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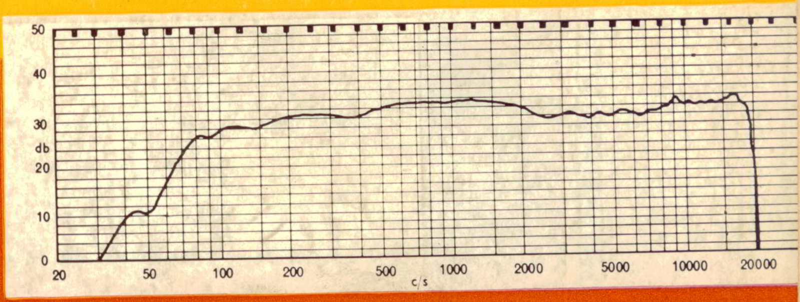

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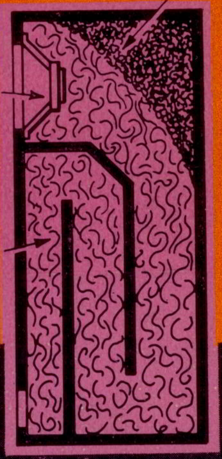

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Wireless World

ELECTRONICS, TELEVISION, RADIO, AUDIO

JUNE 1966

265 "Hall Mark" for Instruments

266 Automatic Gain Control in Transistor Receivers *by K. R. Sturley*

269 Audio Fair Review

272 Matching the C.R.T. Display to the Viewer *by D. W. Kahan*

274 Hill Climbing in Control Systems *by K. C. Ng*

284 Demonstrations at V.L.F. *by T. Palmer*

286 Semiconductors in Electronic Organs *by T. D. Towers*

291 I.E.A. Exhibition Guide

313 A Spark Micro-engraving Technique for Thin-film Circuits

314 Pickup Arm Design—2 *by J. K. Stevenson*

321 The Root-locus Technique *by W. Tusting*

328 Electronics and Shipping

SHORT ITEMS

278 C.E.I. Common Examination

282 Quartz Band-pass Filter

283 LC Networks in TO-5 Cases

283 High-capacity Coaxial Cable

285 Transducers for Fluid Logic Systems

REGULAR FEATURES

265 Editorial Comment

278 World of Wireless

280 Personalities

282 HF Predictions

282 Month's Conferences and Exhibitions

311 Letters to the Editor

324 News from Industry

325 New Products

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ELECTRONICS, TELEVISION, RADIO, AUDIO

"Hall Mark" for Instruments

A MODERN translation of Clause 35 of Magna Carta reads "There shall be standard measures of wine, ale, and corn (the London quarter), throughout the Kingdom. There shall also be a standard width of dyed cloth, russet, and haberject, namely two ells within the selvedges. Weights are to be standardized similarly."

Standardization of units of length, volume and weight have long been established and from time to time inspectors from the appropriate Government department check against transfer standards the "measures" used by tradesmen. But no such transfer standards are available to the U.K. manufacturer of, for instance, radio-frequency measuring instruments, in fact, it is true to say that some instruments made in this country have to be checked against standards at the U.S. National Bureau of Standards, or the Australian or German equivalents—there being no national reference standard. The writer of an article on the U.K. electronic instrument industry published in *International Commerce* in the States in July, 1964, stated: "British firms look to the United States for example and guidance. . . . Instrument producing factories often lack standard equipment. Most producers have inadequate or no standards laboratory or environmental facilities."

In the same month that this article appeared (was it coincidental?) the Scientific Instrument Manufacturers' Association set up an eleven-man Working Party under the chairmanship of R. H. C. Foxwell (chairman of Wayne Kerr) whose terms of reference included "the indentification of gaps in the availability of National Standards and the determination of industry's requirements for testing and certification." The Working Party's report in April, 1965, showed the magnitude of the problem which faces this country if it is to bring "its measurement integrity into line with its major competitors." Among its recommendations was the establishment of a national calibration and certification service; and a plan for the setting up of a British Standards Authority to do this was laid before the Government. These proposals have now borne fruit, for the Minister of Technology announced in Parliament on April 25th, that the Government is to establish a British Calibration Service. The actual calibration and certification of instruments will be carried out in existing public or private laboratories.

The National Physical Laboratory will remain responsible for the basic international standards of length, mass, time, electrical current, temperature and luminous intensity. One of the problems, however, will be the maintenance of the accuracy of the "tranfer standards" at the calibrating centres. One can also foresee the need for R. & D. support at Government level for continuously establishing new standards as techniques advance.

The primary need for the setting up of the calibration service is to increase our exports of measuring equipment in which there is an adverse balance of trade. Manufacturers find it increasingly difficult to export to such countries as the U.S.A., Australia, Sweden and Switzerland, who require a certificate of calibration on imported instruments.

Metrology and instrument technology enjoy high academic status in the United States and also in Germany where there are, we believe, eight chairs in metrology and the subject is now recommended as compulsory for all engineering degrees. It is good to learn that the Minister of Technology and the Secretary of State for Education and Science are discussing how the subject can be adequately covered in the curricula of universities and technical colleges but we would suggest that it is essential in a so fast developing science to establish a close partnership between the industry and colleges.

As we go to press, a series of meetings is being held by the National Conference of Standards Laboratories at Gaithersburg, Maryland, concerning the problems facing measurement standards laboratories. The problems in this country are well known; we hope the U.K. delegates will return with some solutions.

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Automatic Gain Control in Transistor Receivers

By K. R. STURLEY,* Ph.D., B.Sc., M.I.E.E.

A FULLY DETAILED DESIGN FOR SEMICONDUCTOR CIRCUITS

THE calculation of the automatic gain control (a.g.c.) characteristics of a valve receiver presents little difficulty because the control voltage is not required to supply current. The situation is more complicated in the transistor receiver because the a.g.c. source must supply current, and the maximum signal which can be accepted by a transistor is so much less than that by a valve. The controlled transistor acts in a manner similar to that of a non-variable-mu valve with short grid base, and some auxiliary form of a.g.c., such as a damping diode, is required before the controlled stage, to limit the input signal and prevent modulation envelope distortion.

The purpose of this article is to show that by making some normally justifiable assumptions it is possible to calculate the a.g.c. characteristics for a transistor receiver. There are two parts to the task; first to calculate the component values and then to determine the a.g.c. characteristics. We will consider the simplest type of a.g.c. circuit for which the control voltage is taken from the detector diode. The circuit in Fig. 1 shows two i.f. stages, the first of which is controlled and has a damping diode connected across the primary of the input transformer fed from the collector of a frequency-changer transistor. The second i.f. stage is not controlled because this would increase its input signal and could lead to modulation envelope distortion.

We will deal first with the conventional a.g.c. which exploits the variable gain characteristic of the first transistor. Since the mutual conductance (g_m) of a transistor is directly proportional to the collector current, we can use the $I_C V_{BE}$ characteristics as a measure of the variation in gain. Maximum and minimum collector currents will be about 1 mA and 30 μA respectively so that a gain control variation of $20\log_{10}(1/0.03)$, i.e. 30 dB, is possible. Typical values for I_C and V_{BE} are shown in Table 1.

A probable value of d.c. current gain β is 100, and the initial curvature of the detector diode will require it to be given a forward bias of 0.3 volt in order to achieve optimum detection of small signals. With these assumptions we can now begin the calculation of component values.

A resistance (R_4) is required in the emitter lead to achieve thermal stability and reduce the effect of transistor tolerances; a suitable value is 470Ω, producing an emitter-earth bias V_{EO} of 0.47 V for I_C= 1 mA. (I_E is very nearly equal to I_C when β is large). The base-earth bias $V_{BO} = V_{EO} + V_{BE} = 0.47 + 0.25 = 0.72$ V—V_{BE} is obtained from Table 1. Probable values for R_6 and R_7 in the detector circuit are 470 Ω and 5 kΩ respectively, and the current I_2 in R_2 must be such as to produce a forward bias of 0.3 V across R_7. Hence $I_2 = 0.3/5 \times 10^3 = 0.06$ mA, and this current must produce across R_2 a voltage of $V_{BO} - 0.3 = 0.42$ V. Thus $R_2 = 0.42/0.06 \times 10^{-3} = 7k\Omega$, the nearest preferred value to which is 8.2 kΩ. The higher value given to R_2 reduces the required value of I_2 if we are to maintain V_{BO} at 0.72 V, but for the moment we will ignore the effect until R_3 has been calculated.

The current through R_3 is the sum of I_2 and I_B, i.e. $0.06 + 0.01 = 0.07$mA, and

$$R_3 = (V_b - V_{BO})/(I_2 + I_B)$$
$$= 8.28/0.07 \times 10^{-3} = 118 \text{ k}\Omega.$$

The nearest preferred value is 120 kΩ, and we must next determine the effect on collector current of using preferred values in the base-bias circuit which will be increased. Let us try

$I_C = 1.1$ mA, $I_B = 11$ μA, $V_{EO} = 0.516$ V, $V_{BE} = 0.2525$V (Table 1) and $V_{BO} \approx 0.77$ V.

$$I_2 = V_{BO}\,(R_2 + R_7) = 0.77/13.32 \times 10^3 = 57.6\ \mu\text{A}$$
$$V_{R1} = 68.6 \times 0.12 = 8.23 \text{ V} = V_b - V_{BO}$$

The transistor will therefore operate at 1.1 mA when the input signal is zero, and the forward bias on the detector is $I_2 R_7 = 0.288$ V.

