is the same as the frequency of the fork. The couple on the fork then drives it into torsional oscillation on the torsion stem and this is detected by transducers.

The second new 'gyroscope' is also a vibratory device. Developed by the Westinghouse Research Laboratories in the U.S.A. it comprises a hollow cylinder of a piezoelectric material such as barium titanate. It is excited electrically at high frequency and goes into radial vibration with the two ends in opposite phase; that is, one end expands radially while the other end contracts. As a result a torsional vibration appears and any motion of the cylinder about its axis is resisted by a counter torque.

It is too early to say whether either of these 'gyroscopes' will be of practical utility in replacing conventional gyroscopes. They have certain obvious advantages in their small size and absence of moving parts. This makes them superficially very attractive, but at the moment there is little information about their disadvantages, and in particular, about the magnitude of the gyroscopic effect.

With the trend towards higher speed of operation in computers, the time taken to insert information into a store, or to extract it from it, must be kept to a minimum. The tunnel diode can be used as a storage element and is the fastest operating one now available. Its use in a computer store is described in this article.

Tunnel-Diode Computer Stores

By P. M. THOMPSON,* M.A., Grad.I.E.E., M.Brit.I.R.E.

A COMPUTER or data-processing system usually consists of an arithmetic unit and several stores. The stores contain the orders which define the sequence of operations in the computer, and they also remember partial solutions until they are required again in the computation. With requirements for faster computers, in many cases to keep up with events as they happen, quicker operating stores also are required, and those which use tunnel diodes as storage elements represent the fastest which are at present available.

In addition to speed, the capacity of a store is an important parameter. However, there usually must be some compromise between speed and capacity, because both increase the cost, and also the length of the conductors required in very large stores limits the speed of operation. The usual practice is to have available limited high-speed storage capacity, and to back it up with lower speed high-capacity stores. It may eventually prove that the cost per binary digit or bit of information is less for a small store using tunnel diodes than it would be for a store using one of the conventional slower storage elements, such as magnetic cores in a two-core-per-bit system.

The bits are usually organized into words, and the information is read out, or written into the store, a word at a time. A typical complete cycle consists of 4 operations: first, addressing the required word, then reading it, writing information back in, and finally allowing all the circuits in the store time to recover their quiescent state before a new word is addressed. The cover photograph shows an engi-

* The Plessey Co. (U.K.) Ltd.

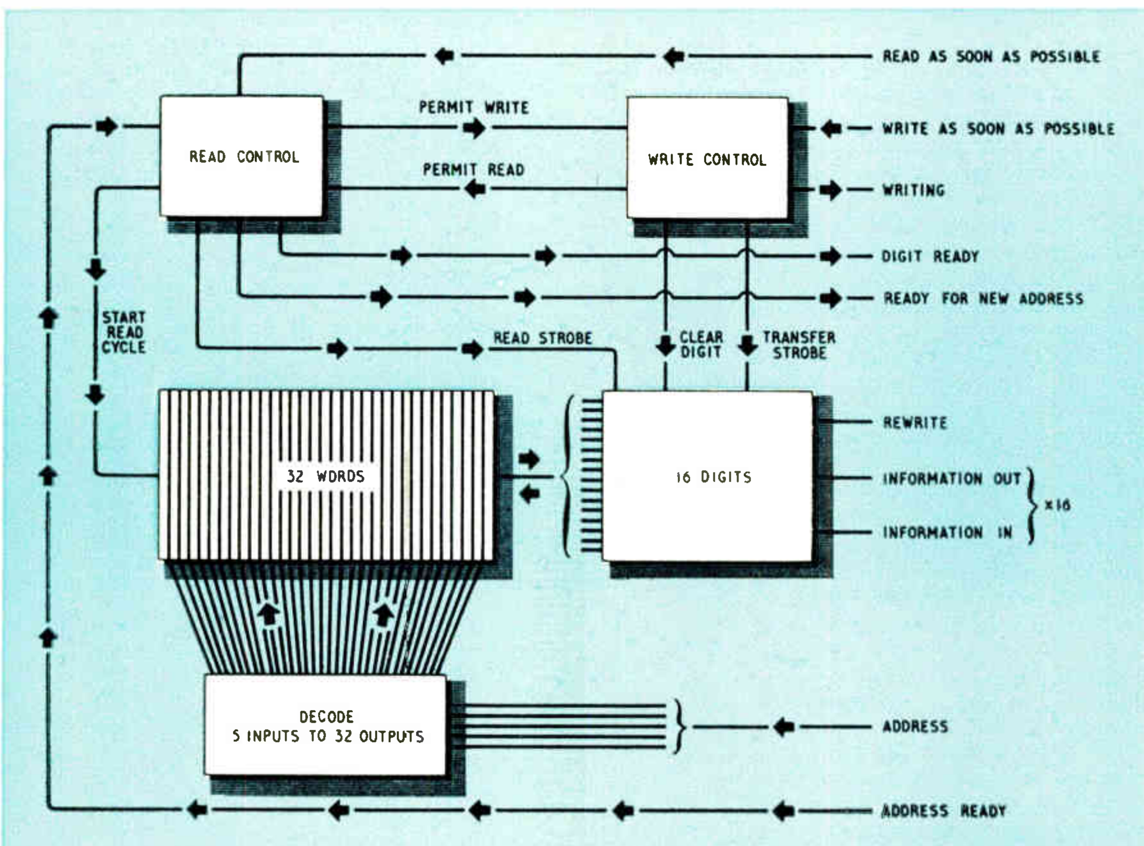


Fig. 1. Block diagram of 32-word store

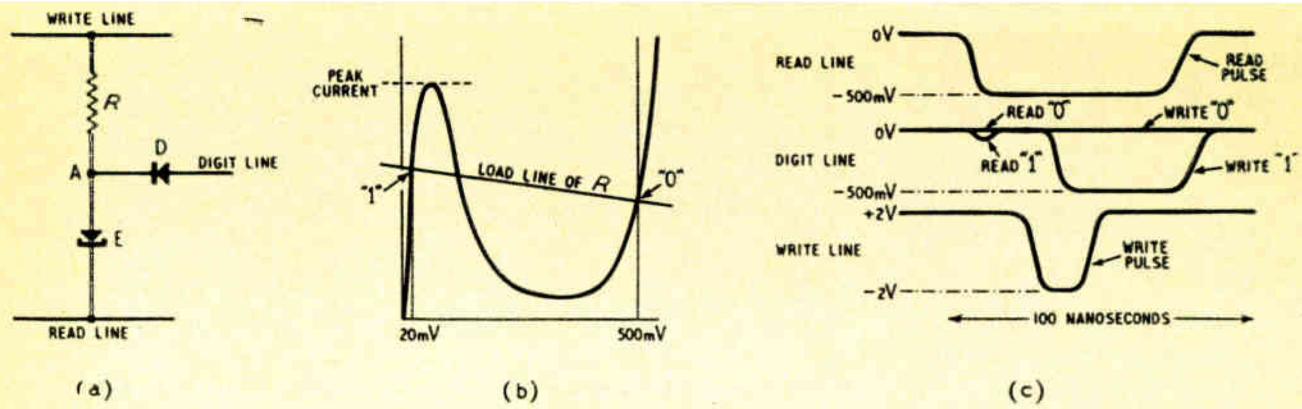


Fig. 2. Single storage element (a), tunnel-diode characteristic with load line R (b), and the drive and output waveforms (c)

neer making measurements on a recently built tunnel-diode store, the capacity of which is 32 words, each of 16 digits. The complete cycle time is less than 150 nanoseconds and it is organized in such a way that it can be connected with any computer which can match its speed.

A block diagram of this store is shown in Fig. 1. When it is provided with the address of a word (a five binary-digit code) and a confirmatory signal (address ready) the read cycle can be initiated. Then at the end of the read cycle the write cycle may be initiated. Signals are provided by the store which indicate the progress of the cycle, e.g. information ready, etc. Also, input signals can order the store to rewrite the previously stored word, or to accept new information, as required.

The Storage Element

A single storage element which stores one binary bit is shown in Fig. 2(a). It consists of a tunnel diode E, a resistor *R* to determine the bias current, and a rectifier diode D for reading and writing. The separate storage elements are connected in parallel to form words, as shown in Fig. 3, and the read–write diodes are connected to digit lines. The tunnel diodes are biased so that they have two stable states, as illustrated in Fig. 2(b), so that the high voltage state represents a '0' and the low voltage state a '1'. Now referring again to Fig. 2(a) and (c), the sequence of operation is as follows. At the beginning of a cycle the state of the tunnel diode is read by switching the read line to −500 mV. With this voltage on the read line, point A will be at approximately 0 mV for a '0' and −500 mV for a '1'. As the digit line voltage for this part of the cycle is zero, and the rectifier diode D requires about 300 mV in the forward direction to conduct, a current will flow in the digit line for a '1', and there will be no current for a '0'. This current flow will add to the bias current in the tunnel diode, and set it to the high or '0' state. Thus the tunnel diode will always be in the '0' state at the end of the read part of the cycle.

In order to write a new state into the tunnel diode, it is reset to its low voltage '1' state by reversing the bias on the write line; and this is done with the write pulse. If a '0' state is required, the potential of the digit line remains at 0 mV, and the tunnel diode is set to its high voltage state at the end of the write pulse in the same way as for reading a '1'. However, if a '1' state is required, the digit line potential is taken to −500 mV during the write pulse, so that when the bias returns no current flows in the rectifier diode. Thus the digit line performs the dual role of transmitting a pulse of current from the storage element to the read amplifier when a '1' is read, and inhibiting the conduction of the rectifier diode when a '1' is written into the element.

A complete word of 16 storage elements is constructed on standard printed wiring board and it is complete with its drive circuits. Thus the word may be addressed by energizing the appropriate 'pin' on its printed connector, and the cycle of operations will be started when it receives the appropriate pulse from the control circuits.

The Control Pulses

As the sequence of operations of the store is fairly complicated, and the cycle time less than 150 nanoseconds, the pulses which control the operations need to be fast, and their timing precisely controlled. The technique, which has been generally applied throughout the store, consists of generating fast and powerful pulses with avalanche transis-

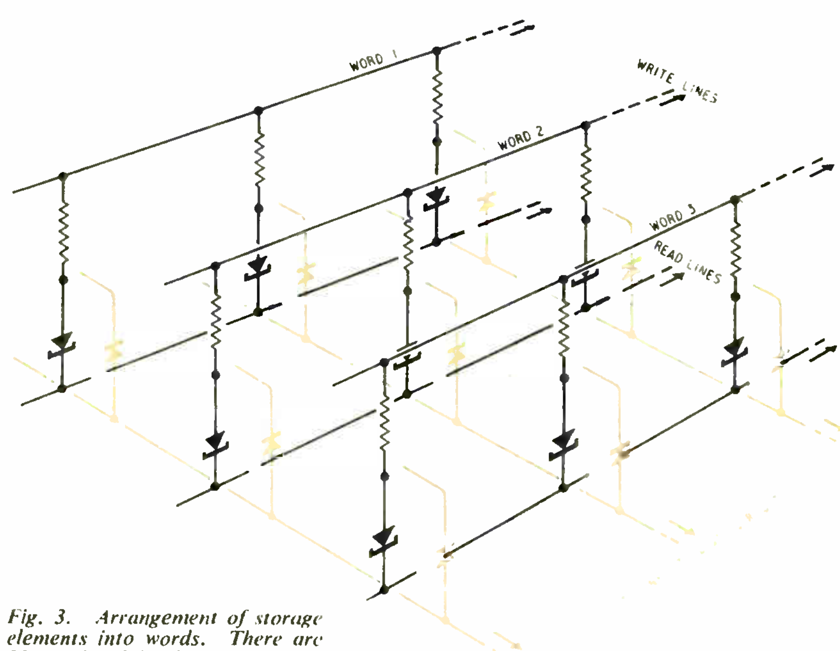


Fig. 3. Arrangement of storage elements into words. There are 32 words of 16 digits

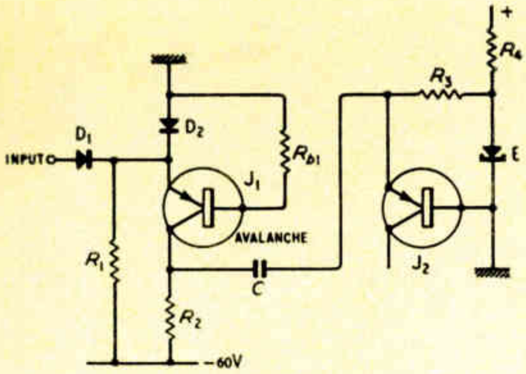


Fig. 4. Simplified circuit of read pulse generator

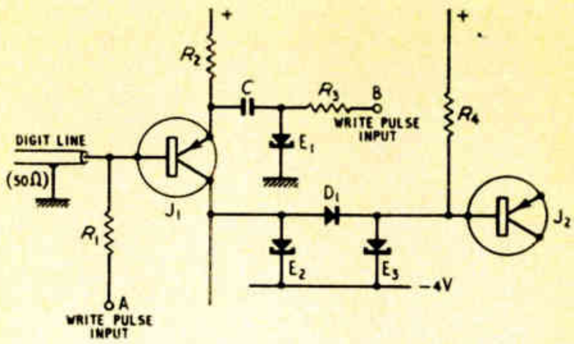


Fig. 5. Part of digit circuit

tor circuits, and shaping them with transistor circuits operating in the conventional mode, but providing little or no gain. An example of this technique is illustrated in Fig. 4, which is a simplified diagram of part of the circuit which supplies the pulse to the read line. Here transistor J_1 operates in the avalanche mode to provide a powerful pulse, transistor J_2 partially shapes the pulse, and the tunnel diode E holds J_2 in conduction until it is switched off by another circuit.

The circuit operation in detail is as follows: Transistor J_1 is a 2N711 which has an avalanche break-down of approximately 25 volts. Its emitter is held off by the forward conducting voltage of D_2, and its collector is connected through a resistor R_2 to a negative supply voltage much higher than its avalanche voltage. An avalanche current, determined by R_2, flows from base to collector, so that when the emitter is made to conduct by a positive pulse at the input, via diode D_1, J_1 switches on rapidly, and discharges capacitor C. The resultant current flows in the emitter circuit of J_2 and causes it to bottom rapidly. A portion of this current also flows in R_3 and sets tunnel diode E to the high voltage state. This in turn holds J_2 on when the avalanche pulse terminates.

The board shown in the photograph controls the timing of the various operations in a cycle. It consists of a 35-nsec delay line, which is a printed conductor running back and forth across the board, and six avalanche circuits similar to the circuit of J_1 in Fig. 4. One avalanche circuit feeds a pulse into the line, and the other 5 circuits can have their input terminals tapped into the line at any multiple of 1·5 nsec. The output pulses from these avalanche circuits are used to initiate the various operations within the cycle.

The Digit Circuits

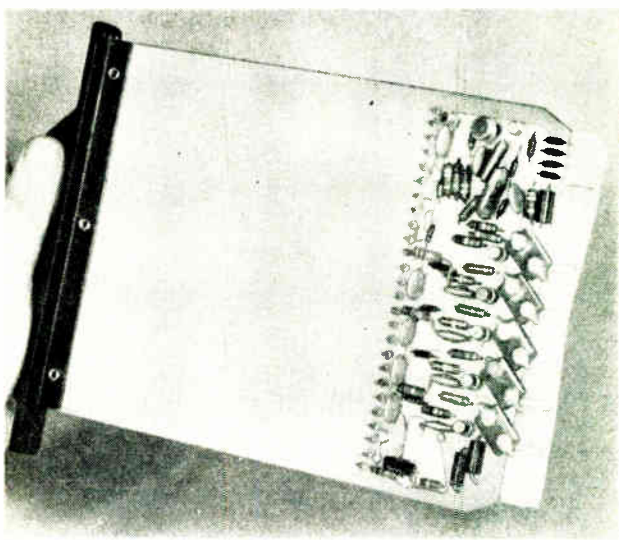
The digit lines, which transmit the read and write information between the storage elements and the digit circuit, are designed as 50-ohm transmission lines with the coupling diode capacitance forming part of the line capacitance. The read signal in the line which must be detected by the read amplifier is approximately 1 mA or 50 mV, while the amplitude of the write signal on the same line is 500 mV. Thus the read signal amplifier must be designed to recover from overload input signals rapidly, if there is to be a minimum delay between one cycle and the next.

The digit circuit, in simplified form, is shown in Fig. 5. The digit line is taken negative, to write a '1', by a negative pulse at A. This pulse is attenuated to 500 mV by the 50-ohm line impedance and R_1. The read circuit consists of transistor J_1 as the read amplifier, tunnel diode E_2 as the current discriminator, and tunnel diode E_3 as the read staticizor or flip-flop. The standing current at the collector of J_1 is determined by resistor R_2 which is decoupled by a small capacitor C. The time constant of C and the emitter of J_1 is short, about 10 nsec, and the recovery of the circuit from a write pulse is aided by a tunnel diode E_1 arranged so that the voltage across it follows the write signal at the base of J_1. The amplified read pulse appears as an increase in the collector current of J_1, and switches E_2 to the high voltage state when permitted by the read strobe pulse. Because E_2 is switched back to the low voltage state at the end of the read strobe pulse, the high voltage state of E_2 is used to set another tunnel diode E_3 to the high voltage state. Then this staticized output is transmitted to the remainder of the circuit via transistor J_2.

The Complete Store

The complete store is contained within approximately three rows of cards in a standard 19-in. rack, as seen in the cover photograph, and its speed is near the limit possible with this type of construction. The boards are constructed with printed wiring on one side and a continuous earthed screening plane on the reverse side. Also, most of the back wiring of the racks is printed with an earth plane on the reverse side of the wiring board, and all fast pulses are transmitted by printed strip lines.

The circuits employ the techniques illustrated in this article, together with conventional high-speed techniques.



Printed-circuit board from the control circuits. A 35-nsec delay line is printed on the reverse of the large empty area

The results indicate that it should be possible to decrease the cycle time to 100 nsec and increase the capacity to 1,024 words if computer designers require it. These techniques have permitted a great increase in the speed of computer stores, and although further increases may soon be possible, they must be accompanied by similar increases of the speed of the arithmetic units with which they work.

Acknowledgments

The design and construction of these stores has involved the co-operation of many people, and particular acknowledgment should go to A. J. Cole, G. B. B. Chaplin, J. C. Vickery, W. Renwick and W. J. Brisland. The author would also like to thank the directors of the Plessey Co. (U.K.) Ltd. for permission to publish this work.

MAGNETIC HARDNESS MONITOR FOR STEEL STRIP

STEEL strip from the cold-rolling mill normally has to be annealed and tempered to bring it to the required degree of hardness and ductility. In the continuous annealing line, strip speed and temperature must be accurately controlled in order to keep the final strip hardness within close limits despite variations in the properties of the ingoing strip. Such a control system obviously requires an instrument which can provide a continuous indication of hardness.

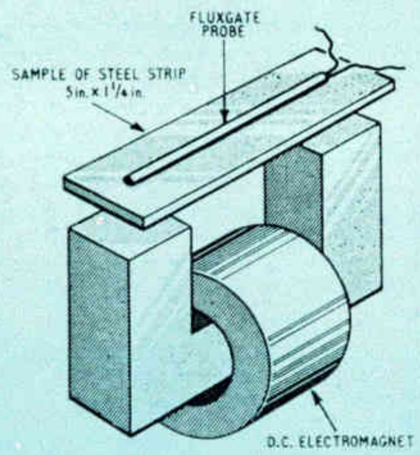


Fig. 1

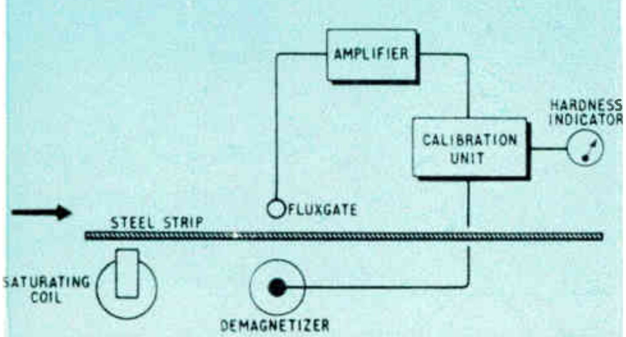


Fig. 2

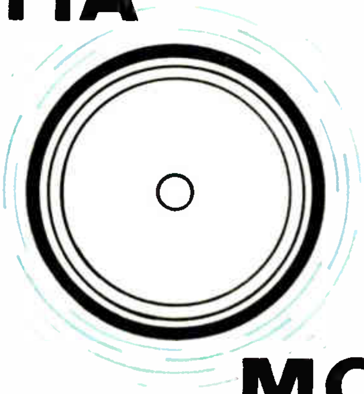
There are a number of mechanical tests from which a hardness value can be derived, but although they are suitable for use on samples, there is no practical way of adapting them for continuous on-line application. However, magnetic hardness (coercive force), which is related to mechanical hardness, can be measured on a moving strip without difficulty. The British Iron and Steel Research Association accordingly chose this as the basis for developing a hardness meter.

The first stage in the development was to construct a laboratory instrument to investigate the relationship between the magnetic and mechanical properties of various grades of steel under processing conditions. The general arrangement is as shown in Fig. 1. The sample bar is placed in the field of a d.c. electromagnet, which applies a sufficiently large flux to saturate the sample, and a fluxgate is applied to it. The fluxgate is an instrument for the detection and measurement of static (d.c.) and low-frequency a.c. magnetic fields. A typical fluxgate probe consists of two coils (with ferrite cores) mounted side-by-side and surrounded by a third coil. The inner coils are connected in series but antiphase, so that with a.c. flowing, the two alternating fields cancel each other out. When the probe is placed with its axis parallel to a d.c. field, the fields associated with the inner coils are no longer balanced and the resultant a.c. field induces in the outer coil a current which is a function of the d.c. field strength. The sample being saturated, the current is then switched off, reversed and slowly increased until the fluxgate reading falls to zero. The demagnetizing current needed to achieve this is a measure of the coercive force.

Correlation between the instrument readings obtained and the mechanical hardness was found to be satisfactory in respect of the large number of samples tested and this technique promises to be suitable for continuous process monitoring and control. Fig. 2 shows the general arrangement envisaged for on-line installation. The signal from the fluxgate is amplified and used to control the demagnetizing current so as to reduce the fluxgate signal to zero. Under these conditions the demagnetizing current, being a function of the strip hardness, can be used to provide automatic control of the annealing temperature and/or strip speed. In the diagram the demagnetizing current is merely used to give a visual indication of hardness via a suitable calibration unit.

Designed for use as an actuator in high performance servomechanisms, the Minertia motor has exceptionally rapid acceleration. With an output of 30 kW at 3,000 r.p.m. the accelerating time constant is only 5 milliseconds.

MINERTIA



MOTOR

By *TERUYUKI FUKUDA** *

UP to the present hydraulic actuators have been widely used in high performance servomechanisms when especially quick response is required. Although electrical actuators are in some ways superior because of their easier maintenance, simpler construction, lower temperature dependency and better mechanical accuracy, their slower response has made them impracticable. This has now been overcome by the 'Minertia' motor (Minimum Inertia Servomotor) which gives exceptionally quick acceleration. An all-electric automatic copying lathe using the Minertia motor has proved superior to hydraulic systems.

The secret of the Minertia motor lies in its special armature construction. It has no coil slots and the coils are

Slotless armature and commutator

secured on the armature core with epoxy resin. As a result the volume of the armature core can be reduced to less than half that of the slotted core. The reason is that the magnetic flux density in the air gap can be increased to 11,000–17,000 gauss whereas it is limited to 5,000–8,000 gauss in the slotted armature because of saturation in the teeth. The armature diameter can also be reduced to less than half of that of the slotted armature. As is well known, the armature diameter is partly restricted by the commutation capability. In the Minertia motor the coils are mounted on the surface, with the result that the self-inductance is very small. The reactive voltage per coil is thus also small, about one-tenth of that with a slotted armature, and this causes an inherent improvement in commutation. This is why the armature diameter can be reduced to less than half of that of slotted machines, while still preserving ample commutation capability against the large maximum torque.

In addition, the weight of the coils is also considerably reduced. The reduced core volume results in a shorter coil length and the excellent cooling effect of coils mounted on the surface permits the current density to be doubled.

The improved commutation capability enables the maximum short-duration current to be increased to ten times the rated continuous current. The maximum torque of the slotted motor is about 250% of the rated torque.

In accordance with such a large maximum torque the shaft diameter of the Minertia motor is twice that of conventional machines. An increase of shaft diameter in a slotted

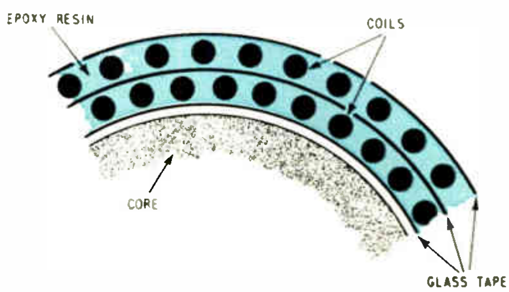
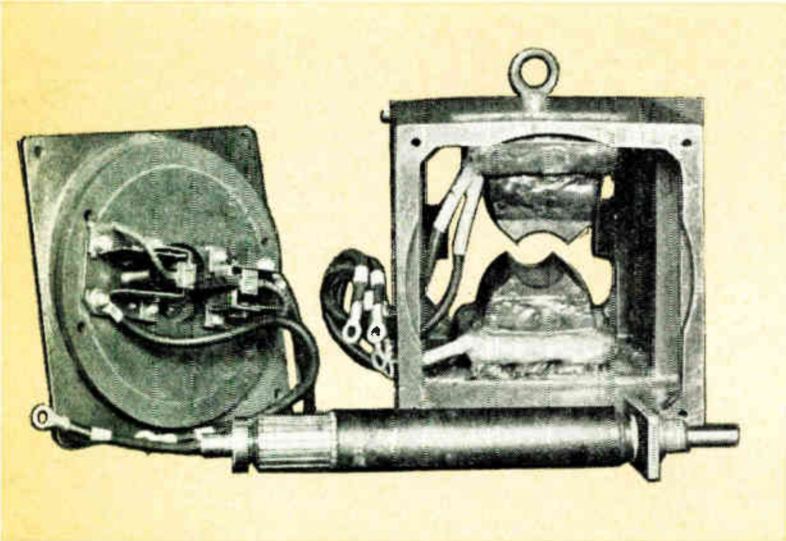
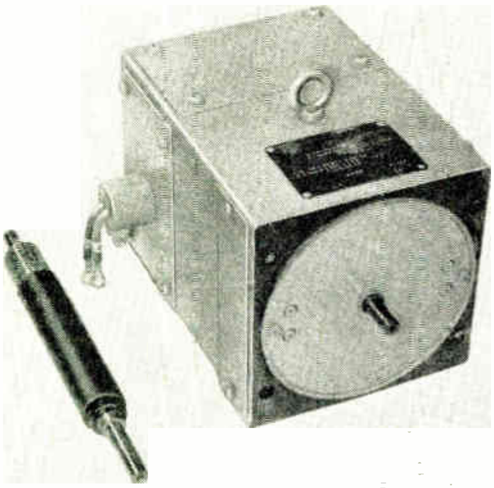


Fig. 1. This diagram shows the arrangement of the coils on the armature core

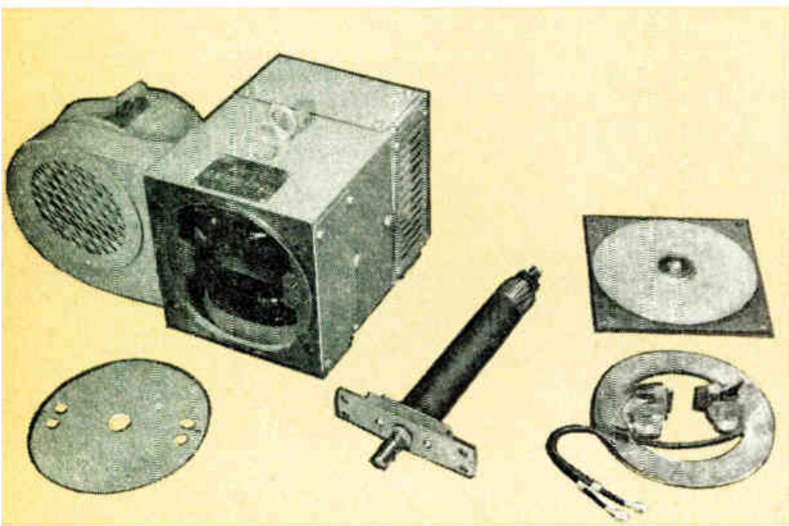
* Yaskawa Electric Mfg. Co., Ltd., Yawata, Japan.



Permanent-magnet field type motor with rotor and end-plate carrying the brushes removed



Motor completely assembled with an armature alongside



Blower cooled motor showing the construction

machine could be achieved only by making the armature diameter larger. Because of the very small mechanical time constant, it might be thought that the electrical time constant L/R would have to be taken into account. However, as the self-inductance is low and the resistance can be higher than usual (because the cooling is good), it has not proved to play an important role in the response characteristic. Because there are no slots there is no slot-ripple in the main magnetic flux. At any angle of rotation the torque is proportional to the current.

As the air gap and the magnetic flux density are large, the effect of the armature reaction is minimized. Excellent linearity is maintained even at 1,000% rated current.

Motor Characteristics

There are eight standard types of Minertia motor with rated torques ranging from 3 kg-cm to 200 kg-cm and maximum outputs (at 3,000 r.p.m.) 0·9 kW to 60 kW.

As an example, the type MM-50 SR has the following characteristics:—

Rated torque		50	kg-cm
Max. torque		500	kg-cm
Rated current		11·8	A
Terminal voltage	(at 3,000 r.p.m.)	146·5	V
Max. output	(at 3,000 r.p.m.)	15	kW
Max. speed		5,000	r.p.m.
GD^2		30·5	kg-cm^2
Mechanical time constant		4·4	msec

Motors with outputs up to more than 1,000 kW have also been developed.

Motor Construction

Apart from the method of securing the armature coils and the ratio length/diameter, the armature is of orthodox construction. First, the slotless armature is wound with glass-tape, the armature coils are placed in position, and a second layer of glass-tape is wound on. The whole assembly is then impregnated with high-polymer epoxy resin under vacuum. The coils proved to have as much mechanical strength as if they were secured in slots.

Two different field systems are employed. For small motors permanent magnets are used, but for large motors energized field windings are employed. Commutating poles have not proved necessary.

Applications

To make the best use of the Minertia motor the power supply is required to have especially quick response. In this respect silicon controlled rectifiers are the most suitable power source for driving it. The values of voltage and current of the standard types of motor are chosen so that they may readily be fed by such a source. Control equipment for the Minertia motor has been developed and consists of an s.c.r. servo-amplifier and transistorized control devices for it.

The response of a servo system using the Minertia motor can be further improved by negative feedback of the motor speed. A special tacho-generator is used for this purpose, the armature of which is a thin epoxy-resin disc with an armature circuit printed on both sides and has therefore extremely small GD^2. A control system for an automatic copying lathe so constructed proved to have a clear superiority over hydraulic systems. Its speed-error coefficient was about 250–300 sec^{-1}, whereas those of conventional hydraulic systems range from 16 to 100 sec^{-1}.

Testing of conductive materials is conveniently effected by inducing eddy currents in them. This article explains how a specimen reacts on the test coil and describes some of the apparatus which has been developed for testing purposes.

EDDY-CURRENT TESTING

By W. E. SCHALL, B.Sc., F.Inst.P.

IT is well known that when a conducting material is placed within the magnetic field of a coil carrying alternating current a current is induced in the material. The action is like that of a transformer with the material acting as a single-turn short-circuited secondary winding.

The induced current itself produces a magnetic field which opposes the primary field which produced the current. The total field is thus less when the conducting material is present than when it is absent. The smaller total field results in a reduced back e.m.f. in the coil and this is equivalent to a reduction of the impedance of this coil.

The presence or absence of the conductive material can thus be detected and, even, some of its characteristics determined, by its effect on the impedance of the coil. The method is commonly known as eddy-current testing because the currents in the conductive specimen are similar to the unwanted eddy currents which occur in transformer cores, for example.

In eddy-current testing two shapes of coil are commonly used according to the shape of the specimen. The coil may be a cylinder wound round a bar specimen as in Fig. 1 or a pancake placed on top of a plate specimen as in Fig. 2.

The test coil is characterized by its impedance which opposes the flow of current. This consists of two quantities —the ohmic resistance R and the reactance ωL where L is the inductance and ω is 2π times frequency. The impedance is given by $Z=\sqrt{(R^2+\omega^2L^2)}$ and can be represented by the hypotenuse of a right-angled triangle as in Fig. 3.

Thus a pick-up coil may have an impedance represented in Fig. 4 by P_0 when the reactance is plotted vertically and the resistance horizontally on the impedance plane. If P_0 is the impedance when there is no specimen within or below the coil, then the insertion of one will change the no-load values of ωL_0 and ωR_0 to ωL_1 and ωR_1 and the no-load value P_0 will move to P_1. The magnitude and direction of this movement will depend on two groups of characteristics:—

1. Apparatus characteristics
   (a) Frequency of alternating magnetic field
   (b) Size and shape of test coil
   (c) Distance between test coil and specimen (i.e., coupling of coil to specimen).

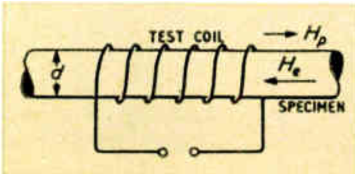


Fig. 1. Cylindrical coil in which the specimen passes through the coil. H_p is the magnetic field due to the test coil and H_e that caused by induced eddy currents

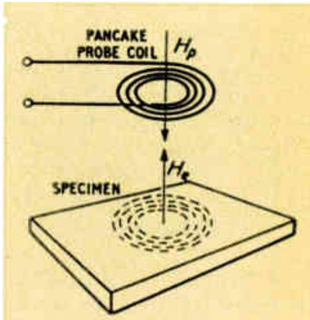


Fig. 2. Pancake coil placed against the face of a specimen. H_p and H_e have the same meanings as in Fig. 1

Fig. 3. Impedance triangle

Fig. 4. Illustrates change in impedance from P_0 to P_1 when a specimen is inserted in the coil

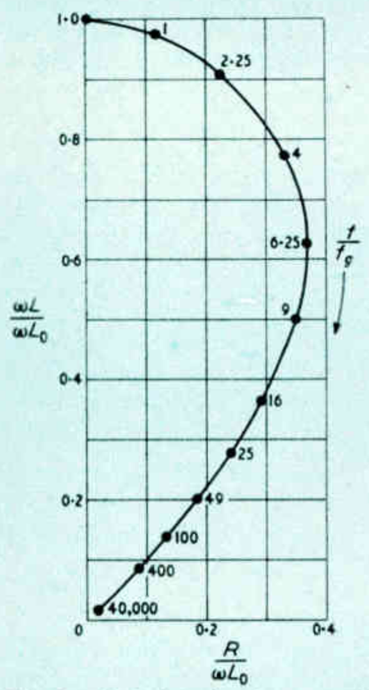


Fig. 5. Variation of resistance and reactance with frequency

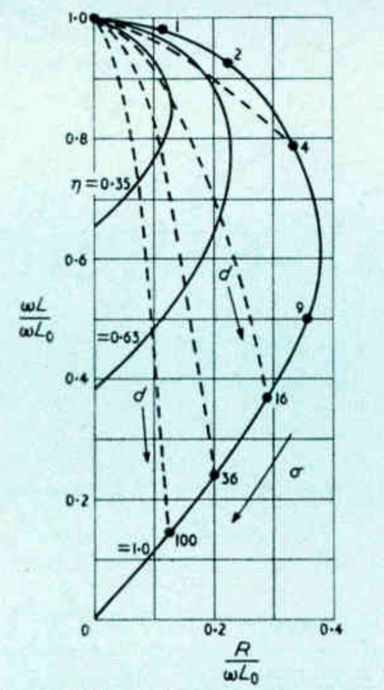


Fig. 6. Effect of varying the relative diameter of coil and specimen for non-magnetic materials

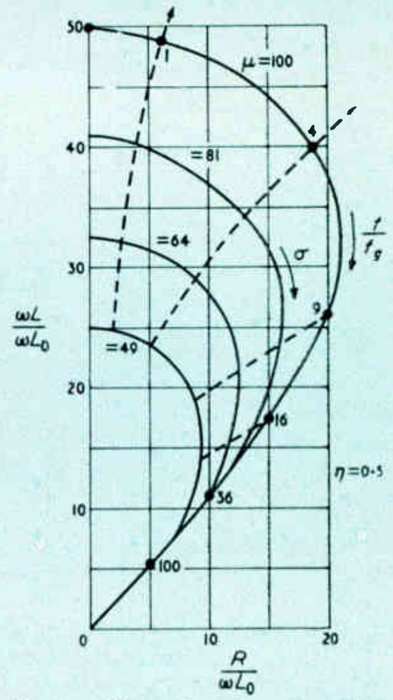


Fig. 7. Effect of varying permeability of magnetic materials

2. Specimen characteristics:—
   - (a) Electrical conductivity
   - (b) Magnetic permeability
   - (c) Dimensions (bar diameter, internal and external tube diameter, tube wall thickness, tube eccentricity)
   - (d) Presence of flaws (cracks, cavities, porosities, slag lines).

In 1879 D. E. Hughes published a paper in which he claimed that from the behaviour of eddy currents he could distinguish between metals and their alloys and observe the effects of heat, mechanical stress and similar agencies.

The matter rested there for 40 years because of lack of instruments to separate the effects of many variables which were changing simultaneously.

The effects of these specimen characteristics on test-coil impedance have been investigated during the years since the first World War by Dr. Förster and his colleagues in the Institute bearing his name. The result is shown in three sets of graphs, Figs. 5, 6 and 7.

Dr. Förster examined mathematically the behaviour of impedance in specimens of known geometrical shape, e.g., bar, cylinder, sphere, and in doing so developed the following expression:—

$$A = \frac{f\sigma\mu d^2}{5066}$$

where

f = frequency

σ = conductivity

d = diameter

μ = permeability

and A is the symbol which represents the expression in his investigation.

When $A = 1$, f is designated f_g and is called the 'limit frequency'. We then have:—

$$f_g = \frac{5066}{\sigma\mu d^2} \qquad (1)$$

If other values of frequency are used we can obtain the ratio f/f_g and plot a graph on the impedance plane showing how the value of impedance changes at constant conductivity but with the change of this ratio f/f_g. The result is shown in Fig. 5.

The formula (1) shows that f_g decreases as conductivity increases. Consequently the ratio f/f_g increases with increase in conductivity. If for a particular specimen $f/f_g = 1$ then the impedance is represented by the point marked 1 on the graph. If for another specimen the conductivity is four times as great—other things remaining equal—then the impedance will be represented by the point marked 4 and so on.

Fig. 6 shows what happens when the specimen does not completely fill the coil, when, in fact, the factor to which Dr. Förster gave the name 'fill factor' changes. It is given by d^2/D^2 where d and D are the diameters of the specimen and the coil (internal) respectively. The three curves are for fill factors η of 1·0, 0·63, 0·35 respectively.

Points can be found on all three curves where the conductivity is the same. The dotted lines therefore indicate what happens to impedance when the diameter changes but conductivity remains constant. The specimens in this case are non-magnetic and therefore their permeability is unity.

When the specimens are magnetic and permeability is greater than unity a different set of curves results. They are shown in Fig. 7. Once again the conductivity is constant while frequency changes and each graph represents a different value of permeability.

The secret of the application of these graphs to testing

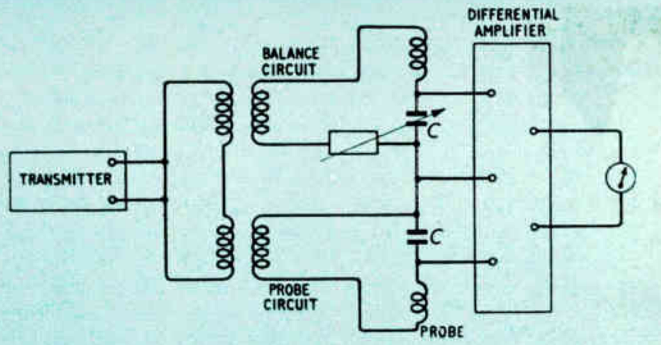


Fig. 8. Circuit diagram of conductivity meter

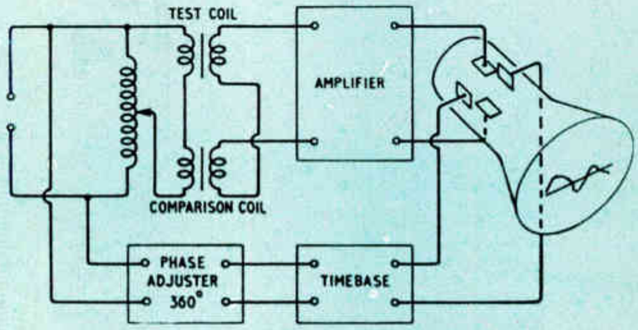


Fig. 10. Block diagram of the Magnatest Q

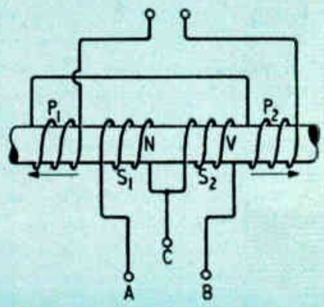


Fig. 9. Arrangement of coils in the Magnatest D

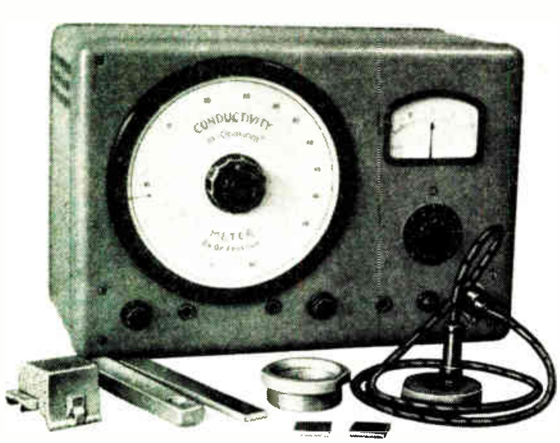
lies in the possibility of separating either diameter and conductivity variation from each other at constant permeability or else permeability and conductivity variation from each other at constant diameter.

Fig. 6 shows that at low frequency the diameter and the conductivity graphs run almost in the same direction while at high frequency they form an angle of at least 45°. It is possible, by suitable electronic circuitry, to separate the signals obtained from these two variations when a phase difference of 45° or more exists. And it is then possible to sort specimens with constant permeability and at a fixed frequency—either according to their conductivity variation or according to their diameter variation.

Fig. 7 shows how variation of permeability and conductivity at constant diameter and at a fixed frequency can be signalled independently of each other. But in this case a low frequency must be employed because the two graphs run very nearly parallel at high frequency whereas at low frequency they enclose a large angle.

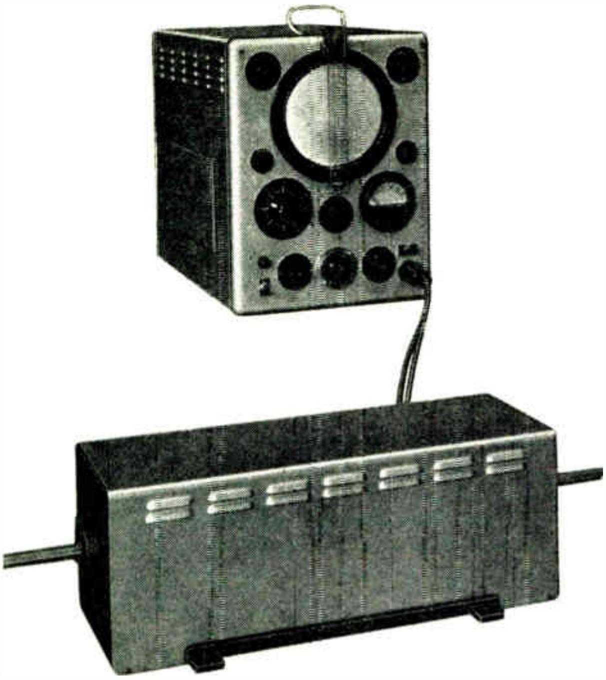
Use can also be made of the effect shown in Fig. 6 to obtain an absolute value of conductivity. The circuit shown in Fig. 8 is used. A transmitter sends current simultaneously into two resonant circuits, one of which contains the probe coil while the other contains a variable capacitor which adjusts the resonance frequency. Both circuits feed differentially into a measuring instrument. Their outputs are opposed and when they are equal the instrument reads zero. The frequency of the comparison circuit varies inversely with the capacitance and in the probe circuit it varies inversely with the conductivity. Consequently the capacitance control can be calibrated directly in units of conductivity.

Two instruments are made by Solus-Schall to do this. One is a precision type of great accuracy. When the probe



Precision conductivity meter

Battery-operated conductivity meter



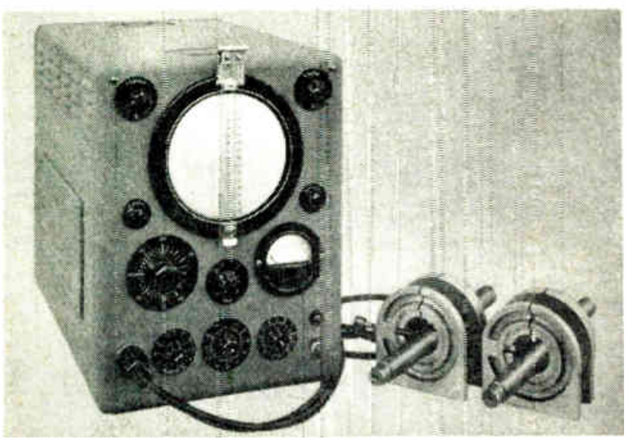
Magnatest D for examining ferrous materials

is first placed on the specimen the meter indicates a current. The large dial is rotated and this varies the capacitance in the comparison circuit until the current on the meter falls to zero. Thee conductivity of the specimen is then indicated by the reading on the large dial.

A second instrument is a smaller and less ambitious edition of the previous one, but suitable for a great majority of the purposes for which conductivity has to be measured.

One great advantage of this simpler instrument is that it does not require mains supply current. Two torch batteries provide sufficient power.

Two other apparatus have been designed as a result of the graphs of Figs. 5, 6 and 7. One of these, the Magnatest D, records cracks or damage and variation in diameter in bar, wire or tube material. The other apparatus, the Magnatest Q, compares the specimen with a standard loop and records variations in the magnetization loop showing variations in conductivity in the specimen and therefore variations in alloy composition, hardness, heat treatment, etc.



Magnatest Q for quality comparison tests. The specimen is compared with a known standard

Fig. 9 shows the circuit of the Magnatest D. Two coils P_1 and P_2 in the same circuit magnetize the specimen. Two pick-up coils S_1 and S_2 are energized in opposition by this magnetic field. A bar specimen when pushed through the coil system, and if it is quite sound, will energize S_1 and S_2 equally. They are in opposition and therefore a voltmeter across AB will not record. But if a longitudinal crack in the specimen reaches S_1 and not S_2 a differential voltage appears across AB. When the crack is within both S_1 and S_2 and of uniform depth the voltmeter again will not read. And finally when with movement of the specimen the crack leaves S_1 and is present under S_2 above, the voltmeter AB again reads but in the opposite direction.

Reference once more to the graphs in Fig. 5, 6 and 7 shows that non-ferrous specimens (i.e., those with permeability=1) must be tested at high frequency if diameter and conductivity variation are to enclose an angle of at least 45°. But for ferrous materials where permeability is much greater than 1 the frequency must be low to satisfy the same condition of angle.

The Magnatest D is therefore arranged to operate at relatively low frequency for the examination of ferrous material. An exactly similar apparatus—the Conductiflux—works at high frequency to examine non-ferrous material where permeability is unity.

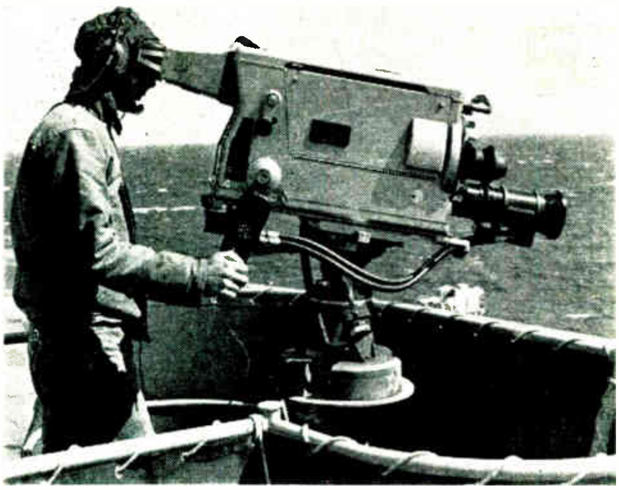
The Magnatest Q apparatus is for quality comparison. Fig. 10 shows the circuit in which a comparison coil and a test coil are connected in opposition. The standard with which all specimens are to be compared is placed in the comparison coil. The specimens can then be placed in succession in the test coil. When they have exactly the same characteristics as the standard the trace on the cathode-ray tube is a horizontal straight line. When they differ, the trace is a curve above or below the line. By means of a phase adjuster the curve can be moved horizontally to right or left whereby a particular section can be brought to the centre. Specimens will produce a 'spread of curves'. Those which fall within the spread are acceptable and others which are above or below are rejected.

ELECTRONIC CLOCK

This picture shows one of two versions of what is claimed to be the first completely electronic clock to be produced by a watch manufacturer, Solvil and Titus of Geneva.

The clock, named Soltronic, contains no moving parts. It can be operated from an a.c. or d.c. supply and the basic control frequency source can be a crystal-controlled oscillator or a signal from a known standard such as that from an observatory. The accuracy will be that of the frequency standard used. Slave time-display units can be driven from the basic clock.

For further information circle 50 on Service Card



(Left) A U.S. Navy cameraman on a platform seven storeys above the carrier flight deck 'zooms in' to photograph a jet aircraft after it has passed over the fixed deck cameras. (Above) a Jet pilot watches the landing he made only minutes before on the television monitor. Rapid replay is made possible by a television tape recording system

For further information circle 51 on Service Card

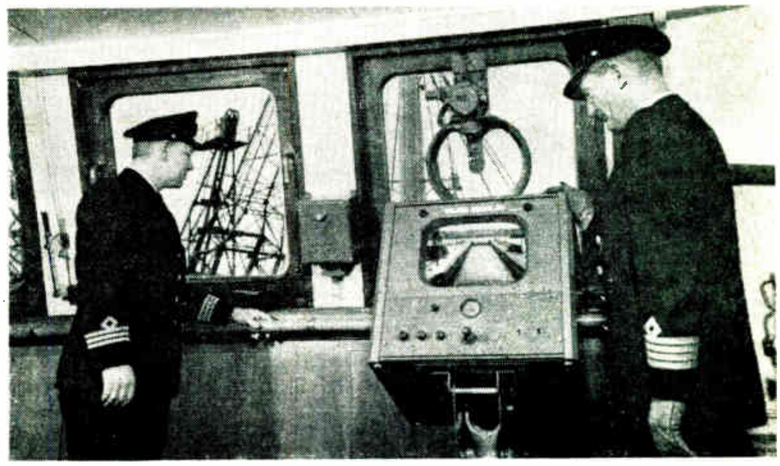
APPLICATIONS ILLUSTRATED

Closed-Circuit Television

Although closed - circuit television systems have been commercially available for a number of years it is only recently that these systems have been accepted and are now being used quite extensively throughout industry. Railways are using them for passing information from signal boxes to stations and for marshalling yards. Banks are using them for remotely viewing documents, and other organizations for the inspection of normally inaccessible places and for viewing dangerous processes.

Illustrated here are three unusual examples of the application of closed-circuit television.

Two of the pictures show part of one of ten new installations of the Ampex/Marconi Pilot Landing Aid Television (PLAT) systems on board United States aircraft carriers. The PLAT system is a multi-channel television and sound monitoring and recording facility designed to improve the proficiency of pilots and landing control personnel. Four Marconi television cameras are used in the system —three $4\frac{1}{2}$-in. image orthicon cameras and one miniature vidicon camera. The other two pictures show the use of closed-circuit television on an oil tanker and at an airfield.



As a preliminary to the installation of Rank closed-circuit television in the Olsen Line's new 80,000 ton deadweight supertanker now being built, it has been tried on the Norwegian mailboat Braemar. This has cameras mounted on the stem and the stern and connected to a monitoring set in the wheelhouse. It provides officers on the bridge with close-ups of the situation fore and aft as the mailboat is manoeuvred in and out of its berths

For further information circle 52 on Service Card

In order to observe display screens airfield radar rooms are kept in darkness. This means that while the radar operators can 'see' aircraft in flight they cannot ascertain whether the runways are clear. This problem has been solved at R.A.E., Farnborough, by the installation of an E.M.I. closed-circuit television system.

A remotely-controlled camera is mounted on the roof of the air traffic control tower where it has an uninterrupted view of the complete airfield

For further information circle 53 on Service Card

EQUIPMENT review

1. Fire-Detecting Computer

MADEWEL Products Ltd. have announced a completely new type of fire-detecting computer. Designed to serve a chain of power stations over a wide area, it will give warning of up to 250 simultaneous fires. The makers claim that it will pin-point potential trouble spots such as smouldering cigarettes and overheated bearings. In the case of a warning, a light is switched on over the name of the department concerned. Cost of the computer: £2,500. — *Madewel Products Ltd., Urmston, Lancs.*

For further information circle 1 on Service Card

2. Thermostatic Soldering Iron

THE CARDROSS Engineering Co. have introduced a range of thermostatically-controlled soldering irons which will heat quickly and maintain a preset temperature to within ±10 °C. In normal use the thermostat operates twice per min, but when soldering is carried out very rapidly it switches off for a longer period in each cycle due to the heating capacity held in reserve.

As the iron is never allowed to heat beyond the temperature required, oxidation and alloying of the bit is considerably reduced. Another advantage is that it can be left switched on indefinitely without overheating when required to be ready for immediate use.

The 50-W miniature iron illustrated weighs $1\frac{3}{4}$ oz, takes 20 sec to heat and is available with bits of $\frac{3}{32}$ in., $\frac{1}{16}$ in. or $\frac{3}{16}$ in. The $4\frac{1}{4}$ oz 70 W model has an $\frac{11}{16}$ in. bit and is available if required with a magnetically-stabilized contact breaker instead of a microswitch to minimize electrical interference. These 'Vari-stat' irons can be supplied to suit most a.c. and d.c. mains voltages.—*Cardross Engineering Co. Ltd., Levenford Works, Woodyard Road, Dumbarton, Scotland.*

For further information circle 2 on Service Card

3. Controlling Ratemeter for Vacuum Evaporation

G. V. PLANER have recently introduced their Controlling Ratemeter Type CEB1 designed to monitor and control the deposition rate of both metals and non-metals in vacuum coating systems which incorporate electron beam heating. The makers state that it is particularly suitable for use with their electron beam Evaporating Source EB1 and associated power units.

The CEB1 has two main functions: first, it allows control of the deposition rate and hence, in many cases, the properties of the deposit; secondly, it ensures reproducibility of film thickness in production. Deposition rates can be controlled over a range of approximately 0·1 to 30 μgm/cm²/sec (as determined with a substrate positioned 8 cm from the evaporation crucible) with an accuracy of around ±1·5%. Reproducibility can be maintained to approximately ±2%.

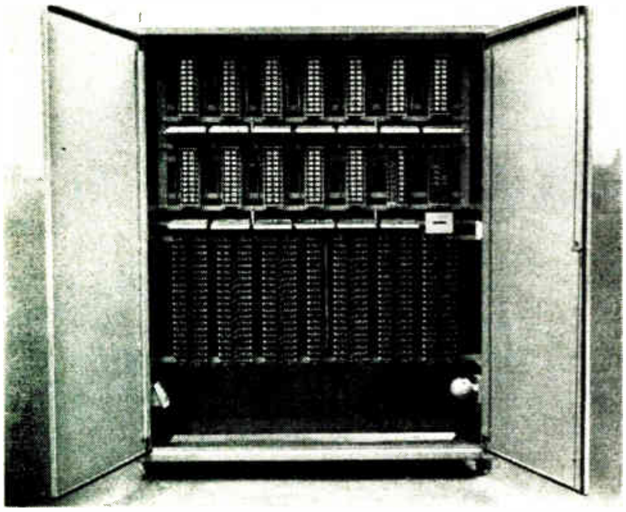
The principle of operation is based on the determination of ionized material in the vapour stream: an ion collector head attached to the vaporizing source is connected by a vacuum-sealed electrode to a differential current amplifier which supplies the indicating controller. This, in turn, is connected by a servo loop to control the emitter supply of the electron beam power unit.—*G. V. Planer Ltd., Windmill Road, Sunbury-on-Thames, Middlesex.*

For further information circle 3 on Service Card

4. Wide-Band Spectrum Analyser

LIVINGSTON Laboratories are marketing a new spectrum analyser, the Panoramic SPA-10, having seven frequency ranges covering 10 Mc/s to 43 Gc/s with maximum sensitivities of −105 dBm for the 10 to 680 Mc/s range and −50 dBm for the 26·5 to 43 Gc/s range. The frequency scale calibrations are accurate to ±1% or ±1 Mc/s, whichever is the greater.