* Chief Engineer, External Broadcasting, B.B.C.

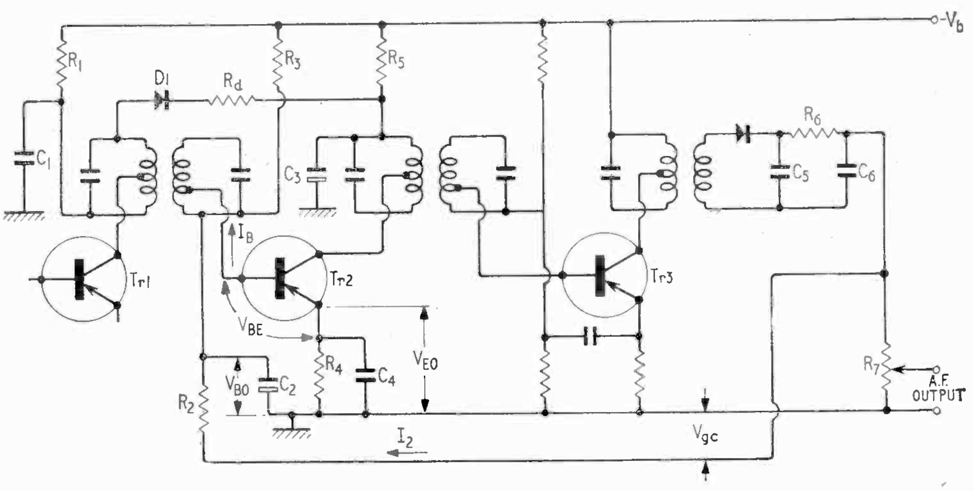


Fig. 1. A.G.C. in a transistor receiver.

Table 1

I_C (mA)	1.2	1.1	1	0.9	0.8	0.6	0.4	0.2	0.1	0.05	0.03
V_{BE} (volt)	0.255	0.2525	0.25	0.247	0.243	0.235	0.225	0.2	0.17	0.15	0.14

Table 2

I_c (mA)	0.03	0.05	0.1	0.2	0.4	0.6	0.8	0.9	1	1.1
20 log 10 I_c/0.03 (dB)	0	4.4	10.5	17.5	22.5	26	28.5	29.5	30.4	31.3
V_{BE}	0.14	0.15	0.17	0.2	0.225	0.235	.0243	0.247	0.25	0.2525
V_{EO}	0.014	0.0235	0.047	0.094	0.188	0.282	0.376	0.423	0.47	0.516
V_{BO}	0.154	0.1735	0.217	0.294	0.413	0.517	0.619	0.67	0.72	0.77
1.07 V_{BO}	0.164	0.185	0.232	0.314	0.44	0.552	0.66	0.715	0.768	0.825
$8.2 \times 10^3 I_B$	0.0027	0.0041	0.0082	0.0164	0.0328	0.049	0.065	0.0735	0.082	0.09
V_{gc}	0.448	0.426	0.375	0.282	0.142	0.014	−0.11	−0.173	−0.245	−0.3
Output E_o	0.748	0.726	0.675	0.582	0.442	0.314	0.19	0.127	0.055	0
$20 \log_{10} \frac{0.748}{E_o}$ (dB)	0	0.2	0.9	2.2	4.6	7.6	11.9	15.4	22.6	—
Input E_i (dB)	0	4.6	11.4	19.7	27.1	33.6	40.4	44.9	53	—

We can now determine the a.g.c. bias (V_{gc}) for any given collector current I_c by using the following voltage-current relationships

$$V_b + V_{gc} = (I_2 + I_B) R_3 + I_2 R_2 \quad \ldots \quad (1)$$

$$I_2 R_2 - V_{gc} = V_{BO} \quad \ldots \quad (2)$$

Solving for I_2 in (2)

$$I_2 = (V_{gc} + V_{BO})/R_2$$

and replacing in (1)

$$V_b + V_{gc} = (V_{gc} + V_{BO})(R_2 + R_3)/R_2 + I_B R_3$$

$$V_{gc} = V_b R_2/R_3 - V_{BO}(R_2 + R_3)/R_3 - I_B R_2 \quad (3)$$

Replacing the resistances in (3) by their preferred values given above and assuming a supply voltage of 9 V.

$$V_{gc} = 0.615 - 1.07\, V_{BO} - 8.2 \times 10^3 I_B \quad \ldots \quad (4)$$

The values of V_{gc} for selected collector currents are given in Table 2, together with the ratio variation (dB) of transistor gain (20 $\log_{10} I_c/0.03$), of output signal (assumed to be the diode forward bias, plus the a.g.c. bias), and of input signal (sum of transistor gain and output signal variations).

When calculating the output signal, no allowance has been made for the curvature of the detection characteristic; this will tend to have a greater effect than in a valve receiver because the maximum signal is so much less, but even so, its influence at the point where a.g.c. is beginning to operate is not very considerable.

The a.g.c. characteristic, represented by the last two rows in Table 2, is plotted as curve 1 in Fig. 2. If the minimum current of the transistor is reduced below 30 μA, modulation envelope distortion begins to be appreciable, and the a.g.c. characteristic turns up, as shown by the dotted extension of curve 1.

Some idea of the signal voltages prevailing at various parts of the circuit can be gained as follows. The effective power gain of each i.f. transistor will be of the order of 30 dB, so that for a detector load of 2.73 kΩ [$\frac{1}{2}(R_6 + R_7)$], and a transistor input conductance of 1250 μmho, we have power in load.

$$P_o = \frac{E_o^2}{2.73 \times 10^3} = 10^3 \times E_1^2 \times 1250 \times 10^{-6}$$

$$\therefore \frac{E_o}{E_1} = (2.73 \times 1250)^{\frac{1}{2}}$$

$$= 58.5 \approx 60 = \text{voltage gain of } T_r3.$$

The voltage gain from base of Tr2 to base of Tr3, assuming 30 dB power gain and equal base conductances, is approximately 32. The detector output with no a.g.c. is about 50 mV giving an input voltage to Tr2 of 50/60 × 32 = 26 μV. With maximum a.g.c., the gain of Tr2 falls nearly to unity, the output voltage from the detector is 0.75 V, and the input to Tr2 base is 0.75/60 = 12.5mV. This represents about the maximum permissible carrier voltage that can be accepted at I_c = 30 μA, and a damping diode is needed in order to achieve a wider range of a.g.c. without exceeding an input carrier of 12.5 mV.

The damping diode, D_1 in Fig. 1, provides a shunt load in the collector circuit of Tr1 to reduce the gain of this stage and prevent overload of succeeding stages. It has the secondary effect of reducing the selectivity of the i.f. transformer, across which it is connected, as the input signal increases. Fortunately this is no disadvantage—it may even be an advantage—because a strong signal will tend to suppress a weaker adjacent channel.

The a.g.c. action of the diode is quite easily calculated since the diode acts as a resistance in parallel with the transistor a.c. resistance, and the load resistance presented by the primary of the i.f. transformer. If the two latter are represented by R_o and r_d is the effective a.c. resistance of the diode, the gain of Tr1 is changed from $g_c R_o$ to $g_c R_o r_d/(R_o + r_d)$, and the attenuation due to the diode

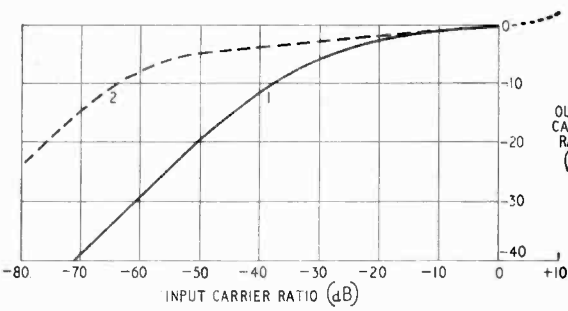


Fig. 2. A.G.C. characteristics of a transistor receiver. Curve 1. Without damping diode. Curve 2. With damping diode.

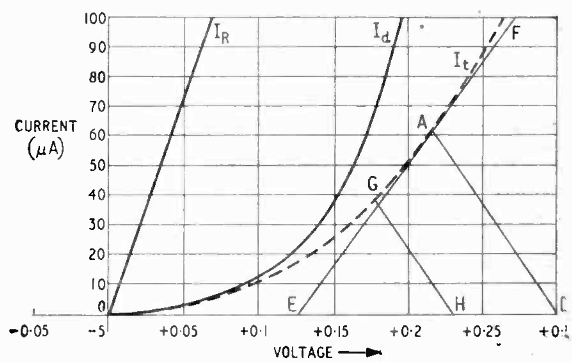


Fig. 3. IV characteristics of the damping diode.

Table 3

I_c (mA)	0.03	0.05	0.1	0.2	0.25	0.3	0.4	0.5	0.6	0.8	0.9	1
$V_{r1} - V_{r5}$	0.3	0.28	.23	0.13	0.08	0.03	−0.07	−0.17	0.27	−0.47	−0.57	−0.67
r_d (kΩ)	1.45	1.55	1.9	3.9	6.8	14.5	100	750	—	—	—	—
$20 \log_{10} \frac{(r_d + R_o)}{r_d}$ (dB)	25.4	24.8	23.2	17.6	13.5	8.8	2	0.3	—	—	—	—
Gain (dB)	0	0.6	2.2	7.8	11.9	16.6	23.4	25.1	25.2	25.3	25.4	25.4
Output (dB)	0	0.2	0.9	2.2	—	—	4.6	—	7.6	11.9	15.4	22.6
Input (dB)	0	5.2	13.6	27.5	—	—	50.5	—	58.8	65.7	70.2	78.3

is $20 \log_{10} (R_o + r_d)/r_d$. Thus if $R_o = 25.5$ kΩ and $r_d = 25.5$ kΩ there is a loss of 6 dB. We have already noted that the maximum signal applied to the base of Tr2 is about 12.5 mV and this is stepped up to about 125 mV

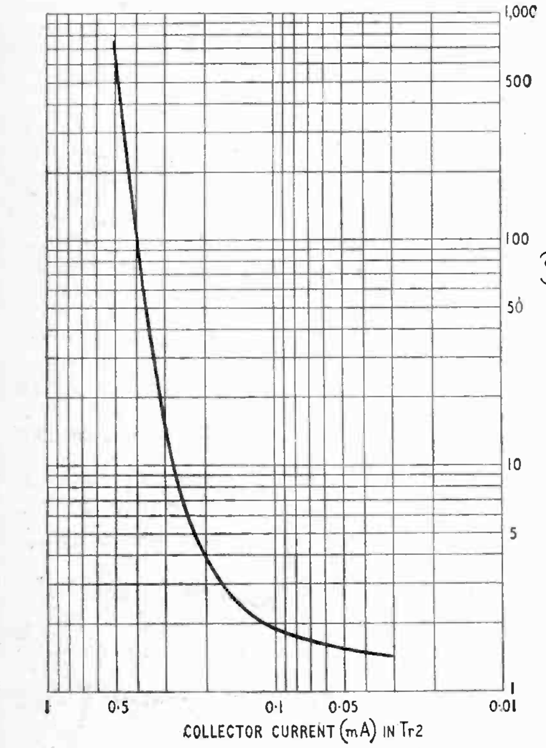


Fig. 4. Change of diode damping with in collector current of Tr2.

across the primary of the i.f. transformer. This is quite a small signal and the diode will tend to be continuously conducting with its a.c. resistance producing the damping. Fig. 3, curve I_d shows a typical *IV* characteristic of a damping diode over the range of bias voltages likely to be used. The relationship is non-linear and reverse current flows so that there is some slight damping with reverse bias. Since the damping is non-linear a degree of modulation envelope distortion occurs and is generally a maximum at a particular bias value. The non-linearity effect can be reduced by adding a resistance (R_d in Fig. 1 about 680 Ω) in series with the diode. Some sacrifice of a.g.c. action occurs because the maximum slope of the combined characteristic, I_t in Fig. 3, is reduced. The curve I_t is the sum of the voltages at given current from the diode curve I_d and the resistance line I_R.

The decoupling resistance R_5 (1 kΩ) in the collector of the controlled transistor Tr2 provides the control bias voltage, and reverse biases the diode to about 1 V at maximum I_c, and R_1 (330 Ω) forward biases to 0.33 V if the collector current of Tr1 is 1 mA. The diode is forward biased when the collector current of Tr2 falls below 0.3 mA.

The resistance values of R_1 and R_3 as well as the voltages due to the collector current of Tr1 and Tr2, determine the actual bias applied to the diode. The actual bias is found by drawing a resistance line of inverse slope equal to $R_1 + R_5$ (1.33 kΩ) from a voltage equal to the difference across R_1 and R_5 due to the collector currents. Thus if the collector current of Tr2 is 30 μA, the voltage across R_5 due to this is 0.03 V (reverse) and if that across R_1 is 0.33 V forward, the true bias is given by the intersection A (Fig. 3) of the combined I_t characteristic with the resistance line *AD* of 1.33 kΩ drawn from a forward bias of 0.3 V.

Fig. 3 shows that the true bias is 0.215 V forward. The inverse slope of the combined characteristic at *A* is given by the tangent *EF*, and is about 1.45 kΩ; this is the value of the damping resistance across the i.f. transformer primary.

This procedure can be repeated for selected values of collector current in Tr2; line *GH* gives the result for $I_c = 0.1$ mA, i.e. a forward bias of 0.23 V. The damping resistance of the diode at various collector currents in Tr2 is plotted in Fig. 4. Using the diode attenuation expression $20 \log_{10} (r_d + R_o)/r_d$ the loss due to the diode damping may be calculated; the reference is a collector current of 30 μA. These gain variations must be added to the input variations in Table 2 to obtain the overall input variations (see last column in Table 3). This has been done in Table 3 above on the basis of $R_o = 25.5$ kΩ.

The overall a.g.c. characteristic is shown by curve 2 in Fig. 2 and the damping diode is seen to have extended the a.g.c. range by about 25 dB, giving an input variation of about 56 dB for a 6 dB change of output. No account has been taken in curves 1 and 2 of the decrease of input conductance of Tr2 with decrease of collector current. The effect is small but it does reduce slightly the effectiveness of the a.g.c.

The biasing resistances R_1 and R_5 should have large capacitors C_1 and C_3 (about 8 μF) so that the a.f. voltage components due to rectification of the i.f. signal by the non-linear diode damping characteristic are negligible and will therefore have little effect on the bias applied to D_1.

Dr. K. R. Sturley, has been chief engineer, external broadcasting, in the B.B.C. for the past three years having joined the Corporation in 1945 as head of the engineering training department. He graduated from Birmingham University and did postgraduate research on electro-thermal storage problems which lead to his Ph.D. In 1936 he joined the staff of Marconi College, Chelmsford, as lecturer and was assistant principal when he left to join the B.B.C.

A LOOK AT SOME OF THE EXHIBITS AT THE AUDIO FAIR AND AT THE CONCURRENT AMERICAN SHOW

AUDIO 1966

THE Audio Festival and Fair in London held a few surprises for the unsuspecting visitor—for a number of well known manufacturers had diversified their interests. Goodmans introduced an integrated stereo amplifier, Leak have come up with a pickup arm, Sonotone (Technical Ceramics) have produced a loudspeaker and enclosure and there has been a surge in the number of small enclosures on the market, such now being available from Goodmans, Richard Allan, Truvox, Braun, Saba and Pioneer (Japan). Many new amplifiers, tape recorders, microphones, pickup arms, turntables and loudspeakers were seen and it is not proposed to deal with them all since space does not allow.

This year many visitors to the Fair could commit " monolithic dual avicide "* by visiting the show of some American equipment at the U.S. Trade Center, which enabled visitors to draw their own comparisons between British and American equipment. From the viewpoint of performance, the importance attached to the various aspects is different, making direct comparison difficult, but the appearance of the U.S. equipment was more professional and business-like. The attention and assistance given to the visitor was also more professional and business-like; the performance of many staffing the stands and demonstration rooms at the Audio Fair seems to leave something to be desired.

Pickup arms

Three of the new arms shown were illustrated in the preview (Leak, Goldring and the Japanese Micro). The Leak arm is noticeably unconventional in design—the unipivot is at disc height, the intention being to reduce the effects of warped records. The use of a single pivot leads to the low bearing friction which is given as 10 mg. The cartridge is a variable reluctance type fitted with all elliptical stylus (to minimize tracing distortion) and gives an output of 1.2 mV per cm/sec. Leak were one of the few manufacturers to quote the tip mass on their literature—which in this case is less than 1 mg.

The Japanese Micro Seiki arm, imported by Medley, and exhibited jointly by Medley and Living Sound, has a low pivot friction and reference to the Fair preview shows the arm has some similarity to the SME arm.

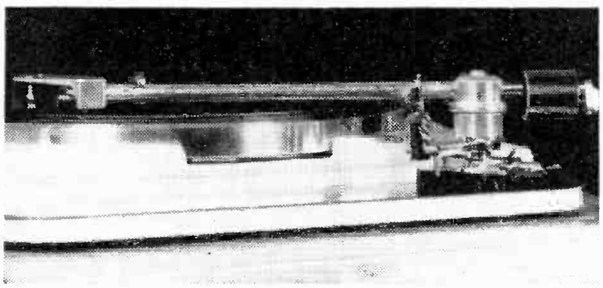
An interesting arm was exhibited by Audio & Design (Fig. 1). The unipivot arrangement, which was slightly misrepresented in the preview, consists of a hardened needle upon which the arm with a miniature ball race rests. The top hub and pivot are illustrated in Fig. 2 and damping, to avoid torsional resonance, may be achieved by use of the cup around the needle. The pivot friction is not measurable, the abolition of the lead out wires contributing to this. Electrical connection is made with four nickel-plated electrodes which rest in four mercury baths when the arm is placed on its pivot. Two other features are the closeness of the counterweight to the pivot, giving a low moment of inertia, and the magnetic side-thrust compensation. The arm was designed for minimum distortion due to tracking error, rather than minimum tracking error†. The arm is undoubtedly a high-quality precision instrument and deserves its title of a " laboratory " pickup arm.