For input frequencies of up to



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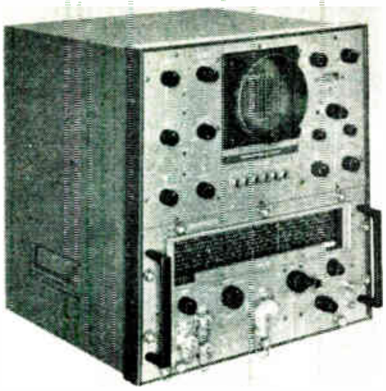

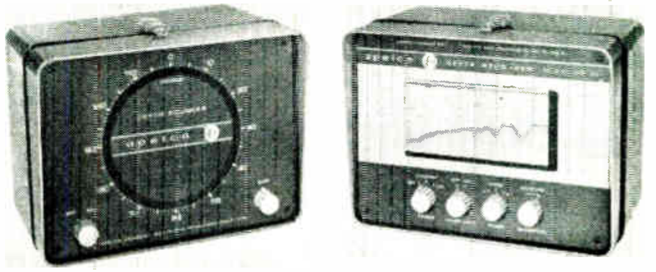

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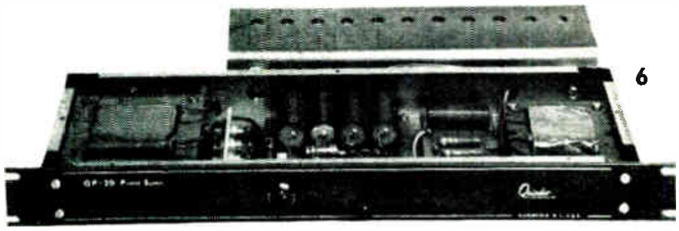

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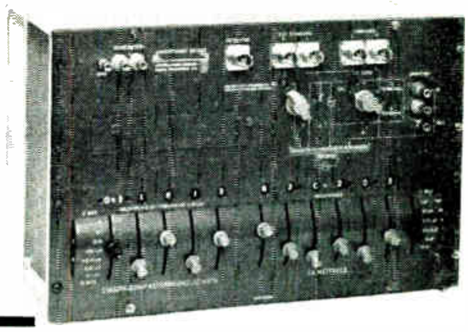

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100 Mc/s, sweep width is variable between 200 kc/s and 5 Mc/s; for inputs between 100 Mc/s and 43 Gc/s, sweep width is variable from 200 kc/s to 80 Mc/s. Sweep repetition rate is continuously variable from 1 to 50 c/s.

Linear 40 dB logarithmic or square-law amplitude characteristics can be selected by means of a switch. Provision is made for sweep width calibration. Crystal controlled markers accurate to 0·01% are available as an optional extra for checks at 1, 10 and 100 Mc/s intervals over the entire r.f. tuning range. — *Livingston Laboratories Ltd., 31 Camden Road, London N.W.1.*

For further information circle 4 on Service Card

5. Marine Depth Sounder and Recorder

THESE TWO robust instruments from Apelco are suitable for both private and commercial use.

The MS-600 Depth Sounder will indicate up to 120 fathoms and over. The barium titanate transducer is housed in a bronze casting and mounted through a single hole in the vessel's hull. An input of 3 A at 12 V d.c. or 1 A at 32 V d.c. is required. The sounding rate is 180 pulses per min at an operating frequency of 125 kc/s. Accuracy is ±5%. A glare-free ring on the indicator allows readings to be made in direct sunlight without difficulty.

The MR-601 Depth Recorder employs the same transducer as the MS-600 but operates at 83 pulses per min to give a trace showing river- or sea-bed contour and density, and the presence of fish. The information is presented on a moving roll chart calibrated to 100 fathoms. Chart speed is 24 in./hr. Input required: 12 or 32 V d.c. Accuracy: ±5%.—*Ad. Auriema Ltd., 414 Chiswick High Road, London W.4.*

For further information circle 5 on Service Card

6. Solid-State Power Supply

A SOLID-STATE power supply unit only 1¾ in. high, for standard 19 in. rack mounting, has been developed by Quindar Electronics Inc. Output is 2·5 A at 12 V d.c. over a temperature range from −30 °C to +60 °C. Maximum noise level is 20 mV.—*Quindar Electronics Inc., 5 Lawrence Street, Bloomfield, N.J., U.S.A.*

For further information circle 6 on Service Card

7. Capacitance Bridge

ONE OF the unique features of the Type 1615-A capacitance bridge recently announced by General Radio is that balance is effected not by rotary controls but by a set of fingertip control levers. In-line digital readout with digits, decimal point and units all indicated automatically, minimizes the possibility of reading error.

The overall range of the instrument is from 10 μpF to 1 μF with six-figure resolution and an accuracy of ±0·01% direct reading. Frequency range is approximately 50 c/s to 10 kc/s. Dissipation factor range is 10^{-6}:1 at 1 kc/s.

The bridge can be used to measure two- and three-terminal capacitors, the latter even in the presence of large capacitances to ground. It is thus suitable for in-place measurements. Dimensions are 19 by 10½ by 12¼ in.—*Claude Lyons Ltd., Valley Works, Hoddesdon, Herts.*

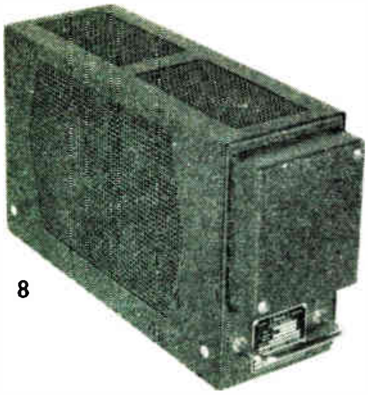
For further information circle 7 on Service Card

8. Static Inverter

PLESSEY have announced the second in a new series of static inverters intended as a replacement for conventional rotary inverters in aircraft and for general applications in industry.

With a rating of 700 VA, the unit inverts a 28 V d.c. supply to produce a single phase 400-c/s output (±5%) over an ambient temperature range from −40 °C to +70 °C. Input voltage is 23·5 to 28·5 V d.c. normal and 18 to 31·5 V d.c. extremes. Continuous output rating is 700 VA at +55 °C or 500 VA at +70 °C. The preset output voltage is 35, 49 or 60 V a.c. r.m.s. ±10%, with a harmonic content of less than 4% at half load.

This solid state inverter, which measures 14 by 4½ by 7⅝ in., will



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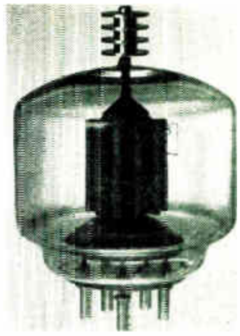
EQUIPMENT review



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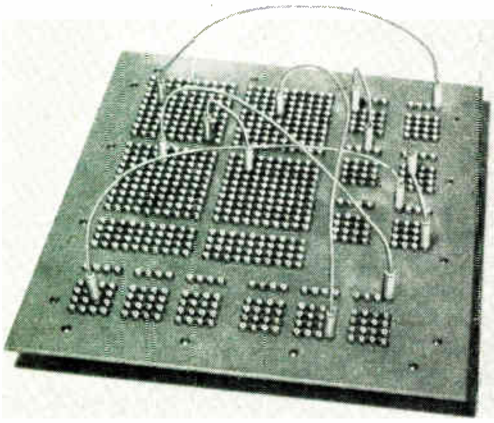

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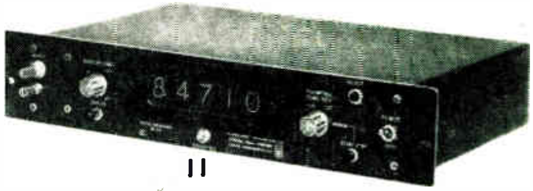

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tolerate input transients of up to 120 V and polarity reversals, and will supply short duration overloads up to 150% of full load (above this value a protection circuit comes into operation).—*Aircraft Equipment Group, The Plessey Co. (U.K.) Ltd., Ilford, Essex.*

For further information circle 8 on Service Card

9. Two-Pole Corded Patchboard

SEALECTRO HAVE introduced a two-pole jack-socket mountable on a ¼-in. matrix for building up corded type patch panels using coaxial wireable plugs and either twin lead or screened single lead patching.

These two-pole points can also be incorporated in bussed socket Sealectoboards. — *Sealectro Corporation, Hersham Factory Estate, Walton-on-Thames, Surrey.*

For further information circle 9 on Service Card

10. Zero Bias Transmitting Triodes

EITEL-McCULLOUGH are manufacturing a new range of triodes with characteristics that make them particularly suitable for linear amplifier s.s.b. applications. They have been designed to give optimum performance with zero grid bias. Power gain is over 20 and intermodulation products are better than 35 dB below p.e.p. level.

Six types are available: three with glass envelopes rated at 400 W (illustrated), 1 kW and 3 kW; three with ceramic envelopes rated at 1 kW, 10 kW and 20 kW.—*Walmore Electronics Ltd., 11-15 Betterton Street, Drury Lane, London, W.C.2.*

For further information circle 10 on Service Card

11. Digital Frequency Meter

GENERAL RADIO have announced a new compact Digital Frequency Meter, the Type 1150-A. This transistorized 5-digit unit with a frequency range from 10 c/s to 220 kc/s can also be used for general counting purposes.

The counter can be started, stopped and reset either manually or by external signals, and the display time is adjustable from 0·1 to 5 sec, or can be infinity.

The timebase is provided by an oven-controlled 100-kc/s oscillator with a stability of ½ part in 10^6. Temperature stability over the range 0 °C to 50 °C is better than 5 parts in 10^6. Sensitivity is better than 1 V peak-to-peak.

Layout is simple and all components are easily accessible. Dimensions: 19 by 3½ by 12¼ in. Price: £352 10s.—*Claude Lyons Ltd., Valley Works, Hoddesdon, Herts.*

For further information circle 11 on Service Card

12. Three Colour Indicator Lamp

A NEW addition to the Thorn range of indicator lampholders is a unit in which three lamps, each with a coloured filter, shine through a single lens. This unit is only slightly larger than a single lampholder and thus provides three indicating functions in a very small space. The red, green and amber filters are fitted inside the body of the lampholder and, naturally, only one indicator can be used at a time.

Installation in a $\frac{19}{32}$ in. panel mounting hole is by means of a locking nut and fixing ring. The indicators are supplied complete with three Atlas S6/8 filament lamps which are available in 4, 6, 12 and 28 V. Overall length: 2·230 in. Diameter: 0·812 in. —*Thorn Electrical Industries Ltd. (Special Products Division), Great Cambridge Road, Enfield, Middlesex.*

For further information circle 12 on Service Card

13. Low Voltage Regulated Power Supply

BRANDENBURG LTD. have recently introduced a relatively inexpensive regulated power supply for low voltage requirements which will provide a variable output from 6 to 25 V at 250 mA.

Output ripple is less than 1 mV and the effective resistance is 0·1 Ω. Up to four units may be connected in series and, if required, two units may be connected back-to-back to give −19 V through zero to +19 V. Input: 200/250 V, 50 c/s. Dimensions: 6$\frac{5}{8}$ by 4$\frac{3}{8}$ by 7 in. Price of the type ST.1 'Stabpak' is 18 gns ex works.—*Brandenburg Ltd., 139 Sanderstead Road, South Croydon, Surrey.*

For further information circle 13 on Service Card

14. Instrument Control Knob

BULGIN HAVE introduced a sunken finger-grip indicating control knob for use with their range of legended escutcheons. Made of glossy black bakelite, it has been designed to give minimum projection from the panel. In applications where there is no main chassis upon which to mount components, a miniature sub-chassis or rear-mounting plate can be supplied.

Front of panel projection (with escutcheon): $\frac{7}{16}$ in. high by 1$\frac{7}{8}$ in. diameter. Fixing details: one centre hole 0·720 in. and two 6 B.A. clearance at 1 in. centres.—*A. F. Bulgin & Co. Ltd., Bye Pass Road, Barking, Essex.*

For further information circle 14 on Service Card

15. Standing Wave Amplifier

GENERAL Microwave Corporation's Model 351 Standing Wave Amplifier is a direct-reading instrument designed to be used with waveguide coaxial slotted lines for the measurement of voltage standing-wave ratio and also for attenuation measurement.

Four v.s.w.r. scales cover the range 1 to 15 and a fifth provides an expanded scale from 1 to 1·3. There is one attenuation scale from 0 to 10 dB and an expanded scale from 0 to 2·3 dB. Re-zeroing is not required when switching between normal and expanded scales.

A special circuit protects the bolometers from burnout when the instrument is switched on and off. Bolometer current can be checked by means of a switch and the calibrations provided on the meter.—*Sylvan Ginsbury Ltd., 8 West 40th Street, New York, N.Y., U.S.A.*

For further information circle 15 on Service Card

16. Coaxial 6-Way Switch

THE WAYNE KERR Probe Switch JB 731 is designed to provide coaxial switching with fully maintained screening and allows selection of any one of six double-screened inputs.

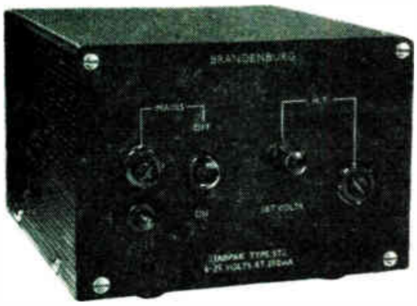
This unit has a six-position selector switch on the front panel and, on the back, six Screenector sockets (Belling Lee L764CS), a coaxial lead associated with the switch rotor mechanism, and a separate earth terminal. Dimensions: 8½ in. by 4½ in. by 6 in.—*Wayne Kerr Laboratories Ltd., New Malden, Surrey.*

For further information circle 16 on Service Card

17. Travelling Wave Tube and Mount

E.E.V. have developed a new travelling wave tube with an associated periodic permanent-magnet focusing mount.

The N1038 tube has a working



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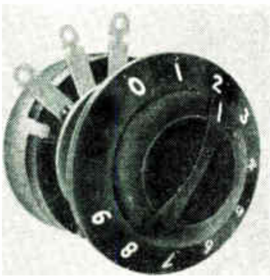

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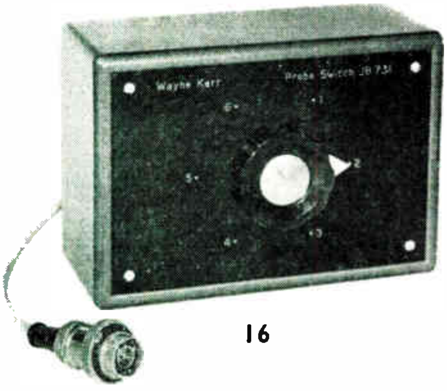

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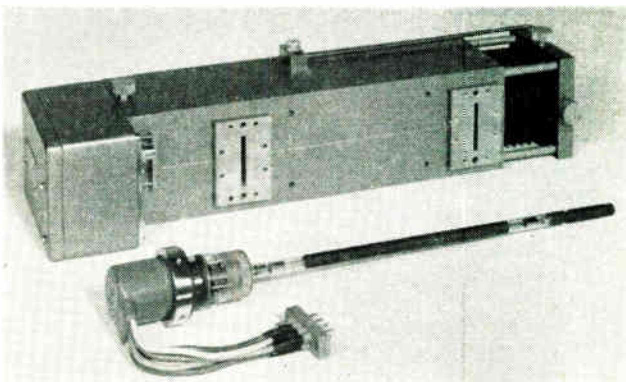

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power output of 5 W (8 W saturated) and a gain of 43 dB over the range 7·0 to 7·8 Gc/s. The useful frequency range may be extended up to 8·5 Gc/s with slightly reduced power ratings.

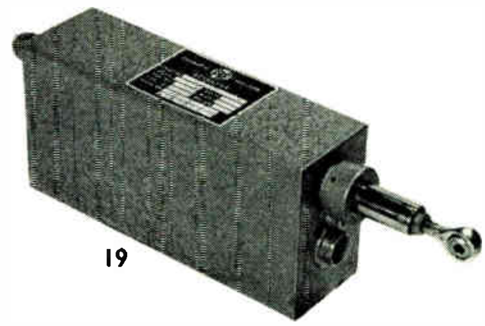
The mount, type N4051, gives a matching better than 1·5:1 over any 500 Mc/s band within the given frequency ranges. This comparatively light and compact unit is cooled by natural air convection. — *English Electric Valve Co. Ltd., Chelmsford, Essex.*

For further information circle 17 on Service Card

18

EQUIPMENT

review



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18. K-Band Isolator

E. & M. LABORATORIES are marketing a new wide-band isolator, the Model K110L1, covering the full K-band frequency range from 18·0 to 26·5 Gc/s. Minimum isolation is 25 dB, insertion loss below 1·0 dB, and v.s.w.r. less than 1·15.

Advanced resonance-absorption techniques have been employed in the design of this isolator to enable it to function effectively in a magnetic field, e.g. in the vicinity of a magnetron, and also to keep the input and output flanges in line.

Overall length is 4·5 in., height 2·7 in. and depth 2 in. Weight: 28 oz. —*Sylvan Ginsbury Ltd., 8 West 40th Street, New York 18, N.Y., U.S.A.*

For further information circle 18 on Service Card

19. Linear Actuator

A ROBUST linear actuator suitable for industrial applications is now available from Pye.

A 28 V d.c. split-field series-wound motor provides the power, and transmission is through a gear train to a lead screw and ram. To reduce overrun to a minimum the motor incorporates an electromagnetic brake with a duty rating of 2 min.

The stroke is adjustable between [illegible] in. and 5 in. Normal working load is 400 lb with a ram speed of 0·2 in./sec on full load. Dimensions: $8\frac{1}{4}$ by $4\frac{1}{4}$ by $2\frac{1}{4}$ in. Weight: 6 lb.—*Engineering Division, Pye Ltd., Cambridge.*

For further information circle 19 on Service Card

20. Unbreakable 2-Way Terminal Block

A TWO-WAY version of the Belling Lee flexible terminal block is now on the market. The terminals are fully shrouded against accidental contact and the captive terminal screws will neither work loose under vibration nor fall out when fully unscrewed. The ends are shaped so as to minimize the possibility of severing fine conductors.

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Rated at 250 V, 5 A a.c./d.c., the L.1579 connector block complies with the safety requirements of B.S.415 and is intended for three-hole fixing with No. 4 or 6 BA screws.—*Belling & Lee Ltd., Great Cambridge Road, Enfield, Middlesex.*

For further information circle 20 on Service Card

21. Transistor Tester

THE HICKOK Model 1885, itself completely transistorized, will measure beta and leakage with an accuracy of ±3%, and can be used to carry out comprehensive tests on most medium and high power semiconductor devices.

A pulse technique is employed for beta measurement: pulse width is continuously variable from 0·1 to 1·66 msec with a constant p.r.f. of 60 c/s. Collector voltage is continuously variable from 0 to 100 V with 50 A maximum current; base voltage is continuously variable from 0 to 10 V with 5 A maximum current.

Data for beta and leakage tests on more than 1,550 transistors are listed on the built-in roll chart, a revised version of which can be supplied by subscription every six months.—*Hickok Export Division, Dept. 6262, EMEC Inc., 127 Grace Street, Plainview, L.I., New York, U.S.A.*

For further information circle 21 on Service Card

22. Servo Driven D.C. Voltmeter

THE Houston Instrument Corporation have recently introduced the Model HV-160 potentiometric d.c. servo voltmeter. The input impedance of this instrument is over 1,000 MΩ on ranges from 3 mV to 1 V and 10 MΩ on ranges from 3 to 300 V. Servo gain is automatically adjusted for each scale by the range switch. Accuracy is 0·15% on eleven scales and ±6 μV on the 3 mV ranges.

The HV-160 incorporates a double zener regulated reference voltage and

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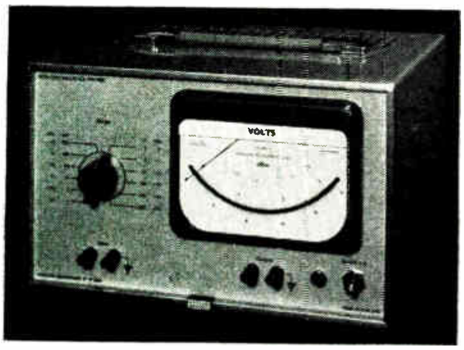

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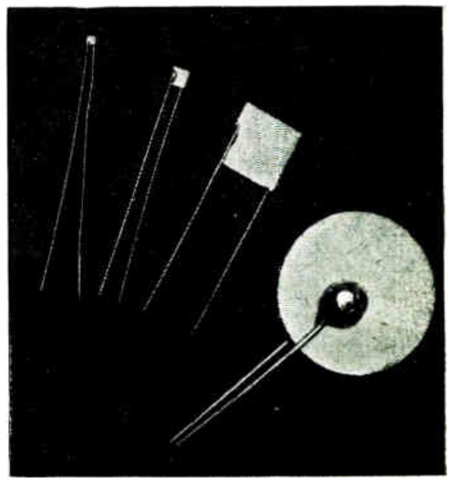

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indication is by means of a knife-edge pointer on a 14 in. mirror scale. Low current measurements can be made by using suitable shunts: on the lowest scale, a 1 MΩ shunt will provide a current sensitivity of 10^{-11} A.—*Scientific Furnishings Ltd., Poynton, Cheshire.*

For further information circle 22 on Service Card

23. Valve Voltmeter

MARCONI have announced a new wide range valve voltmeter, Type TF 2600, which will measure from less than 0·1 mV to 300 V in twelve ranges. The frequency range is 10 c/s to 5 Mc/s with a useful response up to 10 Mc/s. Maximum accuracy of 1% f.s.d. is from 50 c/s to 500 kc/s.

The 5-in. meter is calibrated in terms of the r.m.s. value of a sinewave, but as it responds to the average value, good accuracy is maintained with moderately distorted waveforms. A scale is also provided in dB relative to 1 mW in 600 Ω. A large negative feedback factor ensures high stability of meter indication and the input resistance of 10 MΩ causes negligible loading of the circuit under test.

In addition to applications such as frequency response determination and amplifier gain measurement, the TF 2600 is also suitable for use as a pre-amplifier and as a balance detector for a.c. bridges.—*Marconi Instruments Ltd., St. Albans, Herts.*

For further information circle 23 on Service Card

24. Mercury Elapsed Time Indicator

TRANSIPACK have developed an electro-chemical timing device called the Mercron, in which mercury is employed as the timing element.

There are no moving parts: when current flows through the electro-chemical cell, mercury in the reservoir is transferred to an ⅛-in. wide measuring tube, the amount deposited being proportional to the timing period. Alongside the tube there is a clearly marked linear scale which is illuminated by a neon lamp when timing is in progress.

The Mercron will indicate accumulated hours of operation of any a.c. or d.c. equipment when connected in parallel with the power supply. Standard versions can be used with any voltage between 6 and 500 V, and frequencies from 50 c/s to 800 c/s, over a temperature range of −35 °C to +71 °C. Current consumption is less than 5 mA.

The unit is housed in a robust metal tube 5¼ in. long and 1⅛ in. in diameter. and weighs 5 oz. Standard scales are 1,000 and 10,000 hr. The Type 201/A has to be returned to the manufacturers for resetting to zero. With the Type 201/B, when the total timing period is reached the unit is simply turned upside-down and the reading automatically resets to zero. This model, of course, is suitable only for static mounting where there is no possibility of accidental inversion.—*Transipack Electronic Engineers, 29 Burnt Ash Hill, London S.E.12.*

For further information circle 24 on Service Card

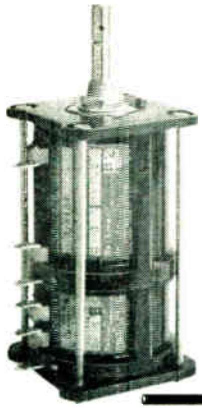
25. Wafer Thermistors

GULTON have announced a comprehensive range of directly-heated wafer thermistors which can be specified for operating temperatures up to 150 °C. The main application of these devices is in temperature measurement and control.

The wafers are made from large sheets which are cut to size to obtain a given resistance. Tolerance is determined solely by the accuracy of cutting, since the properties of the ceramic material can be controlled within precise limits during the wet-mixing of the constituents.

Materials are available with temperature coefficients in the range ▶

EQUIPMENT review



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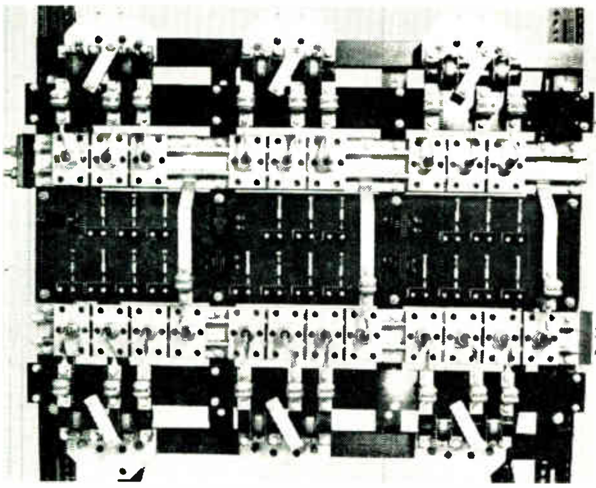

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−3·4% to −6·8% from which thermistors with resistance values between 2 Ω and 1,000 Ω can be made. Standard tolerance on resistance is ±10%, but ±1% is available if required.

All the wafers are made from standard 0·012 in. thick sheet and their dimensions normally vary from 0·060 to 0·410 in square. They can be supplied with axial or radial leads or without leads.—*Gulton Industries (Britain) Ltd., 52 Regent Street, Brighton 1, Sussex.*

For further information circle 25 on Service Card

26. 2-Gang Potentiometers

BECKMAN INSTRUMENTS are producing a series of special potentiometers for use where coaxial dials are required. Each unit is made up of two standard Helipot potentiometers mounted in line with concentric shafts and a ¼-in. diameter collar pinned to the end of the central shaft to equalize the diameters.

The illustration shows a unit consisting of a 3-turn Model C Helipot mounted at the rear of a 10-turn Model A Helipot. This installation provides much finer resolution than a single-turn unit of the same diameter while occupying only 3¾ in. behind the panel.—*Beckman Instruments Ltd., Queensway, Glenrothes, Fife, Scotland.*

For further information circle 26 on Service Card

27. Avo Transistorised Multimeter

A RECENT development in the range of Avo electronic test equipment is the transistorized multimeter with facilities for measuring the low a.c. and d.c. voltages encountered in transistor circuitry.

The instrument is designed around a chopper amplifier with a full-scale sensitivity of 10 mV. D.C. and a.c. (r.m.s.) voltage and current are each measured in eleven ranges, from 12 mV to 1·2 kV f.s.d. and from 12 μA to 1·2 A respectively. The alternating current ranges and the 12-mV a.c. voltage range are suitable for frequencies of 40 c/s to 2 kc/s; the rest of the a.c. voltage ranges can be used up to 20 kc/s. Using an external probe, r.f. (20 kc/s to 1 Gc/s) voltages from 40 mV to 4 V f.s.d. can be measured in 5 ranges. Eight resistance ranges cover 0·1 Ω to 120 MΩ.

A standardizing facility is provided to enable low d.c. voltage ranges to be set up with a high degree of accuracy and there is centre zero operation on all d.c. voltage measurements. Provision is made for checking the battery supply voltage.—*Avo Ltd., Avocet House, 92/96 Vauxhall Bridge Road, London S.W.1.*

For further information circle 27 on Service Card

28. Liquid Cooled Silicon Rectifiers

INTERNATIONAL Rectifiers have developed a liquid cooled heat sink for use with silicon power diodes type 70U. Unlike conventional liquid cooling systems, the type Z is a single diode heat sink which can be used in any circuit configuration with any number of parallel paths.

When used with a single type 70U silicon power diode carrying 250 A, a water flow of 2 gal/min is sufficient to hold the diode base temperature rise at 50 °C.

The new heat sink, which measures 4 by 2¾ by 1 in., is designed for mounting on standard ½ in. copper pipe. The unit illustrated is a rectifier assembly rated at 1,640 A. — *International Rectifier Co., Hurst Green, Oxted, Surrey.*

For further information circle 28 on Service Card

29. Audio Sweep Oscillator

THE Dawe Type 443 is an RC tuned oscillator covering a frequency range from 20 c/s to 20 kc/s in a single dial sweep. Distortion is less than 1%, including hum and spurious signals, and the output is continuously variable up to 100 mW into 600 Ω, balanced or unbalanced, at a constant amplitude.

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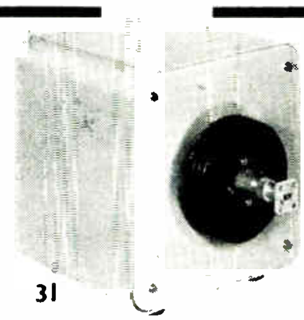
The shaft of the tuning capacitor, which extends from the back of the instrument for coupling to a level recorder, is fully rotatable thus eliminating any need to uncouple the drive while recording.

The charactertistics of the Type 443 make it particularly suitable for use in determining the frequency response of audio amplifiers, tape recorders, loudspeakers, etc.

Dimensions: 8½ by 12¼ by 13 in. Weight: 35 lb. The price is £130 and delivery is from stock.—*Dawe Instruments Ltd., Western Avenue, Acton, London W.3.*

For further information circle 29 on Service Card



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30. Extra Telephone Earpiece

THE S.T.C. Watch Receiver is an earpiece which allows a second person to listen in on a single telephone, for example a secretary wishing to take notes or make a shorthand record of a conversation. Alternatively the user can hold the extra receiver to his other ear in order to exclude unwanted noise.

This unit has full G.P.O. approval and is available in several colours. It employs a sensitive 'rocking armature' receiver to give clear reception and good volume. When not in use the Watch Receiver is disconnected by means of a switch and hangs from a specially fitted hook on the telephone set.—*Standard Telephones and Cables Ltd., Connaught House, 63 Aldwych, London W.C.2.*

For further information circle 30 on Service Card

31. Q-Band Oscillator

SIEMENS AND HALSKE of West Germany are manufacturing a backward-wave oscillator, voltage tunable over the range 26·5 to 42 Gc/s, with an average power output of 40 mW and a minimum power output of 10 mW.