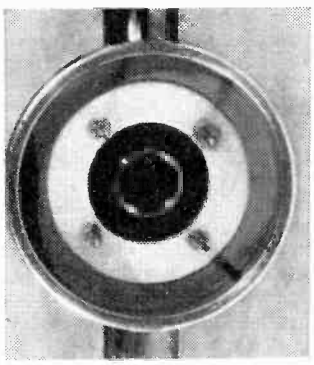
* According to a *Times* critic, killing two birds with one stone!

Semiconductor cartridge

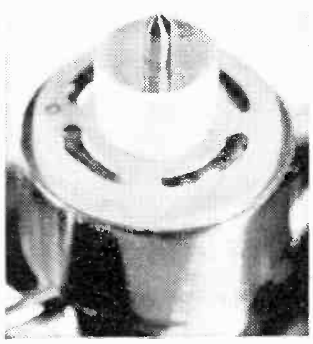
At the business end of arms, perhaps the most significant development in recent years has been the introduction of a cartridge using a semiconducting element as a pressure sensitive transducer. The cartridge on show at the Fair was developed by the Euphonics Corpn. (U.S.A.)—represented in the U.K. by A. C. Farnell. The construction of an element of a stereo pickup is shown in Fig. 3. The silicon element is either compressed or elongated by movement in the plane shown and responds by changing its conductivity. A " bias " current must be passed through the elements so that this becomes modulated, the output voltage being taken across the cartridge. The output impedance is around 800 Ω and output voltage (no load) can be between 12 and 40 mV depending on the voltage supply available and the series resistor. With a series resistor of 2 kΩ,

† Such an approach is outlined by J. K. Stevenson in this and the May issue.





Above: Fig. 1. Pickup arm by Audio & Design. The pivot arrangement is shown in Fig. 2.



Right: Fig. 2. Pivot assembly of the arm of Fig. 1 showing needle, damping cup, mercury baths (bottom), ball-race cup and electrodes (top).

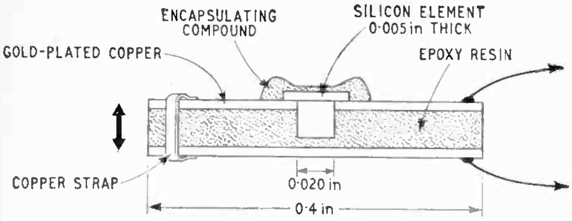


Fig. 3. One element of the Euphonics semiconductor cartridge.

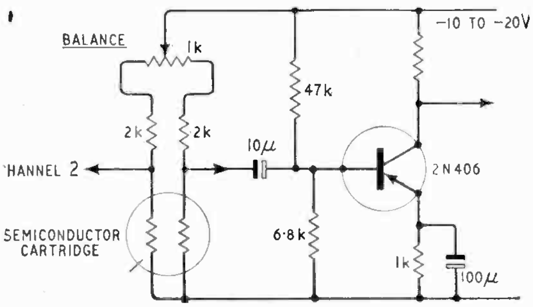


Fig. 4. Typical input circuit and a convenient method of balancing for the semiconductor cartridge.

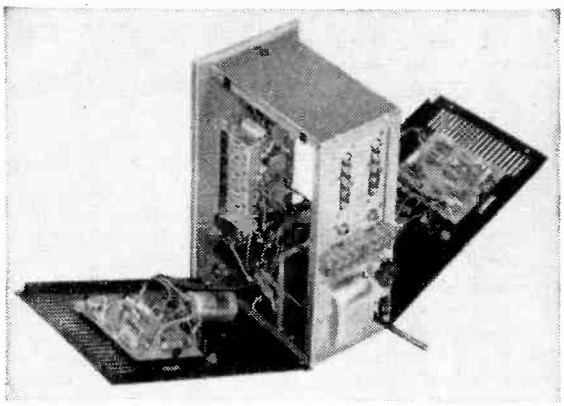


Fig. 5. Hinged panels for easy servicing on the Goodmans silicon transistor Maxamp.

a supply voltage of 20 V and feeding a load of 2 kΩ the output will be about 18 mV with a signal-to-noise ratio of better than 80 dB. For reproduction from an R.I.A.A. recording no external equalization is necessary, this being achieved mechanically. Some low frequency attenuation may be necessary with the cartridge since the output extends down to d.c. A convenient method of balancing is shown in Fig. 4.

Four versions are available, two having elliptical styli (0.0002 and 0.0009 in radii) and a high vertical and horizontal compliance of 25×10^{-6} cm dyne^{-1} (U-15-LS) and two having styli with spherical tips and a compliance of 15×10^{-6} cm dyne^{-1} (U-15-P)—the prices differ by about £10. Separation at 15 kc/s is 10 dB for the U-15-LS; 5 dB for the cheaper model and 25 dB at 1 kc/s for both models. The cartridges are available for standard mounting or in plug-in heads for use with a Euphonic TA-15 arm. An effective tip mass of between 0.3 and 0.6 mg can be achieved. (It was noted that on some of the manufacturer's literature, the necessity for a phase inverter for one channel was stressed, but on other literature no mention was made of this. This would be explained if the cartridge and supply unit have been modified since introduction.)

Silicon transistor amplifier

Probably the most notable development in the amplifier field is the introduction of a silicon transistor amplifier by Goodmans. The amplifier is known as the Maxamp 30 and is the physical companion to the Maxim loudspeaker enclosure. The photograph (Fig. 5) shows the two sides with printed boards hinged for easy servicing. The amplifier gives 15 W per channel into an 8 Ω load or 10 W per channel into a 4 or 15 Ω load. With an 8 Ω load and at full power the distortion is given as 0.4% at 1 kc/s.

The power amplifier circuitry is similar to that of the Tobey and Dinsdale, and Goodmans are by no means alone in adopting this configuration. The use of silicon n-p-n transistors (and consequently the positive supply rail) is the main difference. The preamplifier circuit is also similar, using feedback around the first two stages to increase the input impedance. (These are indirectly coupled, incidentally.) The Baxandall circuit is also used for the tone controls but the filter circuits differ —an *LC* type being used for the low pass filter giving a slope of 12 dB/oct with an 8 kc/s turnover frequency. An input for ceramic cartridges is provided with a sensivity of 50 mV and an input impedance of 100 kΩ. One difference throughout is that most of the resistors in the Dinsdale amplifier are 5% tolerance whereas 10% types are used in the Goodmans amplifier and more critical resistors are 2% and 5% respectively.

Mullard took a back seat this year (for most visitors) in a trade-only room, but Ferranti were out in front and suggested circuits for items of audio equipment using silicon transistors. Literature is available describing 7 W and 15 W amplifiers, and the 7 W version has been described in the article on the silicon transistor tape recorder*.

A circuit of a silicon transistor f.m. tuner was shown which had a novel form of tuning indicator. The circuit of this is shown in Fig. 6 and two gallium phosphide lamps are used in a similar manner to the two neon

* July and August 1965 issues.

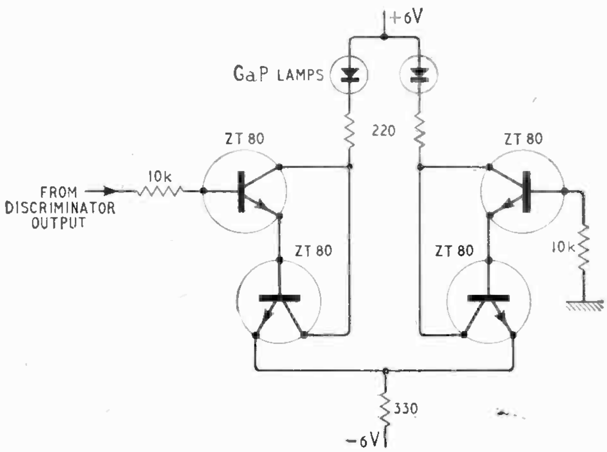


Fig. 6. Novel tuning indicator demonstrating the possibilities of gallium phosphide semiconductor light sources.

lamps of the Quad tuner.† This circuit, though, is obviously unecomonic, and its purpose is merely to demonstrate the potential of semiconductor light sources.

Titanium cone loudspeaker

Development in loudspeakers since last year appears to have been largely a matter of small improvements obtained by the use of materials new to drive unit construction. Neoprene roll surrounds are being adopted more widely for front suspension of cones, for example (in the Mk 2 version of the B139 bass unit made by KEF), as they give a more linear suspension and consequently a reduction in waveform distortion. E. J. Jordan's work in developing wide-range drive units using small metal cones is well known, and the latest phase, shown by Audio & Design, is the use of 4-in titanium alloy cones with plastics/metal laminate surrounds. The high strength/weight ratio of titanium allows the cone to be thin and light but strong. Because of this and the high velocity of sound in titanium, cone break-up starts at a higher frequency than with other materials, and the behaviour of the cone as a transmission line is more predictable for design purposes. The laminate cone surround—a plastic material coated with metal —has been adopted to cope with the conflicting requirements of acoustic sealing, flexibility, cone centring and high-frequency termination, and it has an annular structure giving a "negative" stiffness which tends to cancel the stiffness of the cone and the rest of its suspension. The -3dB frequency response of the D30/20 loudspeaker using these materials is stated to be 20 c/s to 22 kc/s. Maximum output is 115 dB relative to 0002 dyne cm^{-2}.