The RWO 40 is intended for use with waveguide transmission systems, short range radars, microwave spectroscopy, etc. The tube and magnet form a single compact unit weighing just under 17 lb. — *Walmore Electronics Ltd., 11-15 Betterton Street, Drury Lane, London W.C.2.*

For further information circle 31 on Service Card

32. 10-Amp Miniature Relay

THE latest addition to the N.S.F./Union range of miniature, hermetically sealed relays has a 10-A rating and provides a 4-pole changeover.

Known as the 'H' type, this unit is the same size as the 1- and 2-A versions and will operate over a temperature range from −65 °C to +125 °C. Accelerations of 70 *g* in three mutually perpendicular planes, 30 *g* vibration up to 2 kc/s, and shocks in excess of 50 *g* can be tolerated without loss of performance. The minimum working life is 10^5 operations at maximum rated load.

This relay is offered in two main styles: one for flange mounting fitted with spade type terminal lugs, the other a plug-in unit with gold-plated terminal pins and mating socket. Coils available cater for mains supplies from 16 to 200 V d.c.—*N.S.F. Ltd., 31-32 Alfred Place, London W.C.1.*

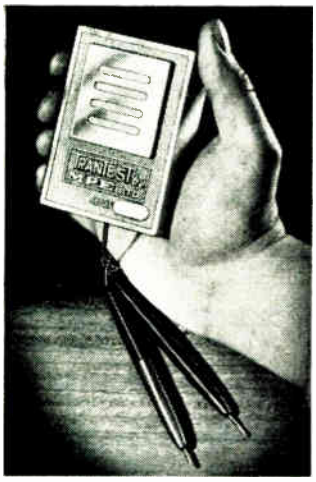
For further information circle 32 on Service Card

33. Miniature Continuity Tester

MEASURING only 2½ by 3⅝ by ⅞ in. and weighing 7 oz without its PP3 battery, the M.P.E. 'Trantest' gives an audible indication of continuity with a response which can be adjusted by means of a sliding control to suit the resistance between the probes.

This instrument will not cause damage to semiconductor devices. In

EQUIPMENT review



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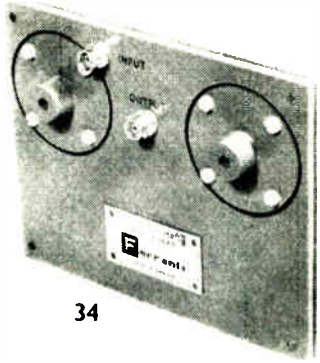

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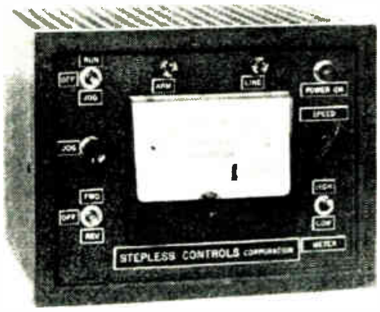

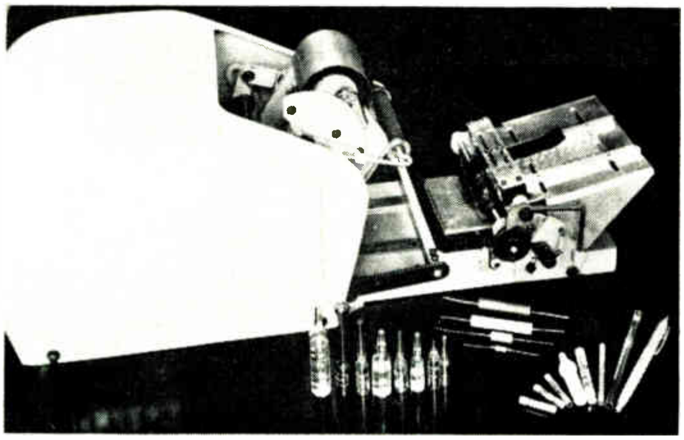

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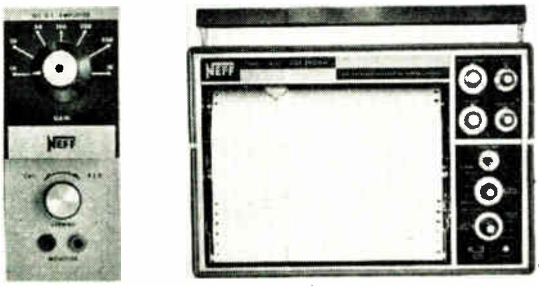

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addition to detecting 'dry joints' and similar faults it can be used for testing the effectiveness of anodized plating, etc. It will not indicate continuity through inductive or capacitive impedances. Price: £4 10s.—*M.P.E. (Finchley) Ltd., Dollis Park, Finchley, London N.3.*

For further information circle 33 on Service Card

34. Printed-Circuit Diode Multipliers

FERRANTI have announced the Series VC2/S variable-capacitance diode multipliers designed primarily for use with strip-line circuitry. These compact and robust printed-circuit units have high conversion efficiency and good reproducibility. The diode element has dimensions of the same order as the thickness of the board on which the circuit is etched.

The type of transmission line employed is a conductor above a ground plane with a Perspex sheet covering to prevent radiation from the circuit.

The characteristics of a typical unit are as follows: input frequency, 315 Mc/s; input power, 4 to 5 W; maximum efficiency, 60%; bandwidth, 25 Mc/s; dimensions, 4 by 5 by $\frac{1}{2}$ in.

Delivery time for multipliers with input frequencies up to 800 Mc/s is approximately three months.—*Ferranti Ltd., Hollinwood, Lancs.*

For further information circle 34 on Service Card

35. D.C. Motor Controller

THE 'SPEEDPROP' solid-state d.c. motor controller announced by Stepless Controls can be used with motors up to $\frac{1}{4}$ h.p. It will maintain a given speed within less than 0·5% under all conditions of motor load over a speed range of 100:1, allowing up to 10% variation in supply voltage.

A tacho-generator provides both feedback and a signal to operate the indicator on the control panel. There is full overload protection. Installation is straightforward and the manufacturer states that the unit will operate over a period of years without maintenance.—*Stepless Controls Corporation, Bear Hill, Waltham 54, Massachusetts, U.S.A.*

For further information circle 35 on Service Card

36. Automatic Printing of Cylindrical Articles

REJAFIX have developed an automatic attachment for their Devon 10 offset printing machine which enables it to handle cylindrical articles from

$\frac{3}{16}$ in. to 1 in. in diameter, e.g. small electronic components, ampoules, pens, etc.

The output is up to 1,500 articles per hour and the available printing area 3 in. by $2\frac{3}{8}$ in. The machine is controlled by a foot switch regulator, leaving the operator's hands free to feed the articles into the chute. Legible (reverse) type or blocks are used and a wide range of inks can be supplied. —*Rejafix Ltd., Harlequin Avenue, Great West Road, Brentford, Middlesex.*

For further information circle 36 on Service Card

37. Amplifier and Recorder

TWO Neff instruments now in production are intended primarily for use in strain gauge systems.

The Type 105 Wideband Amplifier is fully transistorized and has a built-in power unit. The gain control features seven steps from 10 to 1,000 with a vernier giving $2\frac{1}{2}$ to 1 adjustment at any setting. Drift over 100 hr is less than ± 1 μV r.m.s. referred to input. Noise, measured over 50 kc/s bandwidth, is less than 5 μV r.m.s. referred to input.

The Type 401 Recorder employs a heated-ink technique to give a very fine trace: ink in solid form is introduced into a reservoir where it is melted and drawn by capillary action to the paper surface. A range of chart speeds is available and the recorder uses standard untreated paper. The electrical range is 5 mV to 200 V full scale. Sensitivity is ± 5 μV and linearity $\pm 0{\cdot}1\%$.—*Ad. Auriema Ltd., 414 Chiswick High Road, London W.4.*

For further information circle 37 on Service Card

38. Transistorized Universal Bridge

MARCONI have announced a compact Universal Bridge, Type TF2700, which uses transistors and printed-circuit boards throughout and has a basic measurement accuracy of $\pm 1\%$.

Overall ranges are as follows: inductance from 0·2 μH to 110 H in eight ranges, capacitance from 0·5 pF to 1,100 μF in eight ranges, and resistance from 10 mΩ to 11 MΩ also in eight ranges. Q indication is from 0 to 10 at 1 kc/s and D indication from 0 to 0·1 or 0 to 10 at 1 kc/s.

The internal power supply is a 9-V battery and the normal current drain approximately 7 mA. Weight: $8\frac{1}{2}$ lb.

If the instrument is required to perform functions beyond the passive measurement of isolated components, the appropriate external circuits can conveniently be connected via the terminals provided.—*Marconi Instruments Ltd., St. Albans, Herts.*

For further information circle 38 on Service Card

39. 'Press-Fit' Terminals for Deep Holes

SEALECTRO are marketing a new type of terminal designed for installation in deep holes or, in the case of stand-off terminals, in blind holes. These terminals are available in any of the standard 'Press-Fit' lug or turret configurations.

The grooves cut in the Teflon body provide a high degree of internal friction against the walls of the hole especially in the direction of pull-out. The example illustrated is a feed-through designed for deep hole installation. — *Sealectro Corporation, Hersham Factory Estate, Walton-on-Thames, Surrey.*

For further information circle 39 on Service Card

40. Palm Switches

CRAIG AND DERRICOTT palm-operated switches are designed for applications where ease of operation under arduous conditions is essential, e.g. on machine tools, presses and welding machines.

They can incorporate either slow-break or snap-action switch contact blocks for single- or double-pole changeover sequences. If required, a latch mechanism can be fitted to keep the button depressed after operation until repositioned by a separate reset button.

These robust units are oil and moisture proof and can be supplied for panel mounting or in diecast aluminium cases for surface mounting. A number of colours are available including red, blue, green, yellow and black.—*Craig and Derricott Ltd., Royal Works, Coleshill Street, Sutton Coldfield, Warwickshire.*

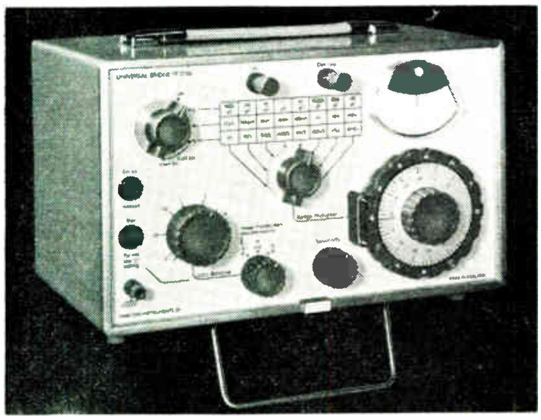
For further information circle 40 on Service Card

41. Industrial Counter Unit

LANCASHIRE DYNAMO have introduced a rugged weatherproof counter, the Series IPU.1, suitable for remote and unattended applications. A completely automatic unit is available if required.

On completion of a pre-set number of counts a set of heavy-duty contacts is operated and, in the case of the automatic version, remains in the operative state for 0·1 sec. The contact ratings are 440 V, 1 A a.c. or 250 V, 5 A a.c.

Counting rates up to 600/min may be realized with automatic batching facilities up to 300/min depending on the duty cycle. The counter coil is designed for a continuous working temperature of 20 °C, but for some duty cycles peak ambient temperatures from −15 °C to +50 °C can be tolerated.



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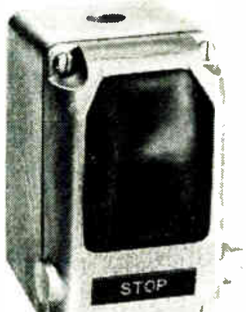

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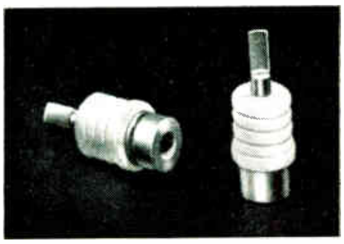


41

EQUIPMENT review

The T1 model is a totalizator unit with manual reset suitable for tool life control and similar applications: the T2 is a pre-set counter with external restart facility for repetitive operations: the T3 is an automatic pre-set counter for repetitive work such as batching, sequence switching, lubrication and remote pump control.

Construction is in aluminium with the top half of the case hinging upwards for access, the two halves being sealed by a lock-operated wedge underneath. — *Lancashire Dynamo Electronic Products Ltd., Rugeley, Staffordshire.*

For further information circle 41 on Service Card

42

43

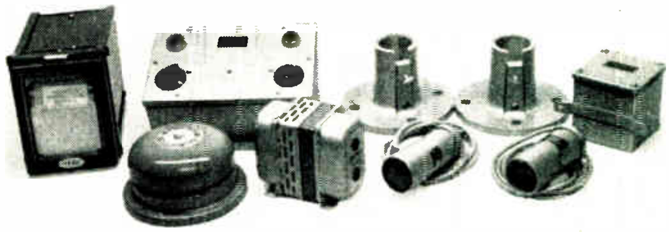
44

42. Process Timers

LONDEX have announced that the type IMP process timer is now available from stock. Time ranges available are from zero to 1, 5, 15, 30 and 60 minutes. All units are designed for use with 200 to 250 V, 50 c/s supplies.

The flush mounting and wall mounting versions cost £13 16s 6d and £14 18s respectively.—*Londex Ltd., 207 Anerley Road, London S.E.20.*

For further information circle 42 on Service Card



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43. Heavy Current Spark Gap

A SPARK gap with a basic rating of 500 A-sec has been developed by A.E.I. for the protection of series capacitors used for power-factor correction on high-power transmission lines where occasional fault current transients are liable to occur.

The gap by-passes the capacitor when the voltage across it reaches a damaging level and restores it to the circuit when the disturbance is over.

The limiting factor on the basic rating (the product of the r.m.s. current and its duration) is the recovery time of the spark gap. If an increased recovery time is acceptable, a rating of 1,000 A-sec can be envisaged for this unit. The breakdown voltage of the gap can be adjusted within the range 500 to 1,500 V. — *Valve and Semiconductor Group, A.E.I. Electronic Apparatus Division, Carholme Road, Lincoln.*

For further information circle 43 on Service Card

44. Subminiature Half-Wave Rectifier

RAYTHEON have developed a subminiature half-wave rectifier for high voltage, low current power supplies.

Housed in a robust metal/ceramic cylinder 0·4-in. diameter and 1¾-in. long, the CK7996 is a gas-filled, cold-cathode device with an output current rating of 12 mA. It can be operated in cascade to produce very high voltages.

Minimum anode supply voltage is 500 V a.c., peak anode current 100 mA d.c., and p.i.v. 2·8 kV. — *Raytheon Company, Lexington 73, Massachusetts, U.S.A.*

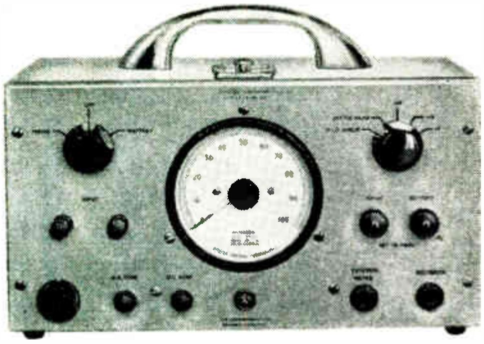
For further information circle 44 on Service Card

45. Smoke Density Indicator/Alarm

HIRD-BROWN have recently introduced a smoke density indicating alarm and recording system suitable for chimneys from 6 in. to 40 ft in diameter.

The smoke-sensing equipment consists of a lamp and a photocell unit attached to the inside of the chimney and connected to a small control unit which energizes a relay at any pre-set smoke density level. The relay operates either an indicator lamp or a bell which, if required, can be arranged to sound for a given time before being automatically silenced.

Continuous monitoring facilities are available in the form of either an 8½-in. diameter meter giving a continuous indication of smoke density



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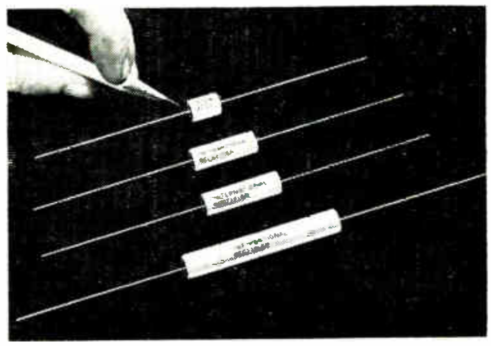

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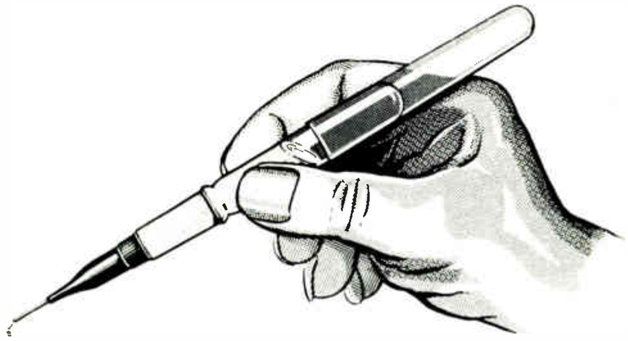

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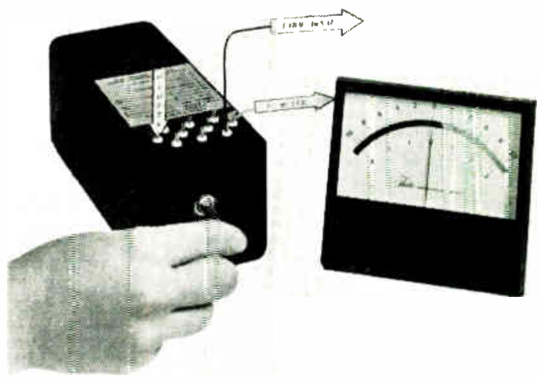


49

or a recorder showing density variations as they occur.

The photograph shows (from left to right): recorder, alarm bell, control unit, voltage stabilizer, receiver flange, receiver, projector flange, projector, and transformer for the projector lamp. Cost of the basic equipment is £57.—*Hird-Brown Ltd., Flash Street, Bolton, Lancs.*

For further information circle 45 on Service Card

46. Frequency/D.C. Converter

METER-FLOW have announced a fully transistorized portable rate-of-flow indicator for use with impeller type flowmeters. In conjunction with the appropriate transducers, it may also be employed as a tachometer or for speed measurement.

Three ranges are provided: 200, 1,000 and 5,000 c/s. Rate of flow indication is accurate to 1%, and the voltage level 1 V or 100 mV. There are additional outputs for an external meter and a recorder.

This converter weighs only 9 lb and can operate either from an internal battery or from the mains. It is particularly suitable for situations where there are a number of flowmeters installed but where only occasional measurements are required. Dimensions (including lid): 10½ by 5¾ by 6 in.—*Meter-Flow Ltd., North Feltham Trading Estate, Feltham, Middlesex.*

For further information circle 46 on Service Card

47. Silicon Cartridge Rectifiers

AS a result of the development of high p.i.v. silicon rectifier junctions, International Rectifier Company has added two types to its range of high voltage cartridges.

The GF1T25 rated at 12·5 kV, and the HF1T25, rated at 15 kV, are hermetically sealed in robust ceramic tubes ⅜ in. in diameter and 2½ in. long, and have current ratings of 75 mA at 25 °C or 25 mA at 100 °C. Maximum leakage current is 10 μA.

The photograph shows the full range of cartridge sizes (ratings from 600 V 250 mA).—*International Rectifier Company (Great Britain) Ltd., Hurst Green, Oxted, Surrey.*

For further information circle 47 on Service Card

48. Oil Pen

NOW AVAILABLE in this country is the 'Lubristyl' oil pen manufactured in Switzerland by Meylan and Co. This instrument allows oil to be applied with precision through a small diameter hollow needle. The flow of oil is controlled purely by finger pressure. The retail price is 12s 6d with two refills.—*Haynor Ltd., 167 Greyhound Road, London, W.6.*

For further information circle 48 on Service Card

49. Solid-State A.C. Voltmeter

THE MODEL TRVM panel-mounted a.c. voltmeter incorporates a solid-state alarm circuit which allows it to function in the same way as a meter-relay, making it suitable for use in process alarm systems, go-no-go equipment, etc.

When the a.c. input reaches a predetermined value the circuit is triggered to give a 24-V, 40-mA d.c. output. The meter reading is unaffected in this condition and the alarm voltage remains 'on' until the input signal falls below the triggering level.

There is no external reset procedure. Input impedance is 2 MΩ. Range: 1 mV to 300 V f.s.d. Accuracy: 2%.—*Theta Instrument Corporation, 520 Victor Street, Saddle Brook, New Jersey, U.S.A.*

For further information circle 49 on Service Card

In an industrial plant, information required by the control system is derived from various sources. Where these are physical quantities, corresponding analogue signals can normally be made available, and this article describes the way in which these are made suitable for on-line computer processing.

collection of Analogue Plant Data for On-Line Computer Processing

By *J. F. ROTH*, B.Sc., A.M.I.E.E.*

WHEN using an on-line computer system for process-control applications, some means must be provided for feeding the relevant plant data to the computer in a suitably coded form. This data can originate in two ways:—

1. Where the nature of the data makes it impracticable for direct measurements of the quantity to be made, and the information must, therefore, be manually prepared. An example of such data would be the location of an item in a stockroom.
2. Where the process data can be directly measured. An example of such data would be the temperature of a furnace where a thermocouple can be used to give a direct analogue signal of the physical quantity.

The manner in which the first type of data can be prepared for insertion into a computer system was described in the January issue of this journal. The present article discusses the way in which the second type of data is handled.

Analogue Signals

Most industrial processes are concerned with physical quantities which, by their nature, are continuously variable. To make a measurement of the quantity the physical effect must first be translated into an electrical signal and then coded in such a way that it is acceptable to the digital computer. This translation is achieved by a transducer whose electrical output is an analogue of the physical quantity being measured and is, therefore, termed an analogue signal. The coding operation is performed by an analogue-to-digital converter, which produces a digital representation of this signal.

* Process Computing Division, Elliott Brothers (London) Ltd.

The way in which analogue signals are processed for use by a computer system can be best understood by referring to a specific example. The one selected will illustrate a further aspect of the modern techniques being used at Spencer Works, the new steel strip plant of Richard Thomas & Baldwins, near Newport, Monmouthshire.

Soaking Pit Temperature Measurement

The hot ingot, having been removed from its mould, is transferred to a soaking pit. Here the ingot is reheated to the required temperature, at which it is held for a soaking period prior to being rolled into a slab. There are in all 20 soaking pits, each of them being about 32 ft long, 10 ft wide and 16 ft deep, with a capacity of up to 150 tons. The weight of an ingot is around 10 tons and about 8 to 10 ingots are placed in a pit at a time. The soaking pit is heated by gas burners, the pressure being reduced or 'cut back' when the pit has reached the soaking temperature. A view of the soaking pits is shown in one of the photographs.

The pit temperature is measured by a thermocouple connected to a conventional chart recorder. A slave resistance slide wire driven from the pen movement shaft is fitted to the recorder so that an independent analogue signal is made available. Associated with the recorder is the control for the gas supply valve, to which is added a switch so that its position can be automatically determined. Only the two conditions of full gas pressure or cut-back have to be measured and, therefore, a simple two-state device is adequate. By utilizing the slide wire energizing voltage in association with the switch, either a full-scale or zero signal is provided to differentiate between the two states. The arrangement is shown diagrammatically in Fig. 1.

As the change of temperature in the soaking pit is rela-

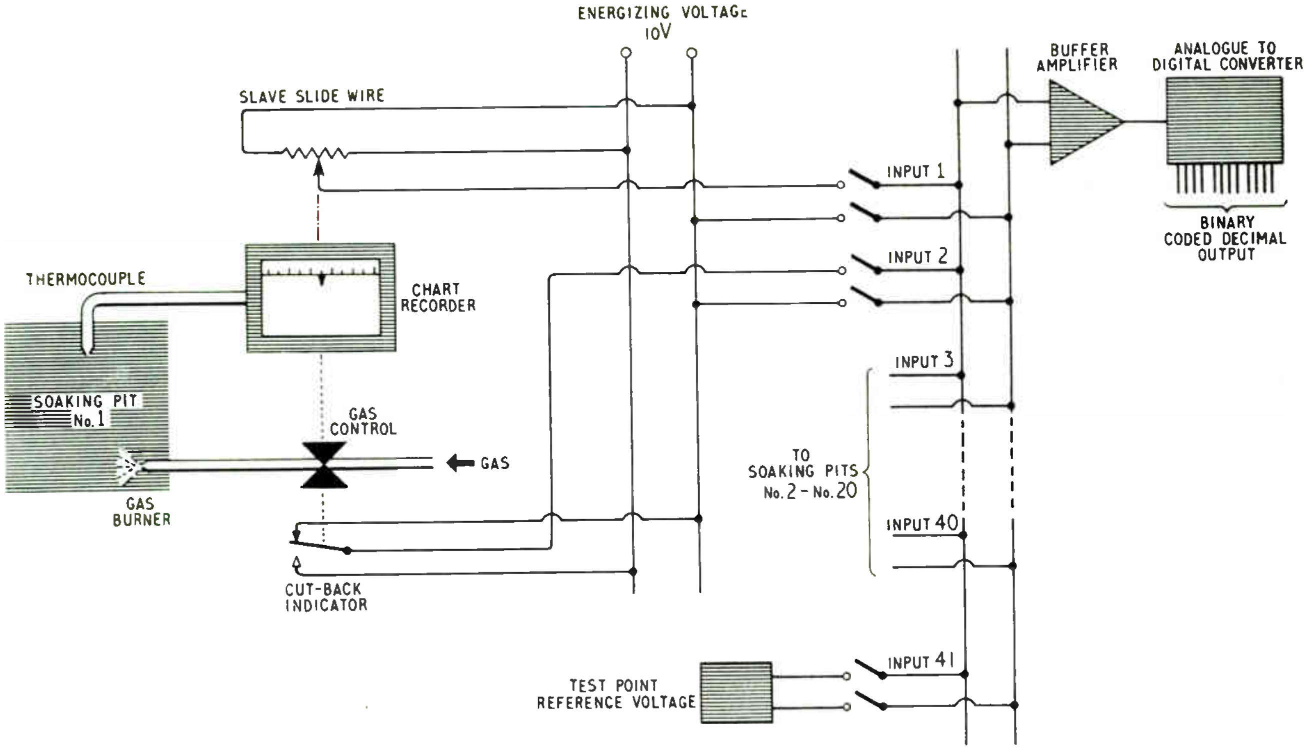
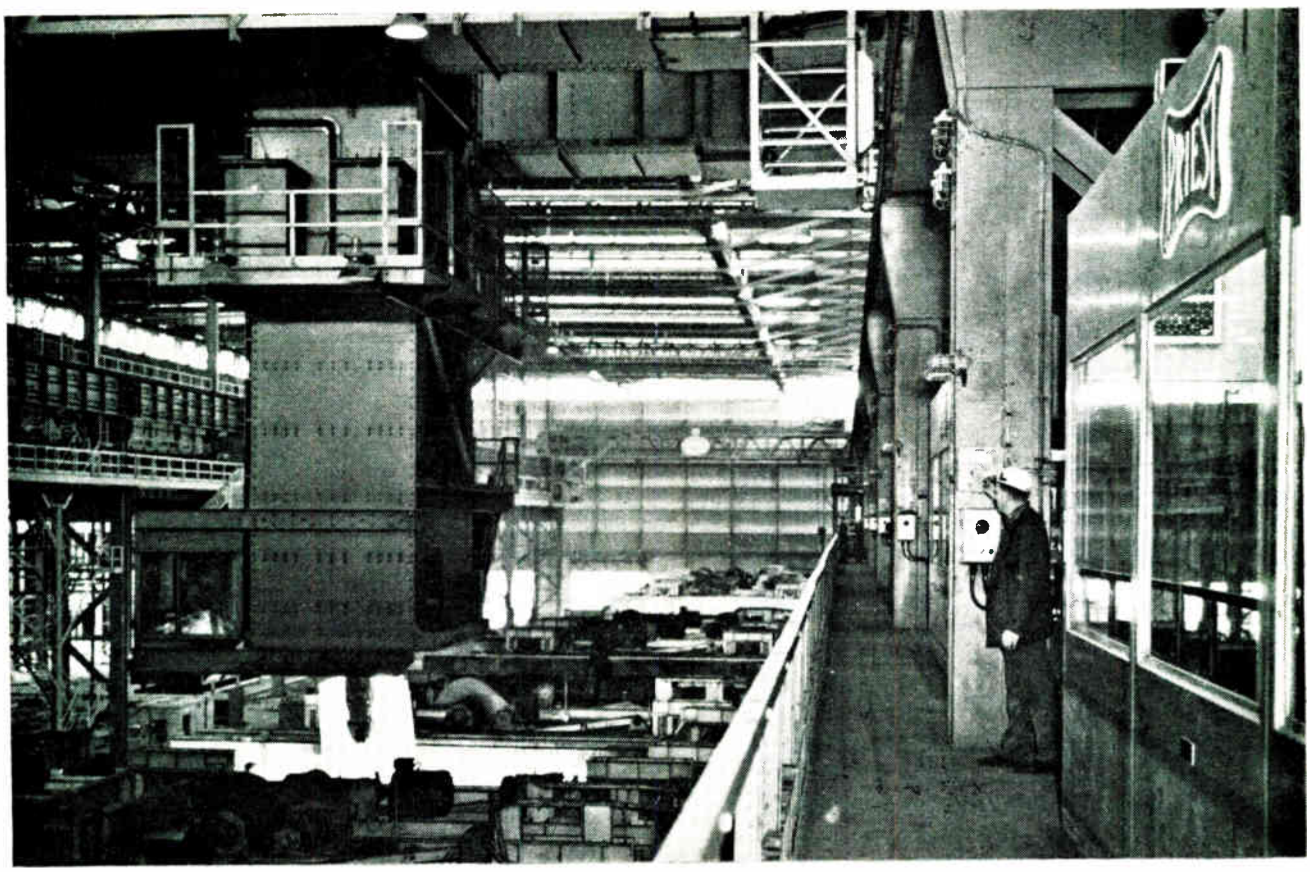


Fig. 1. Schematic diagram of apparatus for measuring the temperature of a soaking pit



Soaking pits showing an ingot being charged. The temperature chart recorders and other instrumentation are housed in the cabins on the right tively slow, it is only necessary to make a measurement at regular intervals in order to obtain a representation of the conditions in the pit. Therefore, the analogue-to-digital converter and associated equipment can be shared between all of the inputs. Each input is therefore selected in turn through a double-pole switch, which in the open condition breaks the signal lines and thus prevents any mutual interference between the various signal circuits. For reliable operation over long periods of time, gold-plated dry-reed relays are used, as they have a low contact resistance. This is especially important should the analogue signal be in the microvolt range, as would occur, for example, when the direct output of a thermocouple is being used as the signal source. Alternatively, mercury-wetted contact relays could be employed which have a very low contact resistance. These have an expected life of 10^9 operations, ten times that obtainable with gold contacts. As an illustration of what this means in practical terms, a gold contact relay operated once every ten seconds should have a life of over 30 years, whereas the mercury relay's life should be over 300 years!