A new name amongst the loudspeaker exhibitors was Technical Ceramics Ltd. who demonstrated the Sonotone "Solent," incorporating a 6-in bass unit and a $3\frac{3}{8}$-in tweeter in a $14 \times 9 \times 8$ in cabinet. (The frequency response is shown on our front cover.)

Some American equipment

One of the components in a transistor power amplifier which is often thought of as undesirable is the loudspeaker coupling capacitor. The obvious way to eliminate this is to use a power supply with +ve and −ve rails. But the capacitor does not quite disappear; it is in effect moved to the power supply, since generally extra smoothing will be required. This method is, however, adopted in an amplifier manufactured by Lansing and a simplified circuit of the output stage is shown in Fig. 7. Another Lansing product is a stereo pre-amplifier ("graphic controller") and it can be seen that the appearance is somewhat unconventional (Fig. 8), the rotary controls being replaced by sliders and illuminated push-buttons. Other controls appear behind a drop-door, a practice common with TV receivers at one time. A 1-kc/s oscillator provides a test tone for balancing stereo channels.

Both in the U.K. and in the U.S.A. the last strongholds where valve amplifiers and tuners have remained supreme are beginning to fall. Quad have now introduced a 50 W transistor amplifier and McIntosh (U.S.A.) are producing transistor pre-amplifiers but are still clinging to valve power amplifiers and tuners. The amplifiers use an output stage similar to that of the Quad—the primary of the output transformer forming part of both cathode and anode loads.

The MR 67 and MR 71 McIntosh stereo tuners feature

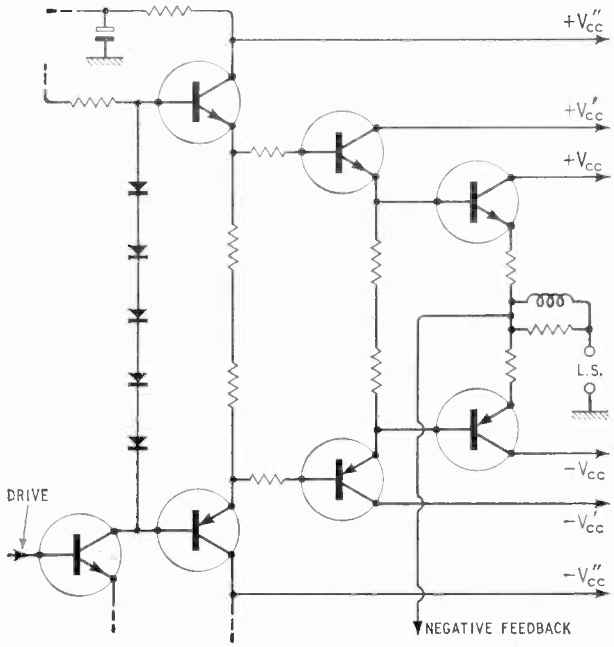


Fig. 7. Elimination of the loudspeaker coupling capacitor by using + ve and − ve supply rails.

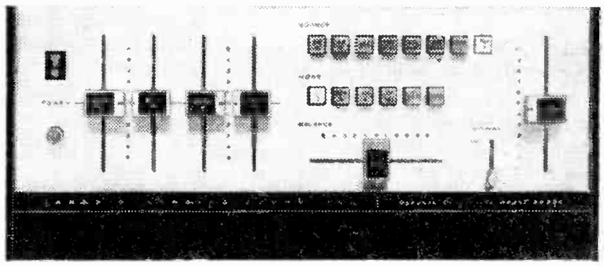


Fig. 8. The unconventional appearance of an American stereo pre-amplifier eliminating rotary controls (Lansing).

multipath indicators as well as the usual multiplex indicators. The MR 71 in fact has four indicators—apart from the frequency scale—the other two being tuning and signal strength meters. On the MR 67 the signal strength and multipath indicators are combined and switched. The indicator is fed from a limiting i.f. stage and signal variations due to multipath reception causes the indicator to fluctuate. The aerial is then adjusted for minimum variation. Signal strength is registered by switching in a shunt capacitor to smooth out the variations.

Marantz introduced a combined multipath and tuning indicator using a 3 in cathode ray tube some time ago and this is featured on their 10B stereo tuner. The ordinate represents signal strength, the signal being derived from a limiter, and the abscissa represents deviation, the signal being taken from the discriminator. With this method of indication, stereo balance, separation and phase may also be visually represented. The valve tuner incorporates 34 diodes and a number of neon-l.d.r. switches for muting and automatic stereo/mono switching.

The Marantz turntable unit was also seen—using radial tracking in order to give zero tracking error and side thrust.

† September 1955 issue, p. 428.

Matching the C.R.T. Display to the Viewer

By D. W. KAHAN, M.A., B.Sc.

There is no point in straining to achieve optimum electronic design in a television receiver if the picture display device does not give optimum transmission of visual information to the viewer in his normal environment. This article shows how the problem is tackled in the design and correct operation of cathode-ray tubes

MANY of the television receivers now coming into the shops have much darker-looking screens than has been usual. The effect of this is to alter the appearance of the receivers and the contrast in their pictures, for the better in both cases—although this is perhaps a matter of opinion as far as the appearance of the cabinet is concerned.

A good television picture is required to reproduce the original scene with adequate contrast between the light and dark parts of the picture. The idea of " black " in a real scene or in a picture is not an absolute one, and in different circumstances the level measured as the " black " may be very different.[1] This is a difficulty with all methods of displaying pictures where it is necessary to reproduce the appearance of a scene originally at a quite different level of luminance. Fortunately, it is not usually necessary for each part of a reproduced picture to be identical in brightness (a subjective quantity) to the original for an acceptable picture to be obtained.

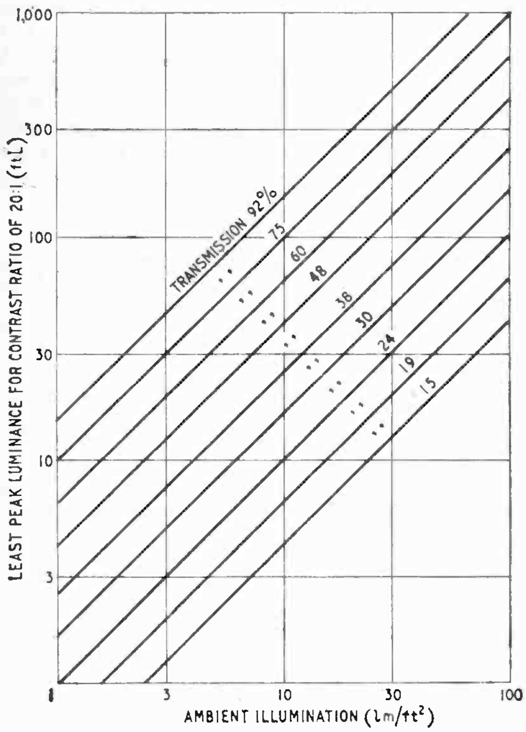


Fig. 1. Luminance needed on c.r.t. screens for 20 : 1 contrast with different levels of illumination and faceplate transmissions.

David W. Kahan, after taking the Natural Sciences Tripos at Downing College, Cambridge, spent two years with Ultra working on the design of radio receivers. He then studied physics at Birkbeck College, London, where he received his B.Sc. He subsequently joined the applications laboratory of Edison Swan Electric Company (now Thorn-AEI Radio Valves & Tubes) where he has since been concerned with the development of cathode-ray tubes. He is 39.

Outdoor scenes will often include luminance levels differing by many hundred times—perhaps by thousands if the view is from a window and some of the interior can be seen at the same time. The eye is able to make use of the whole of this range, but quite good pictures can be produced with less. For example[2] the range in projected colour transparencies is at best 125 : 1, and reflection prints give a range of rather less than 35 : 1.

In television studios and when making films intended for television, it is understood that the range of luminance in a picture should be quite limited and that the larger ratios that are sometimes unavoidable will result in the scale of tonal values being compressed at the ends. The latest versions of the television Test Cards D and E include a column of five squares, intended for checking the grey scale on the receiver, in which the range of contrast is 30 : 1. A slightly different value is used for films for television, where a maximum contrast (transmission) range of 40 : 1 is suggested,[3] and this is considerably exceeded in films which may be shown on television although originally intended for the cinema. However, the range of ratios that can be reproduced well is likely to be between 20 : 1 and 50 : 1.