Signal Amplifier

Having selected the input signal, it is then routed to a buffer amplifier. This provides isolation between the transducer and the rest of the equipment, as well as matching the signal source to the input requirements of the analogue-to-digital converter. In the application being described, the slide wires are energized from a 10-volt source, and therefore the amplifier has a gain of unity to suit the converter.

The analogue signal is not always a linear function of the physical quantity being measured, in which case some form of linearization must be incorporated. This can be achieved by the computer when it receives the digitized value, but it is often preferable to modify the analogue signal directly. By suitably choosing the feedback components the response of the amplifier is adjusted to the inverse of the transducer characteristics. The amplifier output will then bear a linear relation to the physical quantity being measured, as is shown in Fig. 2. If more than one type of transducer is being used, different feedback units will be required for each, and means of switching them must be provided. As the number of types increase, so does the complexity and cost of this method of linearization, and it may become more economic to use the computer programme for the purpose.

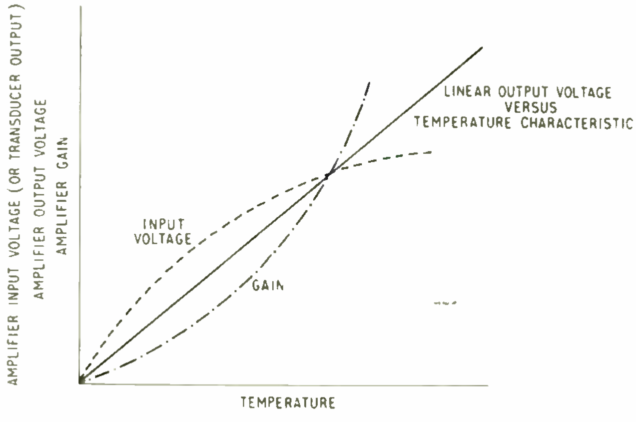
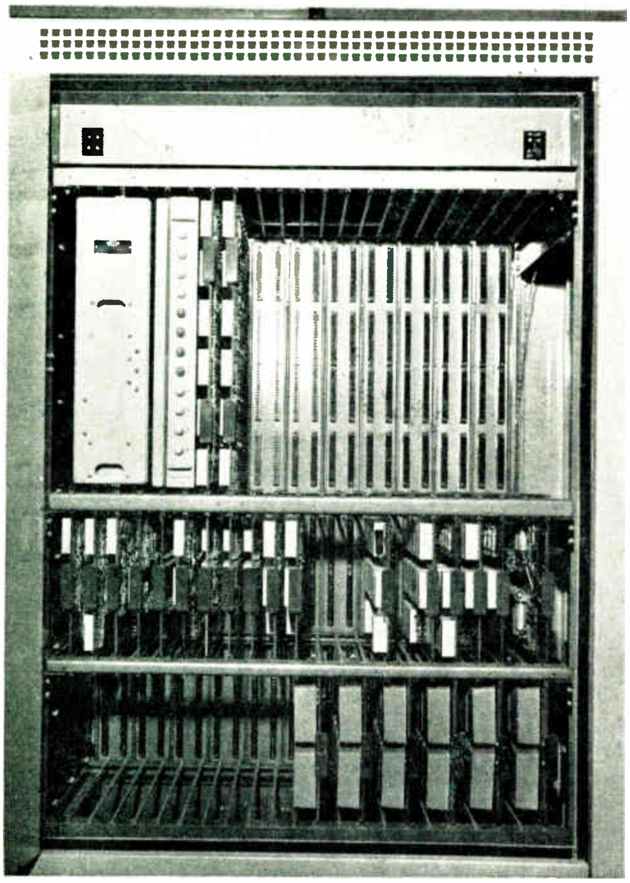


Fig. 2. Linearization of transducer characteristic



Control unit for soaking pit measurements. The analogue-to-digital converter unit is on the top shelf of the cabinet and on the bottom shelf are the input selection relays. The amplifier is on the extreme right-hand board of the centre shelf

Analogue-to-Digital Converter

Conversion of the analogue signal to the digital form is based on a potentiometric-comparison principle. The input signal is successively compared with a series of reference potentials until equivalence is found. The reference signals are arranged to follow the pattern of the output code required which, in the present case, is binary coded decimal. Three digits are provided, giving a range of 0 to 999 and a resolution of 1 part in 1,000.

The actual temperature range of 0 to 2,600 °F does not correspond with that for the digitizer and, therefore, scaling is required. This is performed by the computer programme, which multiplies each digital value by a factor of 2·6.

Control

Two measurements are made for each pit: temperature and state of gas supply valve. As there are 20 pits, 40 measurements have to be made. In addition, a test point is provided whose input is obtained from a stabilized voltage source. By checking the value of this input to fine limits any errors in the measurement system can be detected and should this occur the computer is programmed to raise an alarm.

A digital clock is incorporated so that the measuring cycle can be automatically initiated at 5, 10 or 15 min intervals or as soon as the previous cycle has been completed. The time taken to select, digitize and route each value to the computer is about 200 msec, and thus the measuring cycle takes a minimum of about 8 sec.

The operations of the measuring cycle are initiated from a fixed programme control unit. On starting the cycle the relay for the slide wire on the temperature recorder of the first soaking pit is closed. After a short delay, to allow the amplifier to settle following the switching transient, the value is digitized. A signal is then sent to the computer indicating that an item of information is available to be read in. When the computer can accept it the control unit first sends a unique reference number, from which the computer can recognise the respective soaking pit temperature or gas valve condition, followed by the digitized value. Immediately the computer acknowledges receipt of the information, the relay which was energized is released, and that for the next input—state of gas valve in soaking pit number 1—is in turn energized. The control unit then proceeds, successively taking each soaking pit in turn, and finally the test point value is measured and checked.

The success of an on-line process control computer system depends to a very large extent on the accuracy and validity of the input data. Thus the methods for collecting plant data are of extreme importance. Signals representing plant conditions and actions may take many different forms, and the methods by which they are translated to the form required by a computer have been described in this and the January article.

SMOKE DENSITY EQUIPMENT

With the ending of the 7-year period of 'grace', on 4th July, industrial concerns are obliged to comply with the Clean Air Act and ensure that the pollution of air by smoke is kept below a prescribed level. Infringement of the Act can result in severe penalties.

The Lancashire Dynamo low-cost Series SME2 smoke-alarm installation is a means for indicating when the smoke in chimneys reaches a pre-determined density, thus providing protection against a possible infringement of the Act.

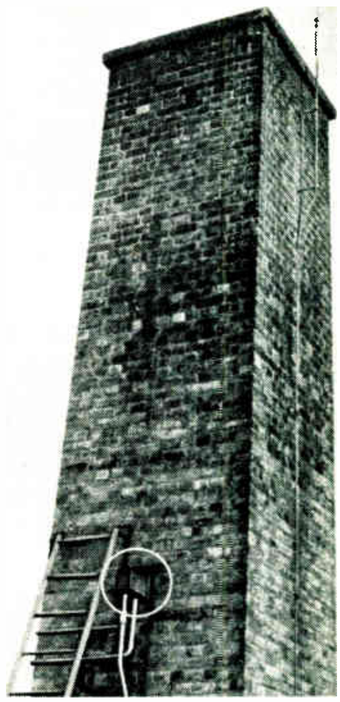
The equipment is operated by the use of a photoelectric device and a bulb which projects a light beam across the inside of a chimney stack. When the smoke density reaches a pre-determined level it reduces the intensity of light falling on the photocell and trips off an alarm bell.

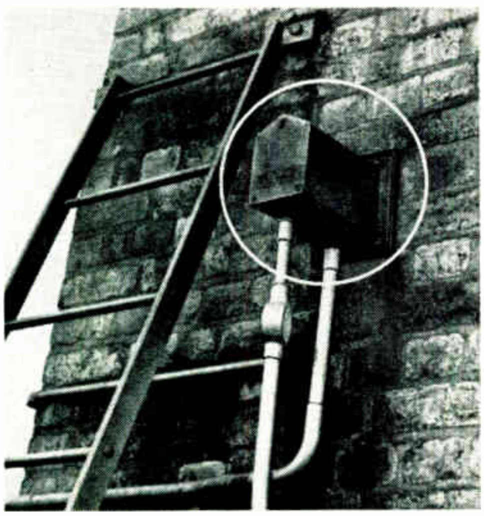
Many accessories are available with this equipment enabling the installation to be used as a densitometer and/or smoke density recorder.

By a simple adaptation, the equipment can also be arranged to indicate directly the density of the smoke over a wide range. This provides a simple form of combustion control enabling the stoker or the person in charge of the boiler to ensure that it is operating at maximum efficiency.

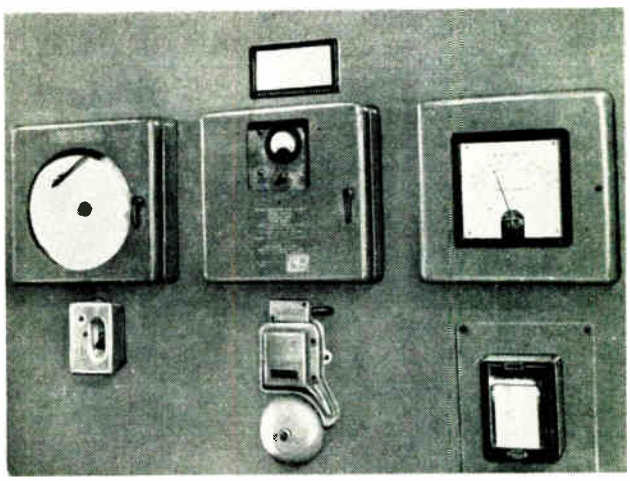
For further information circle 54 on Service Card

Two similar cast-iron units are used, one housing a light projector unit and the other a photo-electric receiver unit ▶





▲ *A close up of one of the units fitted into a chimney showing that connections to the units are made with conventional weatherproofed conduit*



▲ *Illustrated (left to right) a smoke-level recorder; main control unit; percentage obscuration meter; alarm bell and smoke-density recorder*

THE SOLION

A NEW device which is analogous to a thermionic valve or transistor has been announced by Texas Research and Electronic Corporation of Dallas, Texas. It depends for its operation upon chemical action and it is analogous to the valve only in the sense that it has input–output characteristics of similar form. It is essentially a very low-frequency device and has an upper cut-off frequency of about 1 c/s.

It is possible to use the solion as a d.c. amplifier and existing models have a mutual conductance of about 40 mA/V. However, its widest application at the moment seems to be as an integrator. A special feature is its ability to integrate over very long periods, even weeks, so that it may well find application in meteorology.

The basic solion comprises two platinum electrodes sealed into the ends of a glass tube, Fig. 1, which is filled with an aqueous solution containing a small amount of iodine and a larger amount of potassium iodide. The latter dissolves in water to produce positive potassium and negative iodide ions in equal quantities. The potassium ions do not take part in the reaction and so will not be considered further here. In the presence of the iodide ions, the iodine exists predominantly as the tri-iodide ion and is negative.

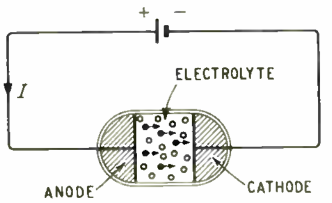


Fig. 1. General form of solion diode

When a voltage is applied between the electrodes of the tube the reaction at the anode and cathode are the reverse of each other. At the cathode a tri-iodide ion combines with two electrons to form three iodide ions and at the anode three iodide ions dissociate to form a tri-iodide ion and two electrons. In what follows the word iodine is used as a convenient abbreviation for tri-iodide ions.

As the applied voltage increases the current rises linearly at first. At some voltage, which depends upon the concentration of iodine but is usually under 0·2 V, a saturation effect sets in and the current is substantially independent of the voltage. This continues until at 0·9 V or more the current again starts to rise. This rise is due to an irreversible chemical reaction in which hydrogen gas is formed at the cathode.

Apart from this final rise, a family of characteristic curves looks much like those of a pentode valve, but with iodine concentration replacing grid volts as a parameter. A typical set of curves is shown in Fig. 2. Solion diodes of this basic type can be used as integrators. For this purpose it is necessary to add a diffusion barrier between the electrodes. This does not affect the normal operation but it prevents the cell returning to normal when the current is interrupted. When the current is flowing iodine is transported from one compartment to the other through the barrier, the amount transported being proportional to the product of current and time (that is, to charge). When the current ceases, however, the barrier prevents the redistribution of the iodine by diffusion.

This form of solion can be left in circuit for hours or days. It is then disconnected and taken away so that the concentration can be determined by measuring its concen-

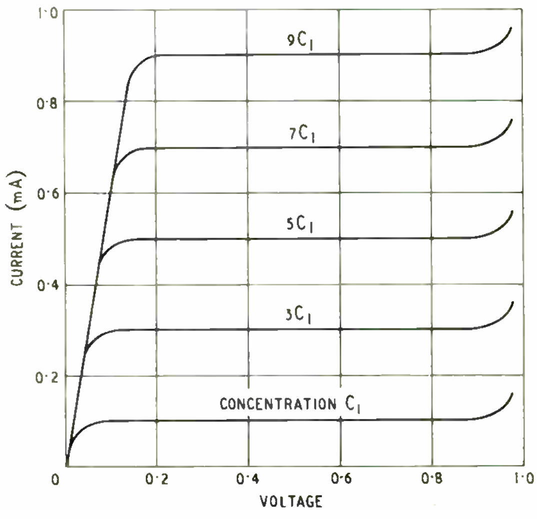


Fig. 2. Typical characteristics of solion diode for various concentrations of iodine

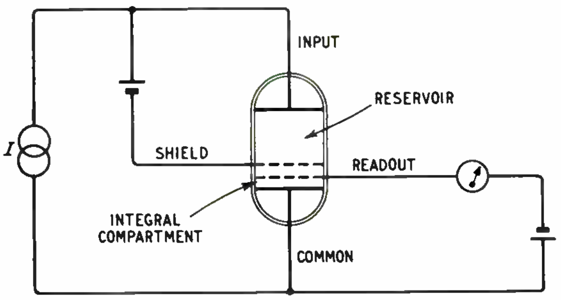


Fig. 3. Basic circuit of integrator using a solion tetrode

tration potential. This is the potential which exists between the electrodes when they are immersed in solutions of different concentrations.

The most generally useful form of solion, however, would appear to be the tetrode type. This has two main electrodes, one at each end of a glass tube and designated the input and common electrodes. Between them two perforated platinum electrodes are fitted to divide the space into three compartments. The one nearest the input electrode is called the shield; the one nearest the common electrode is called the readout electrode. The compartment between the input and shield electrodes is called the reservoir, while that between the readout and common electrodes is known as the integral compartment. The arrangement is shown in Fig. 3 which also shows the basic circuit.

A battery of some 0·7 V is connected between the input and shield electrodes, the latter being negative. This polarizes the shield and keeps the iodine concentration near it small enough for diffusion through the shield to be negligible.

The input signal is applied between the input and common electrodes; that is, right across the whole tube. The results are very similar to those with the simple diode. Current flows and iodine is transported across the system. The quantity of iodine transported is proportional to the electrical charge and thus to the time integral of the current. The concentration of iodine in the integral compartment next to the common electrode is thus proportional to the integral of the input current.

This compartment with its common electrode and readout electrode virtually forms a solion diode by itself and has similar characteristics. It will be remembered that the current-voltage curves have a saturation region in which the current is dependent only on the concentration. This diode region of the tube is operated in this condition with about 0·7 V applied in series with a load of some 400 ohms, making the readout electrode negative with respect to the common electrode. In this way an output current is obtained which is proportional to the integral of the input current. Typically, a constant input current of 100 μA produces an output current rising linearly with time at the rate of about 1·2 mA per minute.

The device is temperature sensitive, but the variations can be compensated.

PRESSURE FIRED CERAMIC

The increasing use of piezoelectric ceramic compounds in the construction of acoustic and vibration transducers has led to the need to manufacture the ceramic elements in a variety of shapes and sizes. Certain of the compounds commonly used are not easily fired into large sized pieces because the stresses introduced in the sintering process are not uniformly distributed throughout the finished ceramic, which thus tends to crack or to have poor electrical properties.

In 1960 Gulton Industries started investigations into the possibility of applying a high compressive force to the ceramic during firing. Work is still in progress, but it was found at an early stage that the process produces a considerably more uniform stress distribution so that it is possible to manufacture exceptionally large transducers; for example, discs with diameters up to twenty inches.

A number of other advantages have been found.

It is normal to adjust the atmosphere of the kiln to prevent loss of volatile elements from the ceramic compound. Application of pressure is even more effective and it has been found possible to produce materials which have not previously been made.

In addition, the product has a higher density than is otherwise attained because the larger voids are squeezed out. This results in an increase in the piezoelectric sensitivity and a general improvement in electrical and mechanical properties, the effect being more marked with the larger pieces.

Pressure fired ceramic is currently made in blocks some 3½ in. thick and either 4 in., 6 in. or 20 in. square. The components are mixed into a paste with organic binders or, alternatively, powders are used. A 'mould' is made from blocks and the material is fired in a kiln which has openings for the arms of hydraulic rams. These press on the blocks forming the top and bottom and two opposite sides of the mould, the remaining two sides being pressed against immovable stops. Pressure to the top and bottom is equalized, as is that applied to the two sides, and the ratio between these two pressures is carefully controlled. Up to 1,000 atmospheres pressure is applied at firing temperatures around 1,200 °C.

The resulting blocks are machined, the various shapes required being cut out, rather than moulded, to size.

Work is still proceeding and it is believed it may ultimately be possible to market a range of entirely new ceramics for ferroelectric and piezoelectric applications.

For further information circle 55 on Service Card

By P. J. LANGLOIS, M.Sc.

DUALITY AND TUNNEL DIODES

(Continued from p. 288 of February issue)

Continuing the discussion of duality, examples are given of tunnel-diode circuits for multivibrators and ring counters and their derivation from their gas-tube duals.

A SIMPLE gas-tube multivibrator is shown in Fig. 13. Using the dual technique previously discussed, Fig. 14 results. The battery voltage power supply is included, since this is a part of the complete network, and its dual, a current power supply, appears in Fig. 14. Fig. 14 is the tunnel-diode multivibrator. Both circuits can be operated in the astable, monostable or bistable mode according to the d.c. bias condition and the loadline chosen. The astable device will be considered using either gas tubes or tunnel diodes. A full qualitative description of both circuits will follow to show the exact correlation between them.

The next two paragraphs have been worded in such a way as to emphasise the duality between the two circuits. The second paragraph has virtually the same wording as the first except for electrical components, which have been replaced by their duals.

Gas-Tube Multivibrator* (Fig. 13)

For astable operation the loadline conditions (discussed later) must be satisfied. Suppose the voltage supply to be switched on. Both the tubes are initially in the '0' condition. As, in practice, one gas tube is slightly different from the other, one will switch first to the '1' condition. Suppose tube A in Fig. 13 be switched to the '1' condition. The voltage across R_a quickly rises to the supply voltage less the voltage

* In the following descriptions the gas-gap tubes or tunnel diodes are being used as switches. To conserve the picture of duality, the condition before breakdown will be called the '0' condition, and after breakdown the '1' condition.

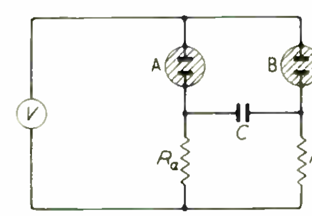


Fig. 13. Single-reactance gas-tube multivibrator

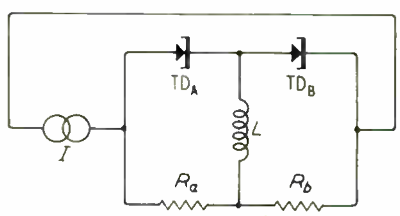


Fig. 14. Single-reactance tunnel-diode multivibrator

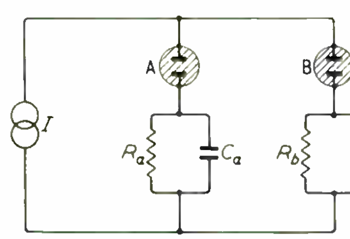


Fig. 15. Double-reactance gas-tube multivibrator

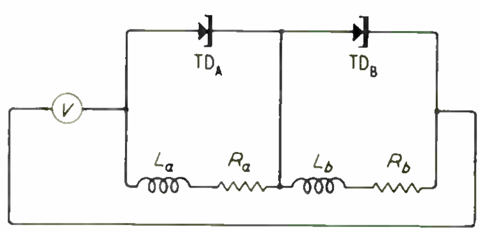


Fig. 16. Double-reactance tunnel-diode multivibrator

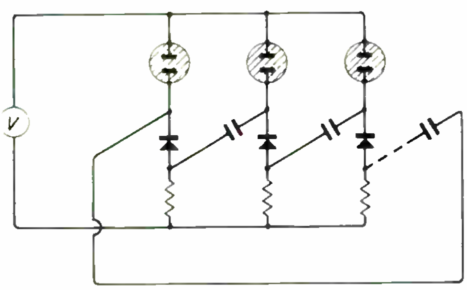


Fig. 17. Simple gas-tube ring counter

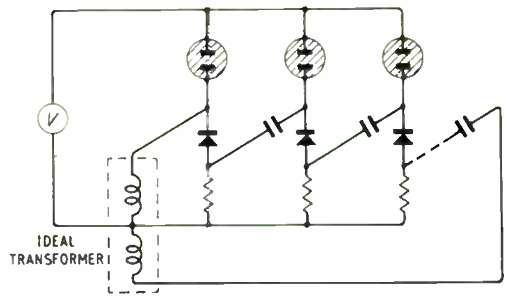


Fig. 18. Ring counter with transformer inserted

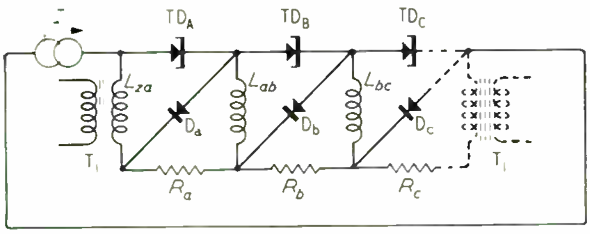


Fig. 19. Tunnel-diode ring counter

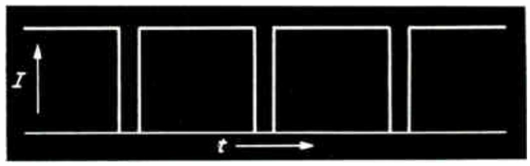


Fig. 20. Pulsed power supply

drop in tube A (in the '1' condition). At this point the voltage across tube B will be the same as the voltage across tube A, so that tube B is held in the '0' condition. *C* now charges through R_b and tube A towards a potential determined by tube A and R_a, with a time constant determined by tube A, R_a and R_b. When the voltage across R_b has dropped enough, the resultant voltage across tube B causes breakdown. The consequent rise in voltage across R_b is transferred through *C* to R_a. The increased voltage drop across R_a reduces the voltage across tube A, switching it to the '0' condition. *C* now starts to charge in the opposite direction until breakdown occurs in tube A. The cycle is then repeated.

Tunnel-Diode Multivibrator (Fig. 14)

For astable operation the loadline conditions must be satisfied. Suppose the current supply to be switched on. Both the diodes are initially in the '0' condition. As, in practice, one diode is slightly different from the other, one will switch first to the '1' condition. The current through R_a quickly rises toward the supply current less the current in tunnel diode TD_A (in the '1' condition). At this point, the current in tunnel diode TD_B is the same as that in TD_A, so that tunnel diode TD_B is held in the '0' condition. *L* now charges, bypassing R_b toward a current determined by TD_A and R_a with a time constant determined by TD_A, R_a and R_b. When the current through R_b has dropped sufficiently due to diversion through *L*, the resultant increasing current through tunnel diode TD_B causes breakdown. The consequent rise in current through R_b is supplied through R_a because *L* is a high impedance.

The increased current in R_a reduces the current in tunnel diode TD_A switching to the '0' condition. *L* now starts to charge in the opposite direction until breakdown occurs on tunnel diode TD_A, and the cycle is repeated.

Double-Reactance Multivibrator

A gas-tube multivibrator using a current supply source is shown in Fig. 15. Here two timing capacitors are used, one in each tube circuit. The dual of Fig. 15 is shown in Fig. 16.

The operation of the tunnel-diode multivibrator only will be described. The gas-tube multivibrator is the dual operation, as demonstrated in the single-capacitor case.

As before, for astability, the d.c. bias conditions must be satisfied.

Suppose the voltage power supply to be switched on in Fig. 16. Since, in practice, components are not identical, one tunnel diode will break down to the low current '1' condition. The inductors instantaneously appear open-circuit, so the other diode is held in the '0' condition. Suppose tunnel diode TD_B switches to the '1' condition. The current through the low resistance of tunnel diode TD_A, R_b and L_b rises towards a high d.c. value, set by the value of the supply voltage, until the peak current of tunnel diode TD_A is reached and switching occurs. Note that, at the same time, a small proportion of the supply current charges L_a; for the present purpose this is small enough to be ignored.

After tunnel diode TD_A is switched, the residual current in L_b circulates mainly through tunnel diode TD_B, in opposition to the supply current flow. This reduces the effective supply current to tunnel diode TD_B, and switches it to the '0' condition. L_b then discharges mainly through R_b and tunnel diode TD_B. L_a charges through R_a and tunnel diode TD_B towards a d.c. value set by the supply voltage. The rates of charging or discharging are the same. When the net current, due primarily to current from L_b, reaches the peak current of tunnel diode TD_B, the diode switches. The cycle is then repeated.

Tunnel-Diode Ring Counter

A good demonstration of the dual technique is to find the dual of a simple gas-tube ring counter. Figs. 17, 18 and 19 show the stages of making the dual, including the method described earlier for eliminating crossover wires.

The tube circuit contains an additional type of component, the diode. The dual of a diode from equations (5) and (6) is a diode operating in the reverse mode.

Fig. 17 shows the tube circuit. Fig. 18 shows the inserted ideal transformer and Fig. 19 shows the final dual. Note here that the transformer now has finite self-inductance, L.

The operation of the tunnel-diode ring counter is the exact dual of the gas-tube ring counter. Several tunnel diodes are connected in series to a common d.c. and pulse current supply as in Fig. 20. Essentially, the operation is to circulate a '1' in the chain of tunnel diodes. The d.c. bias and load resistor associated with each tunnel diode make each a bistable device.

Suppose tunnel diode TD_A, Fig. 19, be in the '1' condition, and all others in the '0' condition, with the d.c. supply on. The ordinary diode in parallel with the tunnel diode is reverse biased, and a high current flows through the load resistance. Since tunnel diode TD_B is in the '0' condition, the common inductance L_{ab} carries the current flowing through R_a. The appearance of a negative current pulse is arranged to reduce the current supply to below the tunnel-diode valley threshold, switching tunnel diode TD_A to the '0' condition. The remanent current in L_{ab} forward-biases tunnel diode TD_B. The current in L_{ab} then circulates through the low resistance of the tunnel diode and the ordinary diode D_b, discharging L_{ab} very slowly. There is, therefore, a current flowing through tunnel diode TD_B.

There is also a current in L_{za}. This discharges through R_a, the forward-biased diode D_b, TD_B and TD_A. Since the direction of this current is in opposition to the biasing current, it must be dissipated sufficiently within the supply pulse width.

On removal of the negative pulse, and reverting to the d.c. bias, the total current through tunnel diode TD_B due to L_{ab} and the d.c. bias is sufficient to break it down. Tunnel diode TD_B is now in the '1' condition. Inductance L_{ab} discharges and charges in the opposite direction, and L_{bc} charges, each to its respective equilibrium condition.

When the negative pulse on the power supply reappears, tunnel diode TD_B is switched to the '0' condition. L_{ab} discharges rapidly through R_b (which is a relatively high resistance), but because diode D is forward-biased, the current in L_{bc} decays slowly through the low resistance path and tunnel diode TD_C.

When the power supply reverts to the d.c. level, breakdown occurs in tunnel diode TD_C, which holds the '1' condition. Subsequent negative pulses now step the '1' condition to successive tunnel diodes. By coupling the last tunnel diode circuit to the first by a transformer whose self-inductance is used as the energy store, a '1' condition can be made to circulate.

(To be continued)

BACKWARD-DIODE MODULATORS

The characteristics and construction of a backward diode are outlined, and a simple discussion of the theory of its operation is included. The properties of the device that are of interest for modulator applications are discussed, and it is shown that in certain respects the backward diode is superior to any other semiconductor diode yet developed.

By D. P. HOWSON, M.Sc.*

THE backward diode, a two-terminal semiconductor element closely related to the tunnel diode, promises to be a useful element for use in rectifier modulators. Already some attention has been given to this matter in the United States[1,2] and the satisfactory operation of modulators with inputs[1] at 100 Mc/s, 8·9 kMc/s and 13·5 kMc/s has been reported. It is felt however that the usefulness of backward-diode modulators extends down to the audio-frequency range as well as up into the kilomegacycle band, and accordingly a balanced l.f. modulator has been made and its performance investigated. This article presents the results obtained on this device along with comments on the others mentioned, and attempts to sum up the relative advantages and disadvantages of this form of modulator when compared with others using tunnel diodes, or more conventional junction or point-contact diodes.

Diode Characteristics and Construction

Backward diodes, which consist essentially of a single very narrow p-n junction some 100 Å thick, have been formed from single-crystal germanium and silicon, and from polycrystalline gallium arsenide[3,4]. There seems no reason why other III-V intermetallic compounds in addition to gallium arsenide should not be used, however, and it is quite possible that indium and gallium antimonide, in particular, will find application. To obtain the desired narrow junction in the diodes it is usual to use an alloying rather than a diffusion technique taking (with germanium or silicon) an n-type wafer and placing it in contact with an alloy blob, the junction being obtained by heating the combination. Suitable ohmic contacts are then made to the wafer and the blob, and the whole structure encapsulated, although backward diodes like tunnel diodes are not very susceptible to surface effects. The capacitance of a diode made in this way is however quite high, probably 5–40 pF, which is a disadvantage for high-frequency working. It has been found possible to make diodes by forming a junction at the end of a gold wire in contact with a semi-

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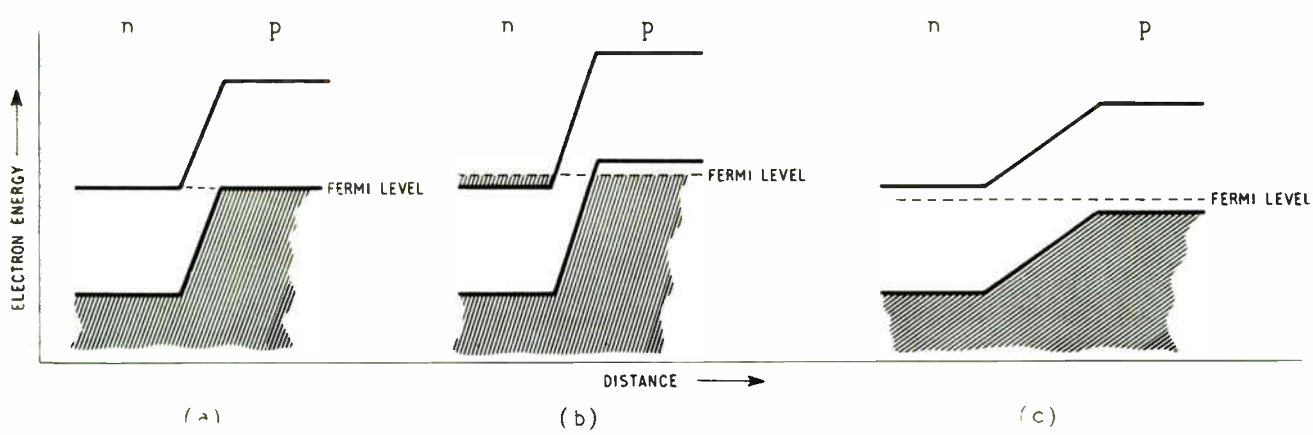


Fig. 1. Energy level diagrams for diodes: (a) is for a backward diode, (b) for a tunnel diode and (c) for an ordinary junction diode

conductor wafer, which reduces this capacitance to some 0·2 pF at zero bias. The gold wire produces a stronger structure than could have been obtained by etching away an alloy junction.

In addition to the narrow junction, the backward diode differs from a normal diode in the heavy doping of its constituent semiconductor, which may be of the order of 10^{19} carriers per cubic centimetre, compared with 10^{14}–10^{15} for a typical junction diode. The result of this heavy doping may best be seen by drawing simple energy band diagrams, Fig. 1(a) being that for the backward diode, 1(b) for a tunnel diode, which is similar but made of even more heavily doped material, and 1(c) for an ordinary junction diode. The shaded regions denote states filled with electrons, unshaded regions empty states. The band across the middle of each diagram is the forbidden band; this is a potential barrier which normally electrons cannot overcome, so that it effectively isolates the top of each diagram from the bottom. However, if it is thin enough, as is the case with the backward and tunnel diodes, it is possible for electrons to pass across the forbidden band by a process known as quantum-mechanical tunnelling, and occupy empty states at the same energy level on the other side of the band. All the diagrams are drawn for zero applied bias voltage, the n and p regions in the diagram being relatively displaced vertically if a bias is applied. Thus if a forward bias is considered to be applied to the diodes (i.e., the p region is raised in voltage relative to the n region in each case) on the diagram the n region must be raised relative to the p. It is clear that if the diagram is so modified, only the tunnel diode has electrons in the conduction band of the n region which can tunnel across to the unoccupied states in the valency band of the p region. This gives rise as is explained elsewhere[3,4] to the characteristic negative-resistance region of the tunnel diode—what is of more interest here is that neither the junction nor the (ideal) backward diode have this region, so that the backward diode has a normal forward characteristic as can be seen in Fig. 2. When the diodes are reverse-biased, however, depressing the left-hand sides of the energy band diagrams, it can be seen that all the diodes have occupied states in the p region on a level with unoccupied states in the n region. The normal diode has too wide a junction to permit an appreciable number of these electrons to tunnel across, but in both the backward and the tunnel diode considerable tunnelling occurs and a large current flows. Thus when reverse-biased the backward diode has a low resistance as shown by Fig. 2.

Some of the properties of the device that make it of interest for modulator applications can also be seen from Fig. 2. It is possible to design the diode so that the maximum non-linearity of the characteristic occurs exactly at zero bias, so that efficient modulation may be obtained with small switching voltages and no applied bias, in contrast with the tunnel diode. The backward diode has a low-impedance region when the diode is reverse-biased, which since it depends upon quantum-mechanical tunnelling varies hardly at all with temperature, see Fig. 3. The high-resistance region which occurs with small positive bias depends in part on tunnelling and changes little with temperature, contrasting with the normal forward low-impedance region occurring with larger forward bias. Thus it is possible to switch the diode from a low to a high impedance, both of which are nearly temperature independent, which cannot be done with either of the other types of diodes mentioned previously. Further, since the action of the device depends mainly on the tunnelling of majority carriers, hole storage effects are absent and the diode will operate as a switch up to a very high frequency.

Sub-Microwave Modulators

The main properties of the diode that are of interest at these relatively low frequencies are:—

(i) Large ratio of reverse to forward resistance when the diode is suitably switched. This may be as high as 1,000.[1]

(ii) Low carrier voltage and power required to perform the switching. For the ratio of resistances mentioned in (i), a switching voltage of 200 mV peak is all that is required.

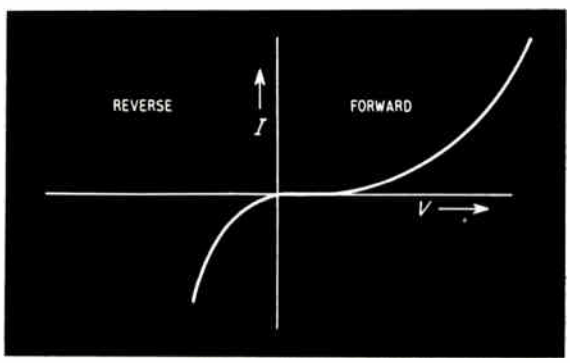


Fig. 2. Form of characteristic of backward diode

Satisfactory operation has been reported with powers as low as 30 μW[1].

(iii) Small variation in diode resistances for large changes in the ambient temperature.

(iv) The low noise introduced into the modulator circuits by the diode[1,2].

(v) The ideal diode is not an active element like the tunnel diode: in practice few special precautions have to be taken to prevent circuit oscillations.

On the other hand, backward diodes do have some limitations when compared with conventional diodes. The two that must be noted are:—

(i) Large capacitance across the junction of most backward diodes. This may be reduced to a very small value by special construction[1], or may be tuned out.

(ii) Due to the small switching voltages that must be employed, backward-diode modulators can only handle small signal voltages, say less than 20 mV. It seems likely that backward diodes made from some of the large band gap III-V semiconductors will not be so restricted in this respect.

Thus, when modulators are to be built using backward diodes, it is clear from the above that efficient circuits may be obtained as long as small signals only are accepted for modulation. The circuit design employed may follow that of conventional rectifier modulators[5], and various forms of tuned circuits may be employed as terminations to keep the conversion loss low[6]. This should be down to about 4 dB for the shunt modulator of Fig. 4(a) and to about 0·1 dB for the ring modulator of Fig. 4(b), if the terminating impedances are correctly chosen. It is in circuits like these that one of the chief advantages of the backward diode may be utilized, since it is possible to maintain the modulator balance and hence reject unwanted carrier and signal leakage into the output circuit far better with backward than with conventional diodes, due to their temperature insensitivity. A test was carried out to prove this on a shunt modulator, and the carrier leak was measured as a fraction of the carrier voltage applied across the bridge. For both the conventional junction diodes and the backward diodes it was found possible to balance the bridge initially so that the unwanted leak was 75 dB below the applied switching signal, but when the temperature was raised by 40 °C, the conventional modulator had a 20 dB increase in leak, whereas the backward-diode modulator leak increased by 5 dB only. For this test the backward diodes were switched from points A to B on Fig. 3, using a specially-constructed transistor square-wave generator working at 1,000 c/s fundamental frequency. All diodes were germanium. Similar results have been reported for a silicon backward-diode bridge[7].

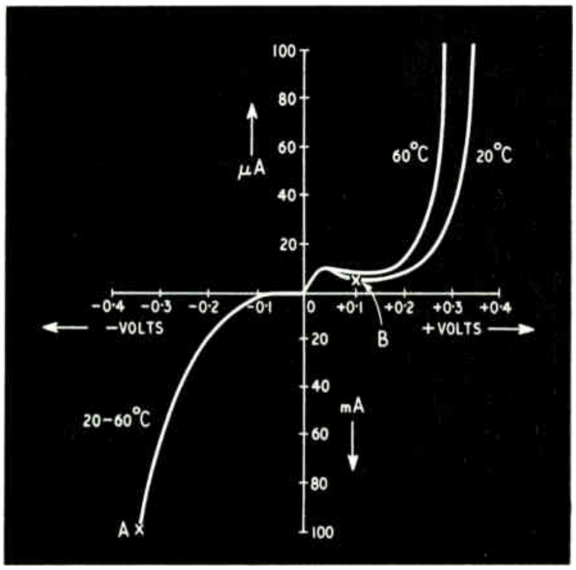


Fig. 3. Showing effect of temperature on diode characteristic

The fact that backward-diode modulators can handle only small signal voltages does not necessarily mean that the dynamic range is less than that of a conventional modulator, since tests have shown the former to have a noise figure some 40 dB less than an equivalent point-contact diode modulator. As the largest signal that can be handled by the backward-diode modulator—say 20 mV—is some 40 dB down on what would be considered a large signal for a point-contact diode modulator, this suggests that the dynamic range of the two circuits will be much the same[2]. It is probable that a junction-diode modulator would have a wider dynamic range due to its low noise figure, but it would of course be restricted in its frequency range because of hole storage effects.

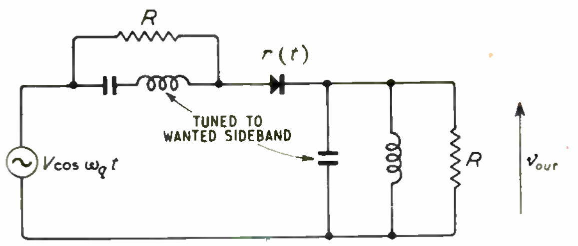
All the forms of diode mentioned produce more noise at low frequencies, the power of which is roughly proportional to $1/f$. Because of this a modulator whose output frequency is below say 20 kc/s may have a smaller dynamic range than would be otherwise expected. The frequency at which the noise from a backward diode stops being '$1/f$' type and becomes shot and thermal noise has been variously estimated at between 1–20 kc/s[1,2]. It seems likely that the diode construction, and the carrier oscillator voltage, will be variables in the equation to determine this frequency.

It was mentioned earlier that the large junction capacitance of some backward diodes was a disadvantage, and to some extent this is true. It should be noted, however, that even in a modulator where it is impossible to tune this out—say a constant-resistance modulator designed to work over a wide band of frequencies—its effect will be less than in a conventional modulator since the backward diode is essentially a low impedance device. Thus the incremental forward and reverse resistances for a S.T.C. JK 100C diode switched by a 200-mV (peak) square wave were measured as 2 Ω and 2 kΩ, so that for a ring modulator the terminating resistances for minimum conversion loss would be only 62 Ω[5]. As these diodes can be obtained with a capacitance of the order of 10 pF, it can be seen that switching speeds from l.f. up into the megacycle band should lead to little degradation of the performance of the modulator.

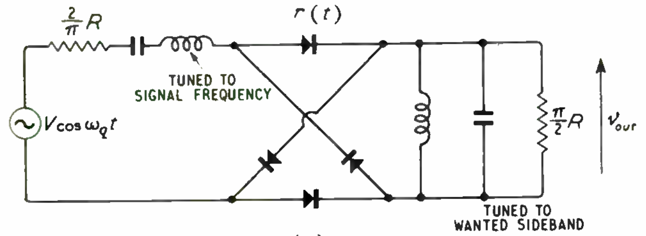
Finally, one further advantage of using the backward-diode modulator may be seen when minimum carrier leak is desired. It has been shown[5] that this occurs when modulators are driven from a square-wave carrier generator, but of course this is difficult and expensive to produce when the carrier frequency exceeds 1 Mc/s, at least for conventional modulators. However, it is possible to use very simple tunnel-diode multivibrators, which are stable and have very short rise and fall times (∼1 nsec), as carrier generators for backward-diode modulators, since only low carrier voltage and power is needed.

Microwave Modulators

In addition to point-contact diodes and tunnel diodes, the backward diode faces competition from varactor diodes at microwave frequencies. With the latter it is possible to make satisfactory low noise up-converters—that is, modulators converting from a low to a high frequency. Parametric down-converters are not considered so satisfactory, however, and usually have poor noise figures, which worsen as the ratio of input to output frequencies increases[8]. Tunnel-diode down-converters have recently been developed



(a)



(b)

Fig. 4. Shunt (a) and ring (b) modulators suitable for backward diodes. The carrier circuits are not shown

which seem to give better noise figures than any of their competitors, and can have large conversion gains—Chang reports 20 dB[8,9].

If, however, the modulator circuit impedances are to present positive resistances at the terminals at all frequencies the gain is restricted to 6 dB, and under these conditions a backward-diode microwave modulator would have little inferior overall noise factor where the system noise including that provided by the following i.f. stage is considered[1,2].

The system noise factor is given by

$$F_{total} = F_{mod} + \frac{G_c}{F_{if} - 1}$$

where F_{mod} is the noise factor of the modulator alone. F_{if} of the following i.f. amplifier, and G_c is the power conversion ratio of the modulator. Thus if G_c is less than one, as it is for a backward diode, the noise factor is larger than for a tunnel-diode modulator with gain. The order of magnitude of the effect has been worked out elsewhere[10] for a similar problem and the increase in noise factor is likely to be about 4 dB. The system noise factor for a backward-diode down-converter is therefore likely to be about 9 dB.

All the points considered in the previous section still apply to backward-diode circuits, so that this worsening of noise factor would have to be balanced against the smaller overall power required to switch the backward-diode modulator, and the improved stability of the element. Either tunnel- or backward-diode modulators would seem to be better down-converters than circuits using other forms of semiconductor diode.

Conclusions

Backward diodes are extremely stable and efficient modulating elements which may be used from audio to microwave frequencies. Modulators using them can be unconditionally stable, and require less power for switching purposes than other forms of diode modulator. Balanced backward-diode modulators may be constructed which retain their balance for changes in the ambient temperature very much better than conventional rectifier modulators, and it is felt that on this score alone such circuits may find wide application. The low noise associated with backward diodes allows sensitive microwave modulators to be constructed, and their performance as down-converters appears superior to either point-contact or varactor diode modulators.

Acknowledgments

The author acknowledges the work of various members of the Graduate Courses of the Electrical Engineering Department, the University of Birmingham, in obtaining the practical results reported here. Also the help and encouragement given by Professor Tucker, head of this same department.

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PHOTOELECTRIC CURVE READER

A prototype instrument designed for the automatic reading of pen-recorder charts, presenting values of the X and Y co-ordinates in digital form, has been demonstrated by W. F. Stanley & Co. The output signals representing the values of the X and Y co-ordinates can be fed into either an electric typewriter or a tape or card punch machine.

The chart to be read is scanned by a sensitive photoelectric head incorporating a light source and a detecting element. A spot of light projected on to the chart is reflected back to the detecting element and as this spot passes a recorded line the change in reflectivity is used to trigger a counting circuit. The detector head and its amplifier are arranged to distinguish between the recorded line and the chart grid lines, typically black and green respectively.

As the detector head passes the recorded line a counting circuit is put into operation, which continues until the head reaches the chart zero, and thus the value of the Y co-ordinate is obtained. The head is moved along the X axis of the chart in 1-mm intervals by an intermittent drive to a lead screw, thus a reading for the Y axis is obtained every 1 mm. The position of the detecting head along the X axis is registered by an optical digitizer attached to the lead screw. The outputs from the counter and digitizer are fed into an encoder and control unit where they are suitably processed for the typewriter or punch machine.

The present instrument is arranged for drum type charts.

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Magnetostrictor Equivalent Circuits

By C. F. BROCKELSBY, B.Sc.*

Lumped-element equivalent circuits for a magnetostrictor are derived by a simple, direct route which exposes the underlying physics, includes from the beginning an adequate representation of magnetic and mechanical losses and contains no approximations beyond those implicit in the model adopted.

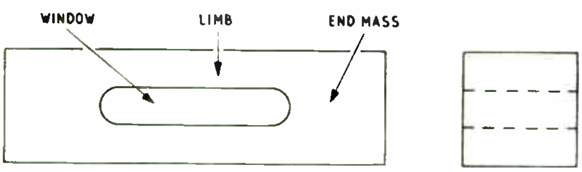


Fig. 1. Window type magnetostrictor

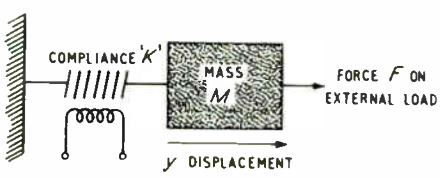


Fig. 2. Lumped approximation to a single-ended (λ/4) magnetostrictor

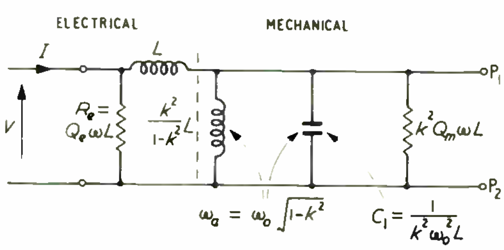


Fig. 3. Circuit represented by equation (4)

REAL mechanical resonators, like their electrical analogues, never have perfectly 'lumped' or perfectly 'distributed' parameters. In particular, window-type magnetostrictors (Fig. 1) are usually about $0{\cdot}4\lambda_0$ long where λ is the wavelength of compression waves in the magnetostrictive material and suffix 0 indicates the condition of mechanical resonance; each end-mass and each half-limb is about $0{\cdot}1\lambda_0$ long. Their linear theory can thus be developed from either a lumped-element or a distributed-element model. For most practical purposes, such as the interpretation of electro-mechanical measurements, a lumped circuit is finally required. The usual route to it[2] starts from a distributed model (a uniform bar) from which a distributed equivalent circuit is derived; this is then approximated by a lumped circuit. Discontinuities of section are allowed for separately[1]. A more direct approach is simpler and exposes the physical meaning of the analysis more clearly. It also simplifies the introduction of terms representing 'exactly' the electrical and mechanical damping during the analysis, not as an afterthought.[3]

The purpose of this note is, then, to derive lumped equivalent circuits by a simple, direct route which exposes the physical considerations to full view, includes from the beginning an adequate representation of magnetic and mechanical losses, and contains no approximations beyond those made in the original specification of the model. In this sense the circuits derived are 'exact'.

Single-Ended Vibrator

The rationalized (Giorgi) m.k.s. system of units is used.

Consider first the simplest model, Fig. 2, which resembles a quarter-wave resonator, one end being rigidly supported. The mass M is the repository of all the kinetic energy; the compliance K, of all the elastic energy. If y is the displacement of M from its rest position the net force P acting on it is given by the equation of motion

$$P = y/K + R_m dy/dt + M d^2y/dt^2 + F$$

R_m represents the mechanical damping. The external force is related to the velocity dy/dt through the mechanical impedance of the load, $F = Z_{load}(dy/dt)$. In an equivalent circuit the terminals representing the connection of the mechanical load must therefore sustain the same velocity $dy/dt = u$ as the mechanical resistance R_m.

For sinusoidal operation at frequency $\omega/2\pi$, the equation for the free resonator becomes

$$P = (y/K)\{1 - (\omega/\omega_0)^2 + j/Q_m\} \quad (1)$$

where $\omega_0 = 1/(MK)^{\frac{1}{2}}$ is the radian frequency of mechanical resonance and $Q_m = 1/\omega R_m K$ is the mechanical quality factor.

The compliance K is that of the idealized half-limb of length b, cross section A and elastic modulus c

$$K = b/Ac$$

The magnetostrictive effect (in this model) is taken as confined to the limb. The direct, linear effect is characterized by the stress flux-density coefficient $h = (\partial T/\partial B)_S$, where T and S are respectively the stress and strain in the material. The driving force P in (1) is therefore determined by the total flux ϕ,

$$P = h\phi$$

hence

$$h\phi = (y/K)\{1 - (\omega/\omega_0)^2 + j/Q_m\} \quad (2)$$

When the magnetic material (of the limb) is strained, the inverse magnetostriction effect produces a proportional effective magnetizing force ΔH; it can be shown by thermodynamic argument, based on the principle of the conservation of energy, that the coefficient $(\partial H/\partial S)_B$ is also

* Mullard Research Laboratories.

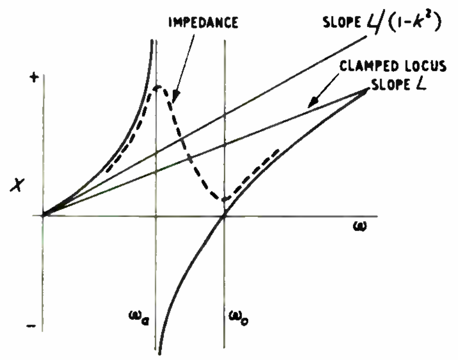


Fig. 4. Loss-free reactance diagram for Fig. 3

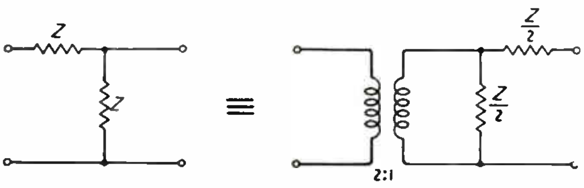


Fig. 5. A useful equivalence

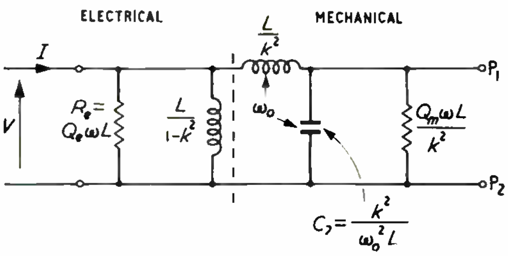


Fig. 6. Alternative circuit represented by equation (4)

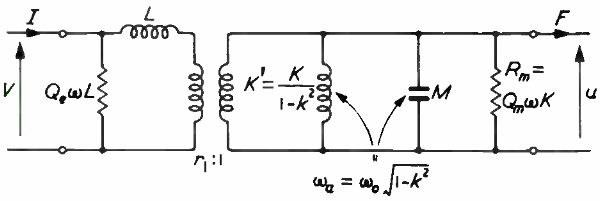


Fig. 7. First complete equivalent circuit of single-ended vibrator

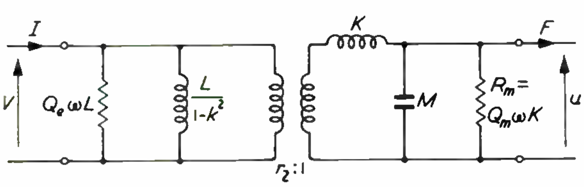


Fig. 8. Second complete equivalent circuit of single-ended vibrator

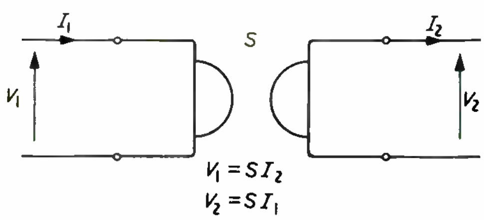


Fig. 9. Gyrator with gyration resistance S

equal to h. The mean strain in the limb, which determines the magnetostrictive magnetizing force, is y/b, so that

$$\Delta H = hy/b$$

The net magnetizing force is therefore

$$H = (NI + hy)/b$$

The reluctance of the flux return path can be allowed for in the effective permeability μ and the magnetic losses in the core material can be represented by using the complex permeability $\mu/(1 + j/Q_e)$, where Q_e is the electrical quality factor of a coil of negligible resistance wound on the core.

$$\phi = \mu AH/(1 + j/Q_e)$$
$$= \mu A(NI + hy)/b(1 + j/Q_e) \quad (3)$$

The terminal voltage of the coil is $V = j\omega N\phi$ and the self-inductance L of the coil with the core clamped is $L = \mu AN^2/b$. Using these and eliminating y between (2) and (3) gives

$$j\omega LI/V = 1 + j/Q_e - k^2/\{1 - (\omega/\omega_0)^2 + j/Q_m\} \quad (4)$$

where

$$k^2 = h^2\mu/c$$

This quantity k is the electro-mechanical coupling coefficient of the material of the limb. Note that k is unaffected by M, which only determines ω_0.

Equivalent Circuits

The impedance Z at the electrical terminals is, from (4)

$$Z = j\omega L/[1 + j/Q_e - k^2/\{1 - (\omega/\omega_0)^2 + j/Q_m\}] \quad (5)$$

The continued-fraction expansion of (5) gives directly, without approximation, the circuit of Fig. 3, for which the (loss-free) reactance diagram is Fig. 4.

Expanding (5) in a different order, or reversing the L-network of inductors in Fig. 3 and inserting the accompanying impedance transformation (Fig. 5) gives Fig. 6 which is exactly equivalent to Fig. 3.

In Figs. 3 and 6, the clamped value of Z is obtained by applying a short-circuit to the capacitance. An impedance representing an external mechanical load must therefore be connected to the points P_1P_2, which agrees with the location noted earlier. Moreover the short-circuit represents zero velocity, so the 'mobility' analogy applies, as expected. The capacitance therefore corresponds to the mass of the vibrator.

To show the values of the mechanical quantities explicitly and provide a mechanical port, an electro-mechanical transformer can be introduced giving Figs. 7 and 8, on which F and u are the force and velocity imparted to the mechanical load.

The turns ratio r_1 of the transformer in Fig. 7 is given by

$$M/r_1^2 = C_1 = 1/k^2\omega_0^2L$$

whence

$$r_1 = h\mu\, AN/b = k\sqrt{L/K} = hL/N$$

Similarly

$$r_2 = r_1/k^2 = cAN/hb = (c/h)\,(L/\mu N) = (1/k)\sqrt{L/K}$$

The first electro-mechanical analogy can be employed if a unit gyrator is added to the circuit. Fig. 9 defines a gyrator[4]. The usual negative sign is avoided by choosing the appropriate direction of I_2 as positive. The gyrator has the property of turning any impedance into its dual. A unit gyrator connected at the mechanical terminals interchanges the positions of F and u and so changes the representation to the first analogy. Moving the gyrator back into the circuit and combining it with the electro-mechanical transformer gives the exact equivalent circuits of Figs. 10 and 11.