The darkest parts of a television screen are never totally black, since they are illuminated by light scattered from the brighter areas of the picture and by the general lighting of the surroundings. As the screen itself is made of a mixture of phosphors whose crystals are themselves fairly highly reflecting, the level of " black " in the picture depends on the illumination reaching the screen. When only small areas of the picture are bright so that the ambient illumination determines that on the screen, the luminance of the dark parts L is set by the illumination E, the reflectance of the screen material P and the fraction of the light transmitted by the glass T. The incident light

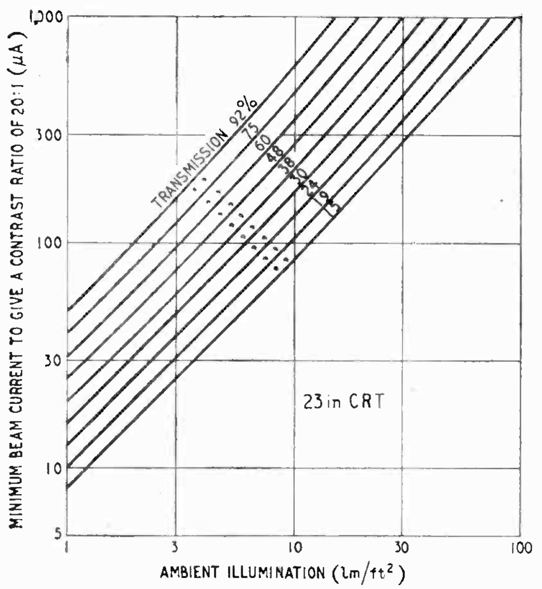


Fig. 2. Beam currents needed to give highlight levels in Fig. 1 on 23-inch c.r.ts with faceplate transmission shown.

traverses the glass and is attenuated twice, before and after its reflection, so that $L = EPT^2$. If a particular ratio of contrast $C : 1$ between the luminance levels of the lightest and darkest parts of the picture is required, the highlights must be seen at a luminance of $CL = CEPT^2$. We can therefore say what the luminance of the highlights must be for the picture to be a satisfactory one, but only if the ambient illumination is known.

There are a few special cases where this calculation gives a more definite result. If the surroundings are well lit, say between 10 and 50 lm/ft², it may be desirable to see the picture at levels the same as if the scene had been in the room; this might be useful for monitor screens in television studios which could be set up so that the studio scene and its television image could be seen at the same luminance and under the same conditions of adaptation of the eye. In studios where it is the practice to adjust the overall gamma of the system to unity, this would give similar luminance and subjective brightness for the scene and the picture at all levels of luminance. In this case, the contrast ratio is known and the transmission of the glass can be set.

A second case is where the surroundings are less brightly lit and can be thought of as a background to the picture. There is very little published information on the way in which ordinary television viewers set up their pictures, although it is fairly certain that there are large variations between them. In an account[4] of experiments in which people could choose the luminance and width of an illuminated frame surrounding a picture, it seemed that the frame was preferred with luminance levels at or below the mean level of the picture. This is what one might expect from the accepted practice in visual measurement work where it is usual to arrange a surround at the mean level of the photometric field of view, for the most comfortable conditions for the observer.

It is reasonable to suppose that a similar preference applies if the ambient illumination is fixed, and that the mean luminance of the picture should be set at least to that of its surroundings. The ratio of peak to mean luminance on the screen varies from one picture to another, and values between 3 : 1 and 5 : 1 are fairly typical. In a recent report[5] describing the measurements taken during two complete evening television transmissions, this ratio was found to be about 2.5 : 1 for the average video voltage signal. This corresponds to a luminance ratio of 10 : 1 when we allow for the non-linear relationship between the drive applied to the c.r.t. and the luminance produced on the screen. The best filter can now be specified for any particular ratio of contrast required in the picture.

In general, if the phosphor screen on clear glass has a reflectance P and the general surroundings of the tube have an average reflectance of S, the ratio of peak (highlight) to mean luminance is R and contrast ratio C, the required filter transmission factor T is:—

$$T = 0.92\sqrt{\frac{R.S}{C.P}}$$

(The figure of 0.92 appears because a " clear " glass loses 4% of light at each face by reflection.) The table below shows some of the values of transmission calculated for a possible case where the screen and surrounding reflectance are equal.

Ratio of highlight to surround luminance	1 : 1	3 : 1	5 : 1	10 : 1
Filter transmission for contrast of 20 : 1	21%	36%	47%	67%
Filter transmission for contrast of 50 : 1	12%	23%	27%	38%

The graphs in Fig. 1 show the luminance needed for the highlights in a picture to have a contrast of 20 : 1 at any particular level of illumination, for a range of transmission values between that of clear glass and 15%, at intervals of 20%. These have been extended to show the peak currents needed to give these highlight levels on modern 23-inch screens, if made with faceplates having these transmissions. Fig. 2 shows the least current needed in the electron beam for a tube run at 16 kV to give a contrast range of 20 : 1, and Fig. 3 shows the similar characteristics for the higher range of 50 : 1. The graphs show how tubes used in well-lit surroundings can be operated at lower beam currents to give pictures with satisfactory contrast if the filter is made with lower transmission. This is an advantage for two reasons; the current available from the usual high-voltage supply derived from the line timebase is quite limited, and it is not always appreciated

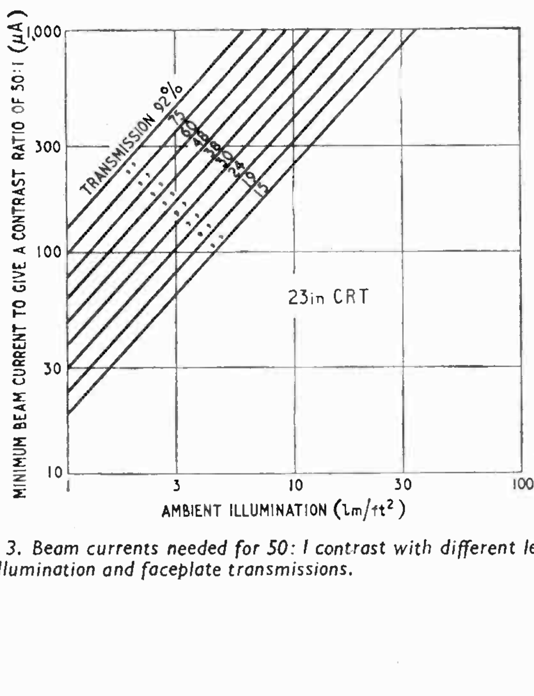


Fig. 3. Beam currents needed for 50: 1 contrast with different levels of illumination and faceplate transmissions.

that the focus characteristics of all c.r. tubes begin to deteriorate as the beam current increases.

There is a limit to the absorption of light in a filter that can be used in this way, since the reflections from the outside surface cannot be ignored entirely. These reflections will not normally be less than 4%, whether the surface is polished or if it is slightly roughened to reduce the specular reflection at the cost of a corresponding increase in the diffuse reflectance. As a result, there is little point in reducing the filter transmission below about 20%, when the luminance of the unexcited parts of the phosphor seen through the filter equals that of the outer surface. The use of surface coatings of the sort used to reduce reflections in camera lenses would allow lower transmissions to be used in special cases where the extra expense could be justified. The obvious idea of using phosphors whose surfaces are themselves black has not proved to be practicable, since such screens are found to be of such low efficiency that the beam current required is too high for the c.r. tubes to be run satisfactorily.

In particular cases it may be possible to avoid the effect of the surface reflections by making sure that lamps and windows are not seen by direct reflection in the surface and that the wall opposite the screen is a dark one. These effects are less significant as the transmission increases, so that for 48% a contrast ratio of 20 : 1 is reduced to 17 : 1 by the surface reflections of light from the walls of the room.

When a separate filter is used with a tube faceplate of relatively clear glass, the extra pair of surfaces between the filter and the screen will also give reflections from the bright parts of the picture, tending to reduce the contrast. It is better to use a filter optically bonded to the faceplate (as in the twin-panel construction) or to use a darker glass in manufacturing the cathode-ray tube itself. This will also help to reduce the effect of light reflected within the glass from the brighter parts of the picture on to otherwise dark parts of the screen.

Acknowledgement.—The author wishes to thank the management of Thorn-AEI Radio Valves & Tubes Ltd., for permission to publish this article, which is based on work done in the Applications Laboratory.

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Hill-climbing in Control Systems

By K. C. Ng*, Ph.D., B.Sc.

In the past few years various techniques have been developed for automatic adjustment of system parameters to obtain the best possible performance from a system—a procedure known as " self-optimization." Few of these techniques have been put into practice but the idea looks promising. The Warren Spring Laboratory of the Ministry of Technology, for example, are working on a system, using electronic digital computing techniques, for achieving maximum economy in the operation of a chemical manufacturing process by automatically adjusting a number of the process variables. This article explains the electronic principles of a method known as " hill-climbing " widely used in self-optimizing systems

AUTOMATIC control is introduced into a system partially or completely to replace the human operator in the control of a complicated process. Simple control systems can be designed, using conventional synthesis procedures, to perform the task to within specified accuracy. Large complex systems are not so easily designed. The design may be further complicated by lack of knowledge of the exact behaviour of system components or by the presence of non-linearities. The system may be working under environmental conditions which vary in a completely unknown manner.

To understand the problem more fully, consider the radar tracking of a target. If the target is assumed to be moving at uniform velocity, the control mechanism can be designed to track the target accurately. Having " locked on " to the target and measured its velocity, and assuming the wind velocity is known, the system can execute the positioning and firing of the gun. The problem is obviously grossly simplified here. Conditions are never ideal; the aircraft may be taking evasive action; atmospheric disturbances will affect the tracking operation; the wind velocity may be vastly different at varying altitudes. If such disturbances are known *a priori* or are measurable, they can usually be taken into account in the design stage. This is obviously not possible in this example. One must therefore resort to more sophisticated schemes to obtain good performance. The homing missile is one approach to this problem.