Double-Ended Vibrator

Most magnetostrictors are double-ended, represented approximately by Fig. 12. If the *total* mass is M ($M/2$ at

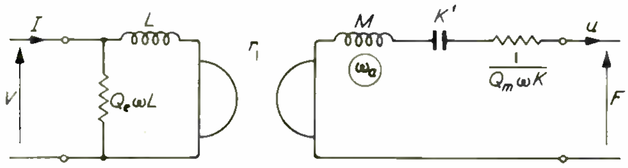


Fig. 10. First complete equivalent circuit of single-ended vibrator (with gyrator)

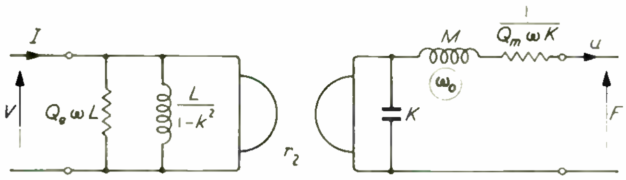


Fig. 11. Second complete equivalent circuit of single-ended vibrator (with gyrator)

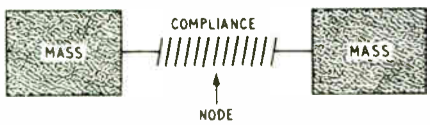


Fig. 12. Lumped approximation to Fig. 1

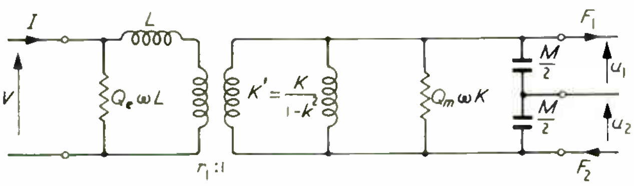


Fig. 13. Full equivalent circuit of double-ended vibrator

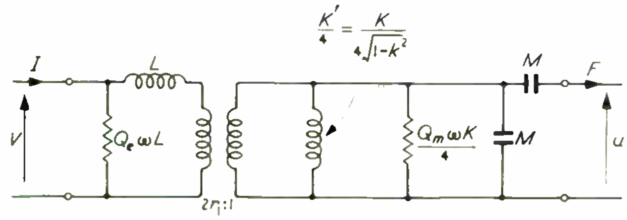


Fig. 14. Two-port equivalent circuit of double-ended vibrator

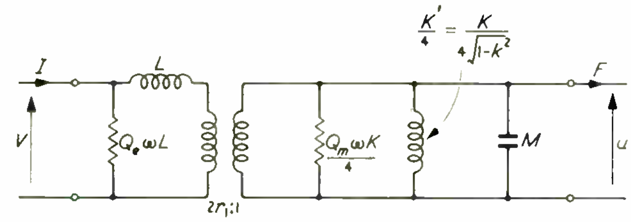


Fig. 15. Two-port equivalent circuit for lightly-loaded vibrator

each end) and the *total* end-to-end compliance is K, the resonant frequency is given by $\omega_0^2 = 4/MK$; the double-ended vibrator is equivalent to two single-ended vibrators each with half the total mass and compliance. The equivalent circuit for a double-ended vibrator can be constructed by drawing Fig. 7 twice and combining the elements. The same result is, of course, obtained by a direct analysis on the lines given earlier.

The result is shown in Fig. 13. The directions of u_2 and F_2 correspond with measuring all forces and velocities outwards from the middle of the vibrator.

When interest is focused on one mechanical port, it is convenient to transform Fig. 13 into Fig. 14 by means of the equivalence of Fig. 5. When the mechanical impedance of the load is fairly low, e.g. when the loaded Q_m of the transducer is greater than 10 and the load is resistive, the series capacitance M has a negligible effect and may be omitted, giving Fig. 15. Thus Fig. 7 may be taken as the equivalent circuit with the following changes: the transformer ratio is $2r_1$ (not r_1); the compliance is $K/4$ (not K). Figs. 8, 10 and 11 also apply provided similar changes are made. A gyrator can be introduced if desired: it should be emphasised that no other way of changing to the first electromechanical analogy gives an 'exact' equivalent circuit.

Effective Values of K and M

The analysis leads to equivalent circuits with element values depending on K and M. Since a real magnetostrictor does not have perfectly lumped elements, these circuit values must be interpreted as the effective or equivalent values. These can be derived with the aid of energy considerations for a given configuration, the basis being that M is the repository of all the kinetic energy and K of all the elastic energy.

If the circuits are used to interpret electro-mechanical measurements on a transducer, the effective values will be obtained directly.

Resonant Frequency

Assuming continuity of force and displacement at the junction of the end mass, resonance occurs when the reactances presented to the junction by the two parts are equal in magnitude. If the radian length of the limb is θ_1 (i.e. $\theta_1 = 2\pi b/\lambda = \omega b/v$, where v is the velocity of compression waves in the material), the compliant reactance is $1/\omega K_1$ where

$$K_1 = K_0(\tan\theta_1)/\theta_1$$

Similarly for the massive reactance ωM_2

$$M_2 = M_0(\tan\theta_2)/\theta_2$$

For a length of $0{\cdot}1\lambda$, $\theta = 0{\cdot}2\pi$ (36°) and the factor is 1·15. The frequency calculated from K_0 and M_0 would then be about 15% too high; in practice, the error would probably be greater, perhaps 20%, since one of the lengths is often somewhat greater than $0{\cdot}1\lambda$.

Acknowledgment

The author wishes to thank Mr. C. M. van der Burgt for valuable discussions.

References

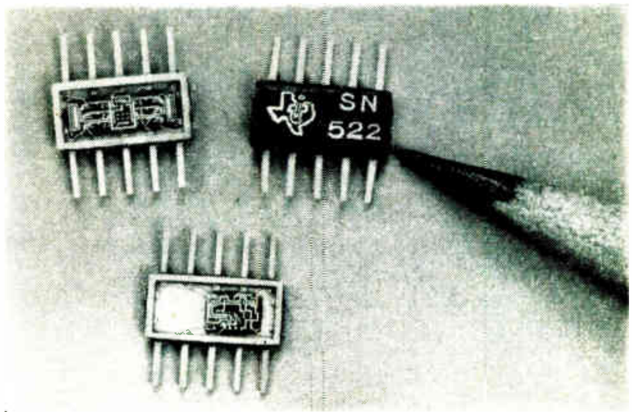
[1] Camp, L., *Journ. acoust. Soc. Amer.*, 1948. Vol. 20, p. 616.

[2] Mason, W. P., 'Electromagnetic transducers and wave-filters', van Nostrand, New York, 1948. 2nd Edn., p. 215.

[3] Nodtvedt, H., 'Magnetostrictive vibrating systems', N.D.R.E., Oslo, 1957. Div. A. Rep. No. 116.

[4] Tellegen, B. D. H., 'The gyrator', 1948. *Philips Res. Rep.* R. 73.

SOLID CIRCUIT AMPLIFIERS



THE solid circuit has been described as the ultimate in micro-miniature electronics: certainly, for applications in which weight and space are at a premium, it is one of the most promising techniques. A number of companies are working in this field, but as yet production has been only on a relatively small scale. High reliability is one of the advantages claimed for solid circuits and this may justify their use even when the requirements of weight and space are not very stringent.

Texas Instruments, who have already produced a range of digital logic 'blocks' such as Flip-Flop/Counter units, NOR/NAND gates and an exclusive-OR gate, have recently announced the development of two solid-circuit linear amplifiers. Although contained in the same size capsule, the circuit blocks themselves are about half the size of the previous units—as can be seen from the photograph in which one of the new amplifier circuits is shown for comparison below a digital circuit. Both of the new circuits are d.c. amplifiers, the difference being that one has an emitter-follower output stage (Figs. 1 and 2). They represent the amplifiers most commonly used in analogue-to-digital converters, feedback amplification, integration, differentiation, etc., and they are also claimed to be suitable for servo and other forms of drive amplification.

Each solid-circuit amplifier consists of two p-n-p and five n-p-n transistors diffused into a single block of silicon with six tapped resistors (values from 5 kΩ to 50 kΩ). Aluminium leads are used for the interconnections. Manufacture involves the accomplishment of four interrelated planar diffusions, with five material layers and four junctions. The main characteristics are as follows: an open-loop voltage gain of 62 dB and common mode rejection of 58 dB, a half-power frequency point of 60 kc/s, a differential input impedance of 18 kΩ, and a d.c. drift of 10 μV/°C referred to input. Capsule dimensions are $\frac{1}{4}$ by $\frac{1}{8}$ by $\frac{1}{32}$ in. with a total weight of less than 0·1 gm.

For further information circle 57 on Service Card

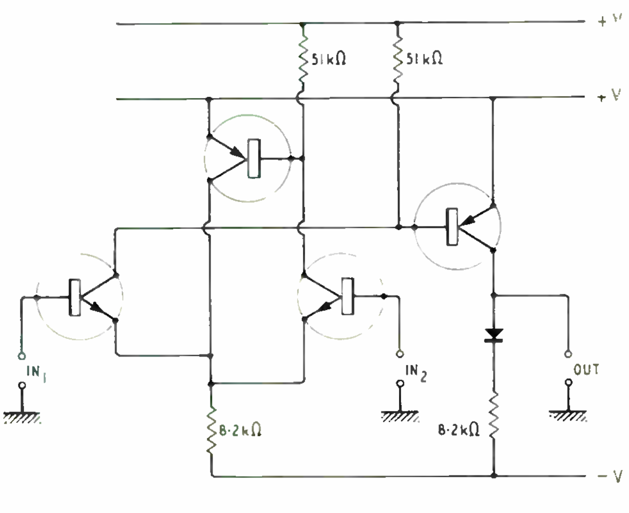


Fig. 1. Basic amplifier

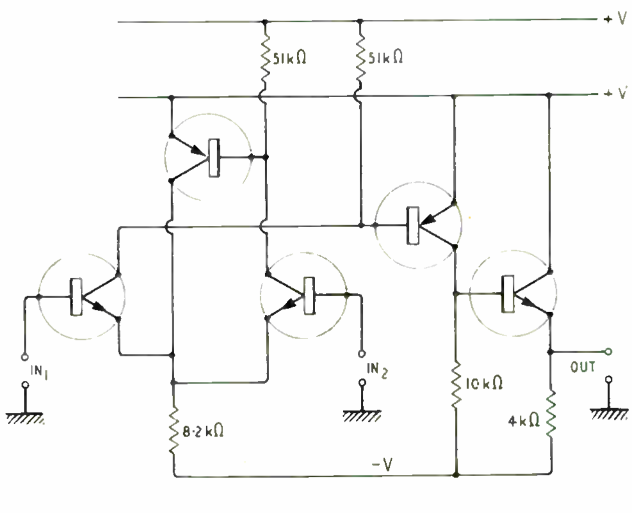


Fig. 2. Basic amplifier with emitter-follower output stage

INDUSTRIAL NEWS

Personal and Company News

W. C. Handley, B.Sc.Tech., M.I.E.E., has resigned his position as chairman of **Telcon Metals Ltd.** He is succeeded by C. O. Boyse, B.Sc.(Eng.), M.I.C.E., M.I.E.E., Fel.A.I.E.E.

George Kent Ltd. has acquired the whole issued share capital of Alto Instruments (Great Britain) Ltd., whose name now becomes George Kent (Stroud) Ltd.

Walmore Electronics Ltd. has been appointed the sole U.K. distributors for Raytheon-Elsi.

F. W. Alexander, Ph.D., B.Sc., A.M.I.E.E., has been appointed superintendent engineer, Sound Broadcasting (Equipment) consequent upon a re-organization of the Engineering Division of the B.B.C.

C. F. Taylor (Electronics) Ltd., of Molly Millars Lane, Wokingham, Berks., is a new company in the C. F. Taylor organization.

Wilmot Packaging Ltd., of Totton, Southampton, has formed an electronics division to specialize in the construction of prototypes and pre-production quantities of electrical and mechanical equipment for research establishments.

J. G. Owen, of Painton & Co. Ltd., has become general manager of **Painton S. A.,** 11 rue Keyenveld, Brussels.

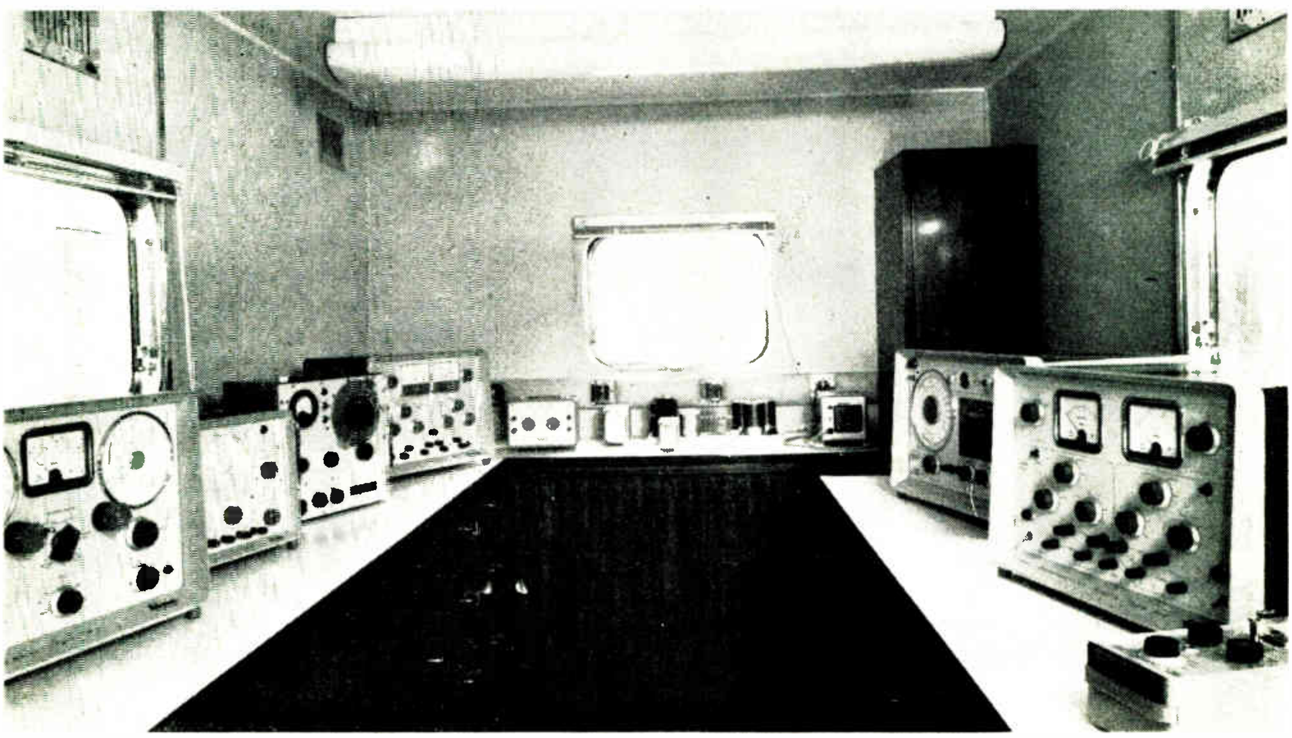
The general sales office of **McMurdo Instrument Co. Ltd.** has been transferred to Rodney Road, Portsmouth, Hampshire (Telephone: Portsmouth 35555).

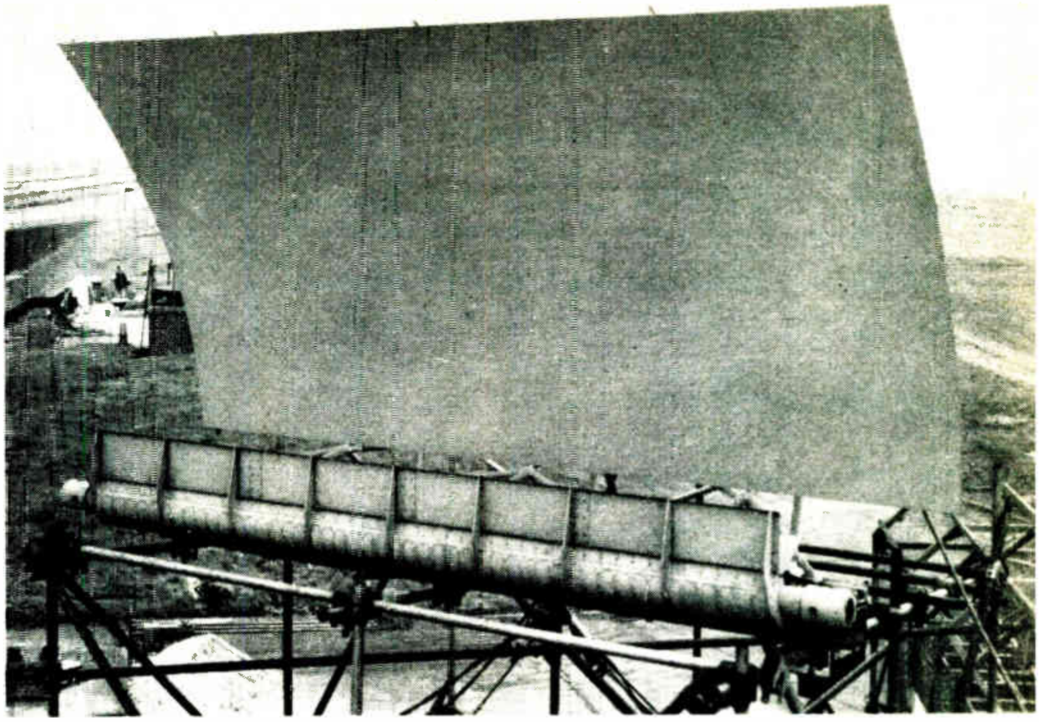
Chilton-Solenoid (U.K.) Ltd. has appointed W. M. Chambers as technical representative for London and South-East England.

Wilfred Padley has been appointed joint managing director of **Metal Industries Ltd.** with John Black.

The aircraft equipment department of **Ferranti Ltd.** has moved to Western Road, Bracknell (Telephone: Bracknell 2020). The engineering services division has also moved to 'Westwick', Bagshot Road, Bracknell (Telephone: Bracknell 1212).

Advance Components mobile exhibition is housed in a vehicle 22 ft. long by 7 ft. 6 in. wide. It enables engineers to study working examples of Advance and Nagard products and it will go by invitation to any interested firm





Faster air traffic control is promised by this new Marconi aerial. Instead of tilting the aerial for height finding the radiated frequency is varied. The aerial is designed so that the vertical angle of the lobe is a function of frequency. Either a helically-wound delay line or zig-zag coaxial delay lines are used to illuminate the aerial

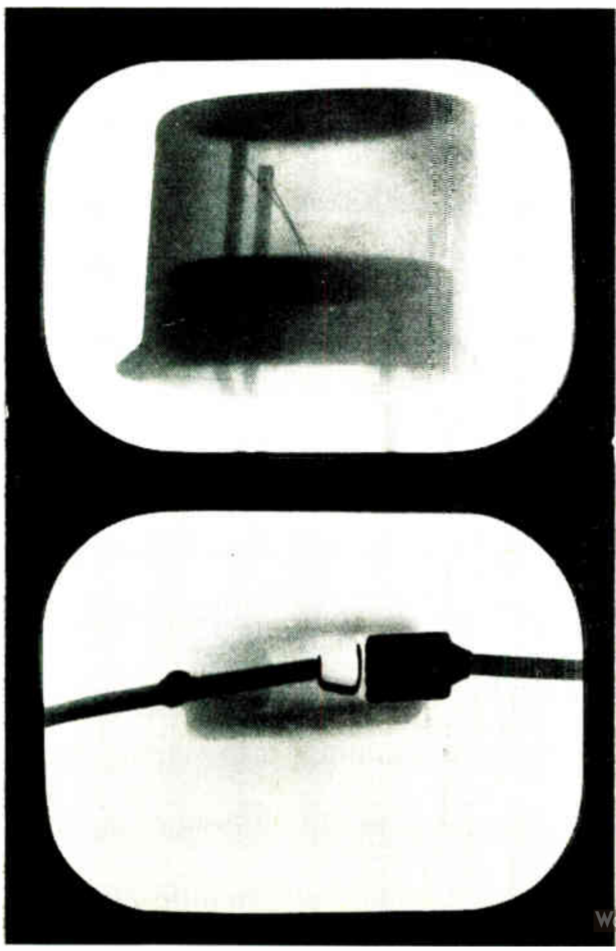
For further information circle 58 on Service Card

G. C. Willingham, Assoc. Brit. I.R.E. has been appointed sales manager of the Sonics Division of **Elliott Bros. (London) Ltd.**

P. Allen Bennett Ltd. Speecon Works, Minto Road, Sheffield, are now agents for the A.E.I. Logicon static switching system, and also design and manufacture equipment incorporating this form of static logic.

Machlett Laboratories Inc. have developed a vidicon sensitive to X-rays. The pictures show views of a transistor and a diode after encapsulation. Magnification up to 50 times is possible and wires down to 0·002 in. in diameter can be seen

For further information circle 59 on Service Card



Vitramon Laboratories Ltd., of 45 Holloway Lane, Harmondsworth, Middlesex, is a wholly-owned subsidiary of Vitramon Inc., Bridgeport, Connecticut, U.S.A. Initially, it will market VY porcelain and VK ceramic capacitors but it is intended later to manufacture these components.

Carrington Compatible Components Ltd. have acquired new premises at 15 Station Road, Reading (Telephone: Reading 51866) and E. Brown Dickson has been appointed managing director.

R. P. Taylor, B.Sc.(Hons.), A.C.G.I., A.M.I.Mech.E., becomes managing director of **Vidor.**

Electrosil Ltd., of Colnbrook By-pass, Colnbrook, Slough, are agents for the Corning Glass Works of America.

G. H. J. Munro has been appointed managing director of **Aircraft-Marine Products (Great Britain) Ltd.**

Subsequent to the acquisition of the McMurdo Instrument Co. Ltd. by Louis Newmark Ltd. the sale of precision wirewound resistors has been taken over by **Harwin Engineers Ltd.,** Rodney Road, Portsmouth.

London Electrical Manufacturing Co. Ltd. has acquired the Universal Capacitor Co. Ltd. of Swindon. Orders for U.C.C. capacitors should now be addressed to Lemco at Bridges Place, Parson Green Lane, London, S.W.6.

Sperry Gyroscope Co. Ltd. has opened new offices at 89 West Regent Street, Glasgow, C.2.

R. G. Wheeler has been appointed publicity manager of **Johnson, Matthey & Co. Ltd.**

John Bunton, M.A., M.I.E.E., A.Inst.P., has been appointed secretary of **Mullard Ltd.**

Associated Electrical Industries Ltd. is concentrating the development and supply of automation systems in A.E.I. Automation Ltd. at Booths Hall, Knutsford, Cheshire. The sales staff of the vacuum products and X-ray departments of A.E.I. have moved to Watling Street, Motherwell, Lanarkshire (Telephone: Motherwell 4571).

H. C. Maguire has been elected to the boards of the **Radio Communication Co. Ltd.** and **The Marconi Sounding Device Co. Ltd.**

A reciprocal marketing agreement has been arranged between **G. & E. Bradley Ltd.,** of Electral House, Neasden Lane, London, N.W.10, and the **Société Ribet-Desjardins,** of Département Mesure Contrôle, 13-17 rue Périer, Montrouge (Seine), France.

Obituary

Sir Isaac Schoenberg, a director of Electric & Musical Industries Ltd., died on 25th January. Born at Pinsk, Russia, in 1880, he studied mathematics, mechanical engineering and electricity at the Technological Institute of Kiev and then joined a Russian company, where he was responsible for the design and installation of early Russian wireless stations.

Sir Isaac settled in England in 1914 and became a British subject in 1919. At first he worked for the Marconi Company, but in 1928 he joined the Columbia Gramophone Company as general manager. In 1931 that company merged with the Gramophone Company to become E.M.I. Ltd., to which he became director of research. He was elected a director of E.M.I. in 1955.

Sir Isaac led the E.M.I. team of scientists and engineers which developed the 405-line television system adopted by the B.B.C. in 1936 for the world's first regular public high-definition television service. In consequence of this he was awarded the Faraday Medal by the Institution of Electrical Engineers in 1954 for his work on television.

Liquid Laser

Hughes Aircraft Co. announce the development of a laser using organic liquids. So far coherent light has been obtained at 13 different wavelengths and it is possible that this may be extended to hundreds of wavelengths. The Raman effect is employed with liquids such as benzene, nitrobenzene, toluene, one-bromonaphthalene, pyridine, cyclohexana and deuterated benzene.

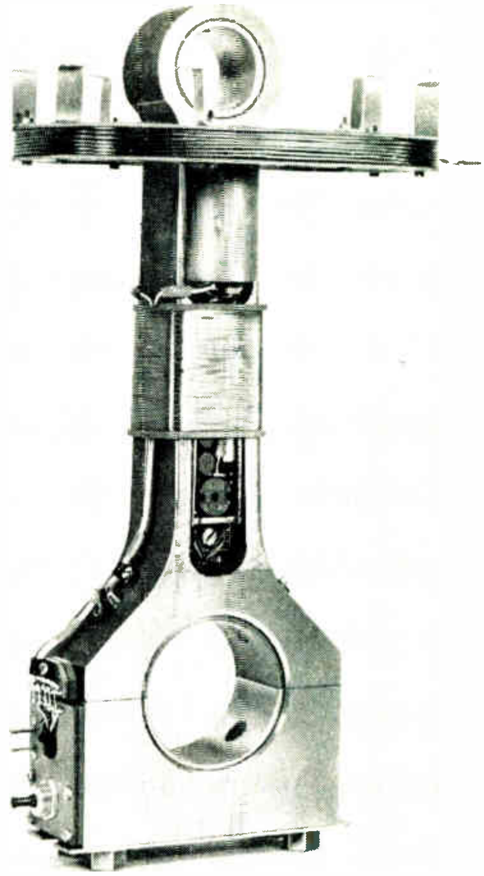
Pumping to a higher energy level is not necessary, but an equivalent is required. Strong incident light is needed to initiate laser action and this is obtained from a high-power short-pulse ruby laser. The applications of the device seem likely to be mainly in materials research.

Exhibitions

The London International Engineering Exhibition will be open from 23rd April to 2nd May at both Earl's Court and Olympia. It incorporates the former Engineering, Marine, Welding and Nuclear Energy Exhibition.

The Business Efficiency Exhibition will be open from 1st to 6th April at the Kelvin Hall, Glasgow. The exhibits will include electronic computers, dictating apparatus and photocopying equipment.

The Research-Development-Production Exhibition will be open from 4th to 9th May at the National Hall, Olympia. It is intended to bridge the gap between laboratory research and industrial production and to show ideas designed to improve the manufacture of new products and processes.



Telemetry can be used over short distances as well as long. Here it is employed in the measurement of oil-film thickness in a big-end bearing and also connecting-rod stress. The receiving loop is shown at the top of the picture and the transmitting loop wound around the connecting rod. E.M.I. Electronics are using the method with a 100-kc/s frequency-modulated oscillator as transmitter

For further information circle 60 on Service Card

Timetable Production

British Railways announce that they are, for the first time, using a computer to produce train timetables and the related working schedules. These timetables are to cover the East Coast route to Edinburgh and the whole Great Northern line of the Eastern Region, including the Sheffield area and Lincolnshire. The first timetable so produced will come into force in June this year.

Normally almost a year elapses between starting the compilation of a timetable and its publication. The use of a computer is expected to reduce this time by some 10 weeks and also to require a smaller staff.

A Ferranti Pegasus 2 computer is being used, and in addition to the timetable it produces locomotive working schedules and crew rostering arrangements. It also, for example, solves the problems of the intricate platform working at King's Cross station

U.K. Agent Wanted

Jay-El Products Inc. are looking for an agent or representative in the United Kingdom. The firm designs and manufactures electronic components and sub-assemblies, including annunciator systems, solid-state time-delay relays, switches, control devices and miniature electrical connectors. The address is 1859 West 169th Street, Gardena, California, U.S.A.

NEW BOOKS

Electron Devices and Circuits

By JOHN M. CARROLL. Pp. 344 + vii. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 46s. 6d.

Of American origin, this book is intended as a basic text at the junior college and technical institute level. It is virtually non-mathematical in spite of the fact that one or two integral equations appear, notably in electricity and magnetism, and matrix algebra rears its head in transistor circuitry.

After dealing with the atomic basis of electron devices and electricity and magnetism, there are eight chapters which cover the various types of device from ordinary valves to masers and parametric amplifiers. Then comes an introduction to electronic circuits, followed by chapters on amplifiers, oscillators, modulators and demodulators and, finally, power supplies.

The treatment is largely explanatory and the book should form a good introduction to the subject.

Elements of Infra-red Technology

By PAUL W. KRUSE, LAURENCE D. MCGLAUCHLIN and RICHMOND B. MCQUISTAN. Pp. 448 + xxi. John Wiley & Sons Ltd., Greencoat Place, London, S.W.1. Price 81s.

The subject of this book is the generation, transmission and detection of infra-red waves. It is not unduly highbrow in spite of the fact that mathematics is freely used and the list of symbols occupies five pages! The first main chapter deals with infra-red sources and there are then three chapters on the infra-red optical properties of media, including the atmosphere. A chapter on the physics of semiconductors follows and then one on sources of noise. Detection mechanisms are considered in the final three chapters, the last of which deals with the comparative performance of elemental detectors. Appendixes giving useful engineering approximations are included.

The book is a serious one and should be of importance to anyone seriously interested in infra-red work who has the necessary mathematical equipment. A good deal of useful information can be obtained from it, however, even if the reader has certain weaknesses on the mathematical side.

Automatic Control Handbook

Edited by G. A. T. BURDETT. Pp. 864 + xviii. George Newnes Ltd., Southampton Street, London, W.C.2. Price 90s.

There are twenty-one sections in this book, ranging from electric motors and control systems to closed-circuit television. On the way, it takes in such diverse subjects as lubrication and gyroscopes. The different sections are by different authors and, as usually happens in such a case, they vary considerably both in style and in level.

Throughout, the treatment is fairly elementary and is mainly of a descriptive character; only occasionally do a few equations enter. The longest section is that devoted to relays and solenoids (90 pages), followed by the one on hydraulic power units and servos (72 pages); the shortest is the one on machine-tool programming, which is of only six pages. In a general book of this nature 60 pages devoted to the specialized subject of gyroscopes seems rather many when, for example, counting devices are given only 18, especially when everything from scales of notation to transistor circuits is included under this heading. It is a minor inconvenience that the pages are not numbered sequentially; the numbering starts afresh in each section.

The book is clearly intended for readers having a moderate technical knowledge. This does not mean, however, that even advanced workers will not find it useful. The advanced worker in one speciality may have but rudimentary knowledge of others, and with so wide a range of subjects as that in this book, he may well find it a useful introduction to those others.

Electromagnetic Theory

By ERIK HALLEN. Pp. 621 + xiv. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 126s.

In his preface, the author states that this book is largely based on lectures given at Uppsala University and at the Royal Institute of Technology in Stockholm. He also says that some parts of the book have been previously published.

The name of Hallen is so well known in the field of aerial theory that it is in itself a guarantee of a serious and comprehensive treatment of the subject. The book is divided into six sections, namely, electrostatics, direct current, stationary electromagnetism, electromagnetic induction, steady-state alternating currents and electromagnetic field theory. Free use is made of mathematics. The author says that the mathematical ability required of the reader is usually restricted to a knowledge of differential and integral calculus, ordinary differential equations and vector analysis. When dealing with aerials, however, more advanced mathematics becomes necessary.

One unusual feature of the book is pointed out in the preface. This is an inversion of the customary meanings attached to **H** and **B**. The magnetic field vector **B** is called alternatively magnetic field strength and magnetic flux density; the other vector **H** is called, alternatively, magnetizing field and ampere-turn density. The author makes the point that it is **B**, rather than **H**, which is a field strength.

This is not just a symbol inversion; **B** and **H** appear normally in all equations and therefore represent the same physical phenomena as usual. What is unusual is the explanation of the nature of these phenomena. The author claims that the change obviates many difficulties in teaching. This is a matter open to argument. What is certain is that it creates many difficulties for those who are accustomed to the ordinary explanations.

Switching Circuits for Engineers

By MITCHELL P. MARCUS. Pp. 296 + xiv. Prentice-Hall International Inc., 28 Welbeck Street, London, W.1. Price 50s.

As is the usual practice in modern books on switching, the starting point is two chapters on Boolean algebra occupying 32 pages. Chapter 3 is called 'Logical Circuits' but this is a misnomer for it does not deal with circuits at all; the nearest it comes to it is to have a box labelled 'switching circuit' and to have various boxes connected together. It actually deals with and, or, nor and nand functions with Boolean algebra and truth tables, as well as with negative and mixed logic.

'Transistor logic blocks' follows and here circuits are introduced, but there are only ten pages of diode, valve and transistor circuits. Chapter 5, surprisingly, deals with 'Contact networks' by which is meant ordinary relays. It is, again, a short one.

The rest of the book deals with ways of simplifying and manipulating Boolean expressions, maps, number systems, codes and sequential systems. Circuits hardly enter and the treatment is entirely in a special brand of mathematics. Few will make any headway with the book until they have become thoroughly familiar with Boolean algebra.

Characteristics of Sylvania Receiving Tubes

Pp. 54. Sylvania Electric Products Inc., 1100 Main Street, Buffalo 9, New York, U.S.A. Price 25 cents.

'This booklet contains the very latest television and radio receiving tubes in addition to many industrial tubes. It is intended as a quick reference to pertinent characteristics and basing connections.'

Taschenbuch der Hochfrequenztechnik

By H. MEINKE and F. W. GUNDLACH. Pp. 1641 + xxxi. Springer-Verlag, Heidelberger Platz 3, Berlin-Wilmersdorf, Germany. Price DM 97.50.

Manufacturers' Literature

Plessey Communications Receiver. The Type PR152 transistor receiver is suitable for reception of AM, MCW and CW signals on the MF and HF bands. Full specifications are given in a 2-page leaflet.
Telecommunications Division, The Plessey Co. (U.K.) Ltd., Ilford, Essex.

For further information circle 61 on Service Card

TMC Extensible Line Connector. This 6-page leaflet describes how a full telephone service can be provided for up to 22 subscribers with a maximum of four exchange lines. Some typical trunking schemes are shown in block diagrams.
Telephone Manufacturing Co. Ltd., Martell Road, West Dulwich, London, S.E.21.

For further information circle 62 on Service Card

Miles Merlin Electro-Mechanical Actuators. This 10-page catalogue lists the current range of Miles electro-mechanical actuators. The actuators are designed with interchangeable standard parts. It is claimed that because of this 10,000 versions are available to designers.
Miles Hivolt Ltd., Old Shoreham Road, Shoreham-by-Sea, Sussex.

For further information circle 63 on Service Card

Imhofs Instrument Cases. Imhofs have just published a new 48-page catalogue on their range of ready-made instrument cases. Lavishly illustrated, this contains full details of over a hundred cases. These vary from their smallest ($3 \times 1\frac{5}{8} \times 2\frac{1}{4}$ in.) to a case nearly 55 in. high that will accept five $10\frac{1}{2} \times 19$ in. panels.
Alfred Imhof Ltd., Ashley Works, Cowley Hill Road, Uxbridge, Middlesex.

For further information circle 64 on Service Card

Two-Way Mobile 'Outercommunications' System. Outercom Electronics Corporation have produced three leaflets describing the latest additions to their range of two-way radio communications systems. These include models for operation at 25 to 54 Mc/s, 148 to 174 Mc/s and 450 to 470 Mc/s.
Distributed by: *Rocke International Corporation, 13 East 40th Street, New York 16, N.Y., U.S.A.*

For further information circle 65 on Service Card

Electronics Versatile By Airtech. This 10-page brochure gives some details of the products and services of:
Airtech Ltd., Haddenham, Bucks.

For further information circle 66 on Service Card

RCA Computer Memory Systems. An 8-page brochure gives details of the RCA MS series computer memory systems, including optional extras.
RCA International Division, 30 Rockefeller Plaza, New York 20, N.Y., U.S.A.

For further information circle 67 on Service Card

Pye Ingold pH Electrodes and Accessories. A short-form 8-page catalogue which describes the new range of Pye Ingold pH electrodes and accessories, manufactured to the specifications of Dr. Werner Ingold of Zurich. These include low and high temperature and industrial electrodes.
W. G. Pye & Co. Ltd., Granta Works, York Street, Cambridge.

For further information circle 68 on Service Card

Weir Proximity Switch. This single leaflet gives details of a proximity switch, rated at 5 A 250 V a.c., which has been designed as a replacement for mechanically-operated limit switches and photoelectric switches.
G. & J. Weir Ltd., Cathcart, Glasgow.

For further information circle 69 on Service Card

Synchro and Servomotor Broadsheet. This 22 × 11 in. broadsheet gives the salient details of over 100 Muirhead synchros and servomotors. This is available as a fold-out leaflet or a wall-hanging chart.
Muirhead & Co. Ltd., Beckenham, Kent.

For further information circle 70 on Service Card

Vacuum Variable Capacitors. A 6-page leaflet which describes a range of vacuum variable capacitors, produced by English Electric. All of these capacitors are rated to carry 40 A at frequencies up to 27 Mc/s.
English Electric Valve Co. Ltd., Chelmsford, Essex.

For further information circle 71 on Service Card

Fluxes for Electrical Work. In this 16-page booklet some details are given of Fry's 'Alcho-Re' soldering fluxes and their application to a number of different types of electrical connection.
Fry's Metal Foundries Ltd., Tandem Works, Merton Abbey, London, S.W.19.

For further information circle 72 on Service Card

Londex Relays and Electrical Automatic Control Apparatus. As a guide to those who use or who are contemplating using automatic electrical control apparatus, Londex have published this 56-page booklet. It contains the specifications for the relays, timers, photoelectric devices, counters, fluid and gas control devices and many other control units which are marketed by:
Londex Ltd., 207 Anerley Road, London, S.E.20.

For further information circle 73 on Service Card

Theta Decitrak. In this 12-page leaflet the 'Decitrak' shaft-position encoder is described along with one or two applications. Basically this is a device that converts shaft position into decimal code directly: the angle of rotation is presented on a numerical display unit.
Theta Instrument Corporation, 520 Victor Street, Saddle Brook, New Jersey, U.S.A.

For further information circle 74 on Service Card

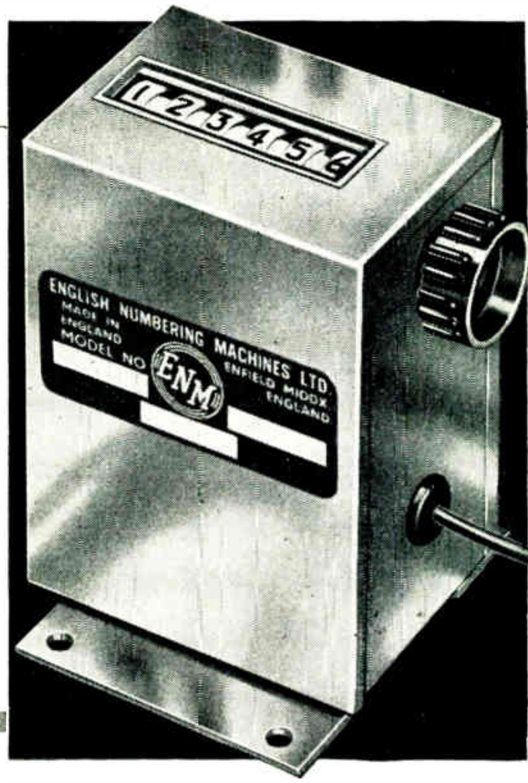
Counting Made Easy. A 4-page leaflet giving brief details of the counters and accessories produced by:
Radiovisor Parent Ltd., Stanhope Works, High Path, London, S.W.19.

For further information circle 75 on Service Card

Relays—Technical Information. This is a 42-page manual which describes a comprehensive system of plug-in relays and related units, with accessories for pre-assembling and wiring them in groups.
D. Robinson & Co. Ltd., 5/7 Church Road, Richmond, Surrey.

For further information circle 76 on Service Card

Electro-Magnetic COUNTERS



MODEL 442

6 figures — adds or subtracts
Resettable by hand — or non-resettable
Standard Model — up to 500 counts per min
High Speed Model — up to 1000 counts per min
Standard Voltages

DC	12v	24v	48v	110v	
AC	115v	230v	50c/s	115v	60c s

Base or Panel Mounted
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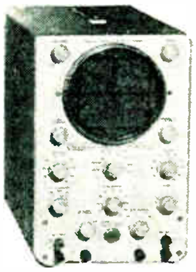

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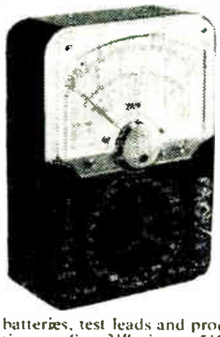

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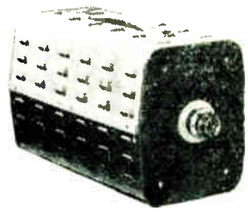

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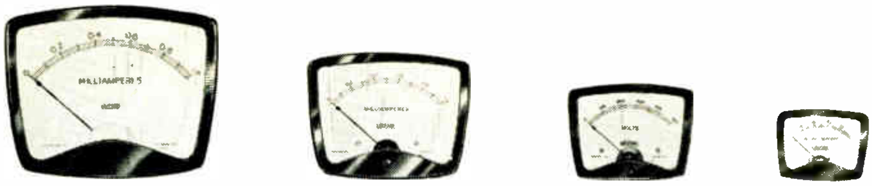

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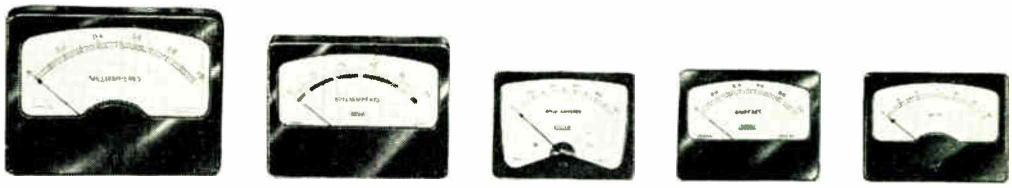

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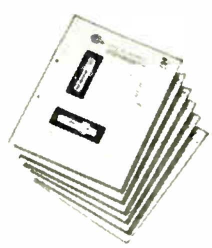

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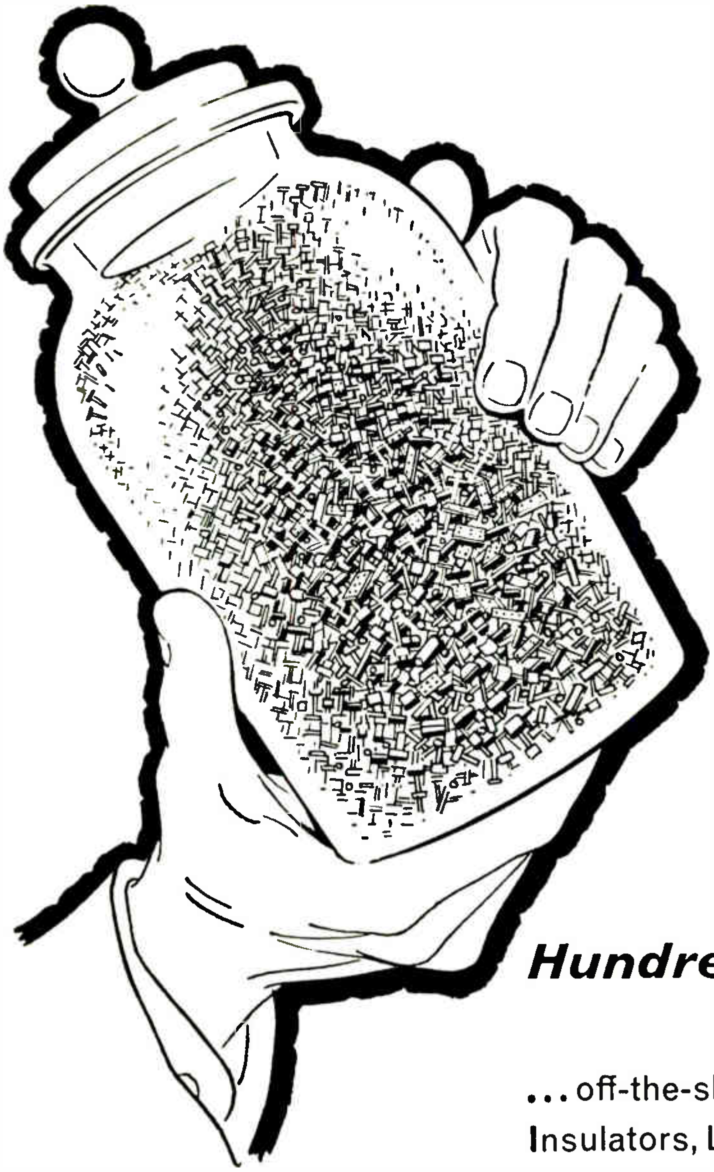

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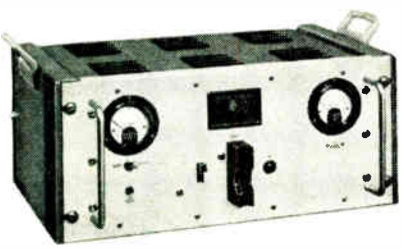

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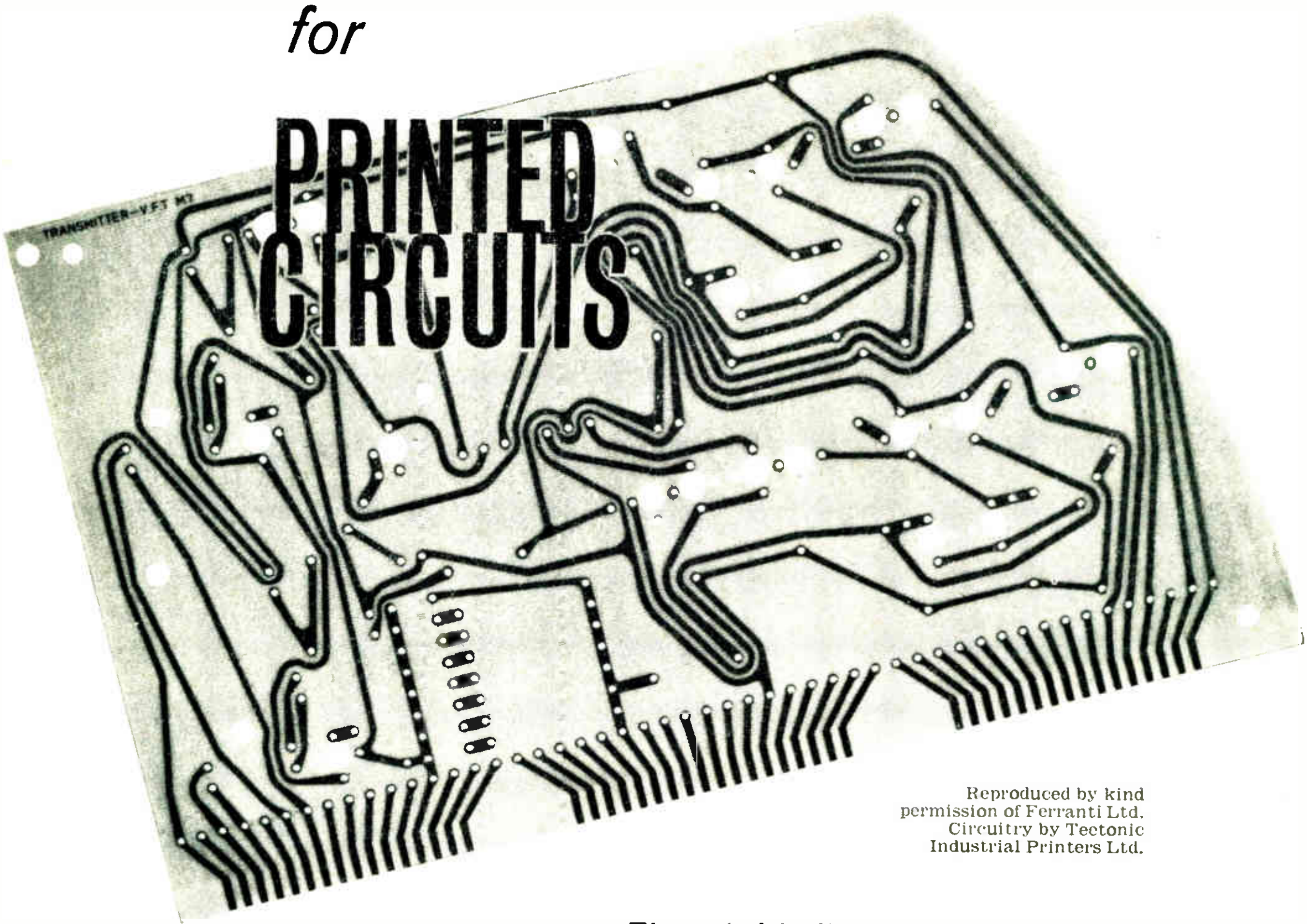

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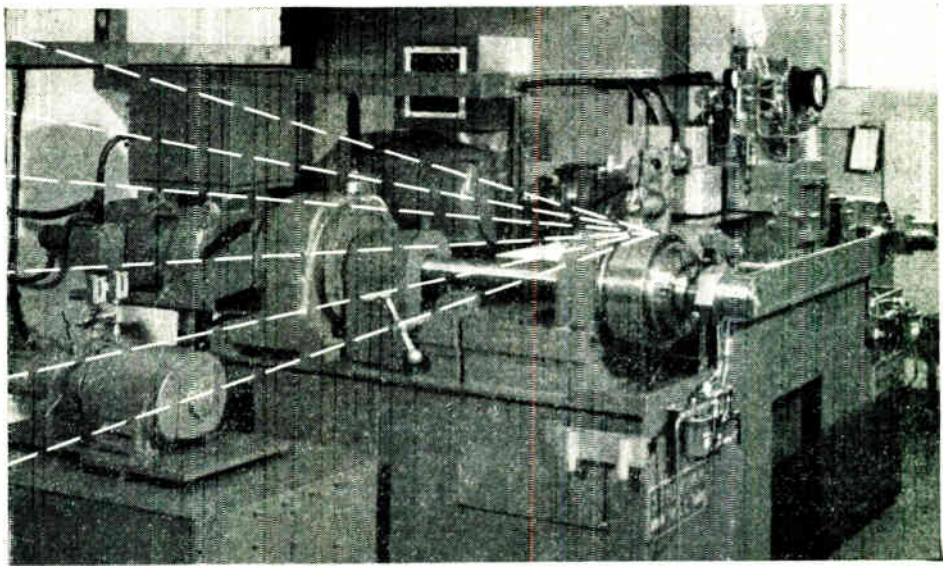

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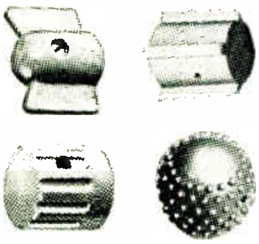

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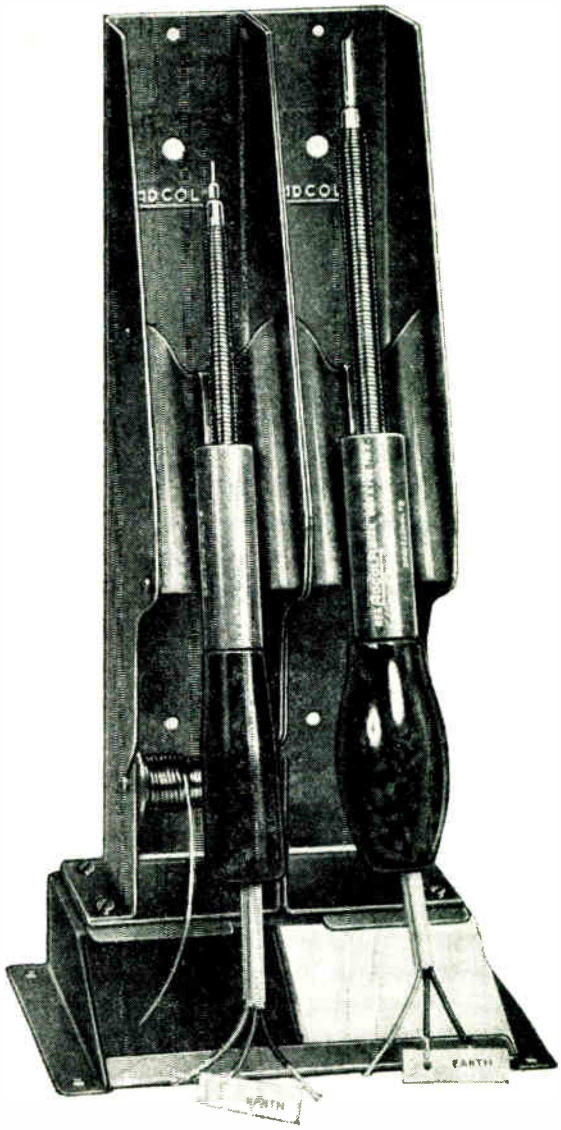

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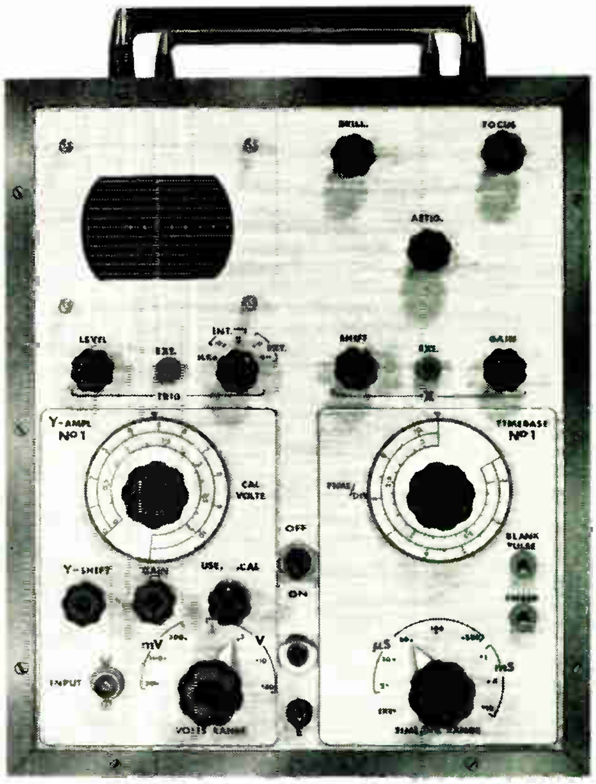

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A limited number of postgraduate awards is available, covering tuition fees, board-residence in Hall and personal grants.
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PATENTS

Patent No 766,033 entitled "Improvements in or relating to Piezo-Electric Crystals" is for sale or licence. For details apply to CHATWIN & COMPANY, Chartered Patent Agents, 253, Gray's Inn Road, London, W.C.1. [2018

BOOKS, ETC.

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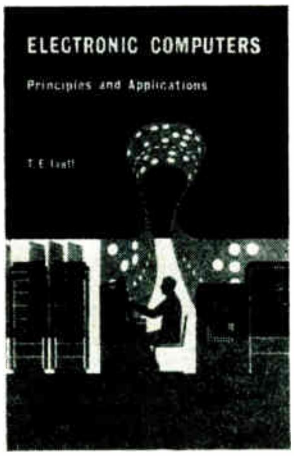

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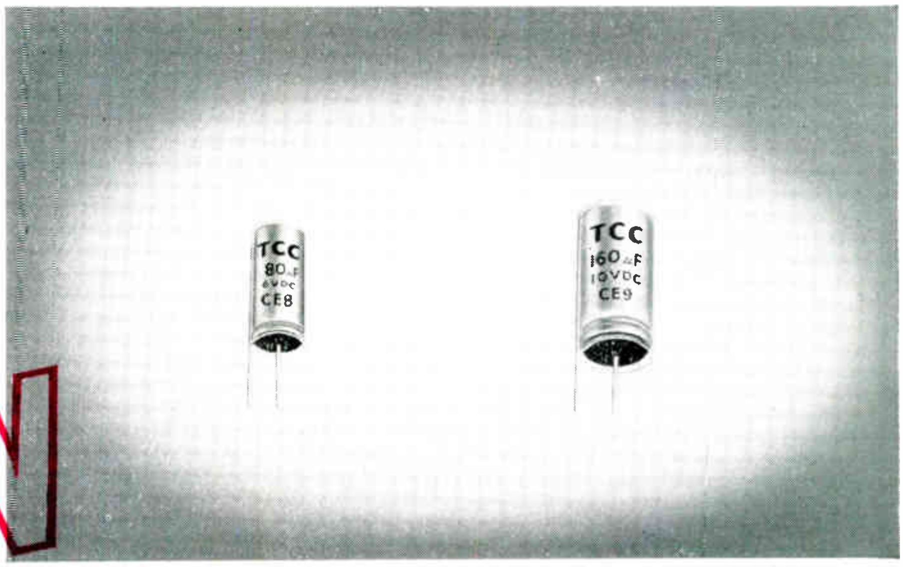

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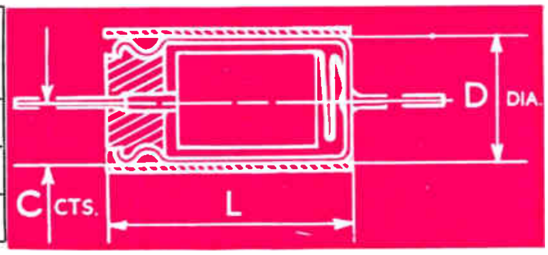
	D	L	C	3V.	6V.	10V.	15V.	25V.	50V.
CE.8	$\frac{1}{4}$	$\frac{3}{4}$	0·14	100	80	60	40	25	8
CE.9	$\frac{3}{8}$	$\frac{3}{4}$	0·2	250	200	160	100	60	20



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