This much simplified example is one of many practical cases where the system is working under conditions varying in an unpredictable manner, or under unknown conditions. The variations or disturbances may be external to the system or may arise from within the system—for example, change in gain of a valve in an

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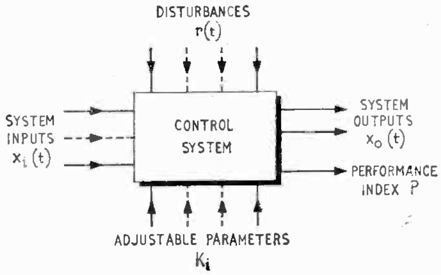


Fig. 1. A general control system with a performance measure, P.

amplifier. In most cases, these variations are not only unpredictable but they cannot be measured directly. Here an indirect method must be used in which the effect of these disturbances on a suitably chosen quantity in the system is measured and appropriate corrective action is taken. If this quantity is used to indicate the " goodness " of the system, then it is obviously desirable that the system should function with the best or optimum value of this quantity at all times, despite variations in system operating conditions.

The " hill-climbing " technique.—Consider the general control system shown in Fig. 1. The variables $x_i(t)$ and $x_o(t)$ are the normal input and output of the system. The signals $r_n(t)$ are unknown disturbance signals. P is a measure of the performance of the system. This may be the accuracy of control, efficiency or profit. There may be practical limitations on the maximum control power available or restrictions on the quality of the product. The different and possibly conflicting requirements, e.g. maximum profit with a minimum guaranteed product quality, can normally be combined into a single figure-of-merit or performance measure.

In general P will be a function of the system variables, that is the system inputs, the disturbances and the settings of the parameters K_i of the system, some of which are adjustable. The performance can be controlled by adjusting these parameters, and a maximum value of P can usually be found for a particular setting of the parameters. A typical relationship between performance and parameter is shown in Fig. 2, curve A, where it is assumed that only one parameter is adjustable. The shape and height of the " hill " depends on the system inputs and disturbances. As the system operating conditions change, the characteristic may change to the curve B. Provided K can be adjusted to be at the optimum

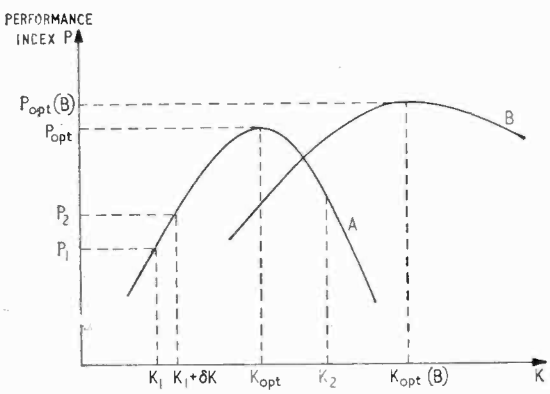


Fig. 2. Performance index vs. parameter characteristic.

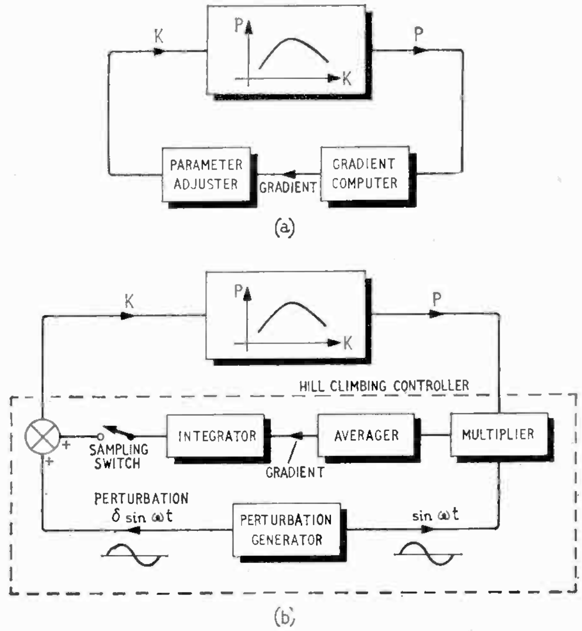


Fig. 3. (a) Basic hill-climbing system ; (b) hill-climbing system with sinusoidal perturbation

setting as the characteristic curve moves, then peak performance can be maintained.

Assume that K is at the non-optimum setting K_1. One way of adjusting K to K_{opt} is to measure the slope or gradient of the performance characteristic at K_1 and then, using this information, adjust K in the direction which improves the performance. The gradient at the working point may be obtained by trial-and-error method. The parameter is displaced by a small trial step δK and the corresponding change in performance measure, $\delta P = P_2 - P_1$, is observed. If increasing K by δK improves the performance, as at K_1, then K must be adjusted in this direction. If the change in P is negative (point K_2), then the parameter setting must be decreased. The process is repeated at each new parameter setting. The technique thus involves determining the gradient of the hill and climbing up the gradient to the peak: hence the term " hill-climbing."

The same method can be applied if the object is to minimize the cost of operating a plant. In this case the characteristic is a valley or trough and the parameter is adjusted in the direction of negative gradient.

Practical system.—In practice the hill-climbing technique is made automatic by perturbing the parameter with a periodic signal of amplitude δK. The gradient is obtained by phase-sensitive rectification of the performance measure with respect to the periodic perturbation. The output of the gradient computer is then used to adjust the parameter K. The hill-climbing system now takes the form shown in Fig. 3(a), where the original system has been represented by the steady-state performance characteristic.

Fig. 3(b) shows schematically the system with a sinusoidal perturbation. The phase-sensitive rectifier consists of a multiplier and an averaging circuit, the output of which is the gradient. The parameter is adjusted once every perturbation period. The system within the dashed line comprises the hill-climbing controller.

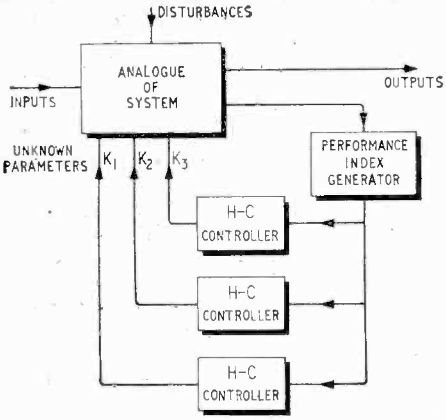


Fig. 4. Use of hill-climbing controllers to optimize the designer of a system.

Such a controller can be attached to any system to optimize the parameter K according to some suitably chosen criterion of performance.

Assume, for example, that the performance index P is related to the parameter K by a quadratic relationship:

$$P = P_o - (K - K_{opt})^2$$

where $K = K_1 + \delta K \sin \omega t$

The output of the phase-sensitive rectifier is given by:

$$G = \frac{1}{2\pi}\int_0^{2\pi} P \sin \omega t \, d(\omega t)$$

$$= \frac{1}{2\pi}\int_0^{2\pi}\Big[P_o - (K_1 - K_{opt})^2 + 2(K_1 - K_{opt})\,\delta K \sin \omega t - \delta K^2 \sin^2 \omega t\Big]\sin \omega t \, d(\omega t)$$

$$\doteq 2(K_1 - K_{opt})\,\delta K$$

since $(\delta K)^2$ is negligibly small.

The gradient of the $P - K$ characteristic is $2(K_1 - K_{opt})$

$$\therefore G = \text{grad.} \times \delta K.$$

At the end of each cycle the switch S is closed and the parameter is adjusted by an amount proportional to G.

i.e. $\Delta K = \alpha \int_0^T G\,dt = \alpha G T$

Thus the rate of adjustment $\frac{\Delta K}{T}$ is proportional to the gradient. At the optimum, the only movement will be due to the intentional perturbation. It is desirable, therefore, to keep the perturbation amplitude small, of the order of 10% of the maximum value of K.

Applications. — The hill-climbing technique described has been applied successfully to various engineering problems. One of the earliest applications was the optimization of internal combustion engines. The efficiency and power output of the engine depend, among other things, on the instant during a working cycle at which the air-fuel mixture is ignited. Draper and Lee used the hill-climbing technique for controlling the ignition-timing of the engine to optimize the engine performance. Similarly the combustion process in a gas burner which forms part of an industrial plant has been optimized by controlling the air supply. The air supply is subjected to the perturbations, and the performance criterion here is the completeness of the combustion and is determined by the amount of CO present in the combustion products.

The technique has been used to adjust more than one parameter simultaneously using several controllers of the type shown in Fig. 3(b), in parallel operation. Such controllers have been incorporated into an analogue computer. Such a computer has many useful applications. It has been used to study optimization of the performance of particular control systems.

It can be used in the *design* of control systems. If certain parameters of the design cannot be determined mathematically, then their values can be found in the following way. The design is simulated on the analogue computer with the unknown parameters built in as adjustable variables. The system is subjected to normal input signals and expected disturbances, and a suitable performance measure is generated. Several hill-climbing controllers, one for each unknown parameter are then employed, as shown in Fig. 4, to adjust these parameters, thus yielding an optimum design under the given operating conditions.

A similar application is in system identification or model building. It is expensive and sometimes dangerous to carry out experiments on complex systems like chemical plants. Initial tests are best conducted on an electronic model or analogue of the plant. If an analogue is not available, it can be built by first setting up an approximate analogue with adjustable parameters. Recordings of the normal plant inputs are used as inputs to the analogue The output of the analogue is compared with the recorded output of the plant. The hill-climbing controllers then adjust the variable parameters until the difference in the outputs is minimized. The analogue will then be a very accurate dynamic model of the plant.

The hill-climbing technique can be applied to any system in which a performance measure can be formulated and where one or more parameters can be controlled. As a final example, the optimization of an electromechanical system will be described in detail.

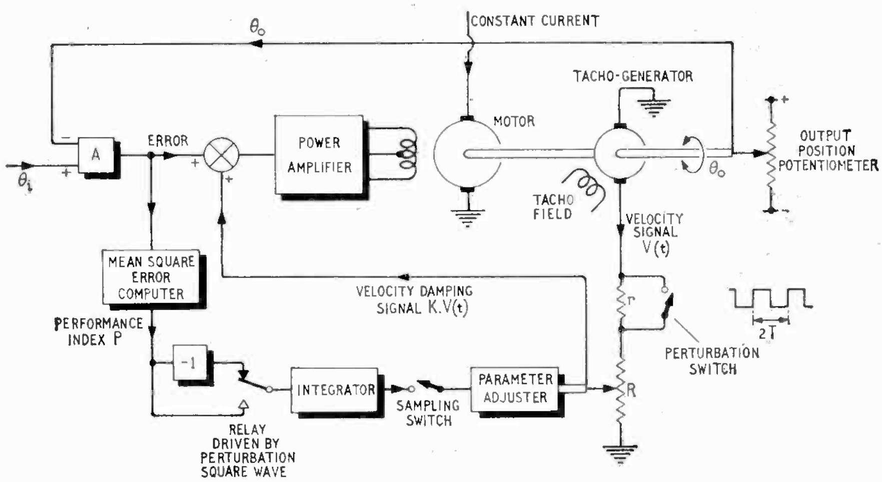


Fig. 5. A practical system based on a position-control servo.

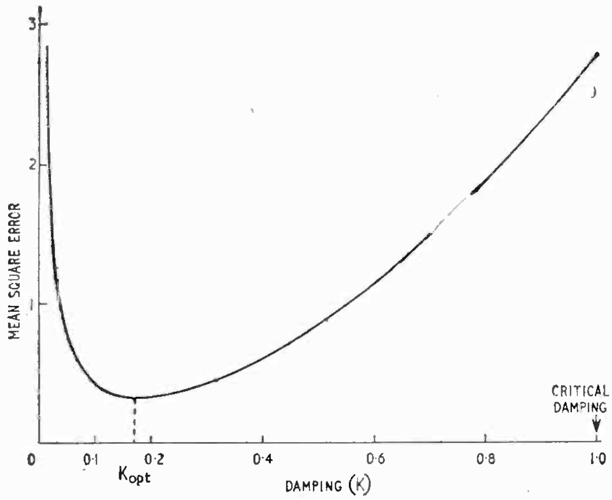


Fig. 6. P-K characteristic of the position control system of Fig. 5.

Fig. 5 is a system for controlling the position of an output shaft θ_o to a demanded position θ_i. The output position is measured using a rotary potentiometer. Amplifier A compares θ_i with θ_o. The difference or error $e = \theta_i - \theta_o$ is used to control the motor driving the output shaft. The motor will rotate until the error is zero. This system will oscillate continuously at a natural frequency ω_o radians per second unless some damping is introduced. Stabilization is achieved by using velocity damping, the velocity signal being obtained from a tachometer generator.

The accuracy in following a varying input demand is dependent on the amount of damping. Too little damping produces an oscillatory response, while too much damping produces a sluggish system. Also the amount of damping required depends on the type of input signal; for example, the optimum value of damping for minimum mean-square value of error in following a step change in position is half-critical damping, while that for a sinusoidal input of frequency equal to $\omega_o/2$ is zero.

Fig. 5 shows how the hill-climbing technique is implemented. The performance index used is mean square error. The damping is varied by controlling the potentiometer R. The damping is perturbed periodically by shorting out the small resistance $r(\doteqdot 0.1R)$ in series with R. This method introduces a constant percentage perturbation instead of a constant amplitude perturbation, and is generally preferable. The perturbation signal is a square-wave signal. Phase-sensitive rectification is performed by multiplying the performance signal by ± 1. This is achieved using a relay as shown.

The change in the integrator output in one cycle of the perturbation is given by:

$$\triangle e_o = \frac{1}{T_i}\int_0^T f(K - \delta K)\,\delta t - \frac{1}{T_i}\int_T^{2T} f(K + \delta K)\,dt$$

$$= \frac{T}{T_i}\left[f(K - \delta K) - f(K + \delta K)\right]$$

$$= -\frac{2T}{T_i}\frac{df(K)}{dK}\,\delta K$$

for small values of δK. This is proportional to the gradient $\frac{df(K)}{dK}$. The sampling switch closes once every perturbation cycle so that the parameter adjuster changes the damping potentiometer setting in steps proportional to $\triangle e_o$.

Fig. 6 shows the steady-state relationship between mean-square error and damping for a random input signal θ_i. It is observed that optimum here is a minimum; the characteristic is not a " hill " but a trough. Typical responses of the system as it approaches the optimum from an initial offset in damping are shown in Fig. 7. The gain of the optimizing loop is readily varied by adjusting the gain of the integrator and is set as high as possible consistent with reliable operation. In practice, it is possible to adjust the parameter to the optimum in a time interval equal to about twenty cycles of the perturbation.

Features and limitations.—The perturbation method of gradient measurement described is one of many methods of " hill-climbing ". It is not possible in this article to consider all the various techniques described in current literature on the subject. It is relevant, however, to mention certain features and limitations of the method described. The main advantage of the method is that it is easy to mechanize. Analogue studies have shown that it is applicable to a wide variety of control problems. Very little information about the control system to be optimized is required. Basically, we only need to know what performance measure to use, how to generate this signal and which parameter to control.

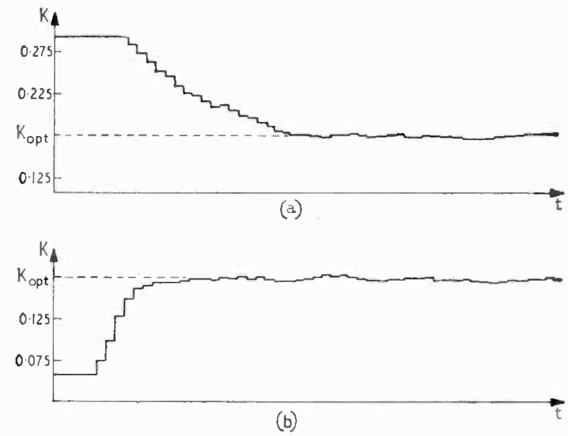


Fig. 7. Response of the hill-climbing system to initial misadjustment in damping ; (a) $K > K_{opt}$; (b) $K < K_{opt}$.

The technique is easily extended to control several parameters simultaneously.

The main limitation is on the maximum speed of response, which is of the order of ten times the response time $\left(\frac{1}{\omega_o}\right)$ of the control system. If the performance curve has more than one " peak ", the technique is not capable of discriminating between these to find the highest peak. Starting from any initial point it will find the peak nearest to the initial point. These limitations are common features of other " hill-climbing " systems at present.

Current research in this field is directed mainly towards methods of gradient measurement which will increase the speed of optimization and of applying " hill-climbing " techniques to industrial plants.

WORLD OF WIRELESS

Record Number of Teleprinter Messages

IN April 1961 a Philips Type ES automatic switching system was installed in Kershaw House near London Airport at the S.I.T.A. (Société Internationale de Telecommunications Aeronautiques) Telegraph Centre which is operated by B.E.A. Since then the system has been in operation for 24 hours every day and at the end of the five year period the equipment has processed what is believed to be a record for the automatic routing of teleprinter messages—over 72 M messages. When first installed the system operated in a semi-automatic mode but was converted subsequently, without withdrawal from service, to fully automatic operation. High speed uniselectors stepping at 300 points per second are used for switching. All control and routing functions are electronic and re-transmission of incoming messages is commenced automatically as soon as sufficient information is obtained from the message to indicate the outgoing circuit required for re-routing. When the outgoing circuit is engaged messages are stored and then when the circuit becomes available transmitted in order of priority and waiting time. Storage is effected by ferrite core memories and magnetic tape.

Radio "Bugging"

AFTER seeing a film of American "bugging" equipment, the Postmaster General, the Rt. Hon. Anthony Wedgwood Benn, M.P., said "There is no doubt at all, having seen that film, that the menace of the micro-bug and eavesdropping equipment is a serious problem in other countries. Happily not many of them, so far as we know, are in use in this country." In discussing the legal position, the P.M.G. continued, "As far as the legal position is concerned, it is very simple: to attach anything to a telephone without permission is illegal and as far as radio-microphones are concerned we've tightened the conditions and made it a condition of the use of a radio-microphone that they can't be used for eavesdropping. So eavesdropping is illegal and we shall prosecute."

C.E.I. Common Examination

ONE of the functions undertaken by the Council of Engineering Institutions is to establish standards for the qualification of professional engineers. While the 13 constituent institutions* of the Council will remain responsible for the conditions of entry to their own membership, and some may require qualifications additional to those called for by the Council, the Council itself will set standards to which corporate members of the constituent institutions must in due course conform for the designation "Chartered Engineer."

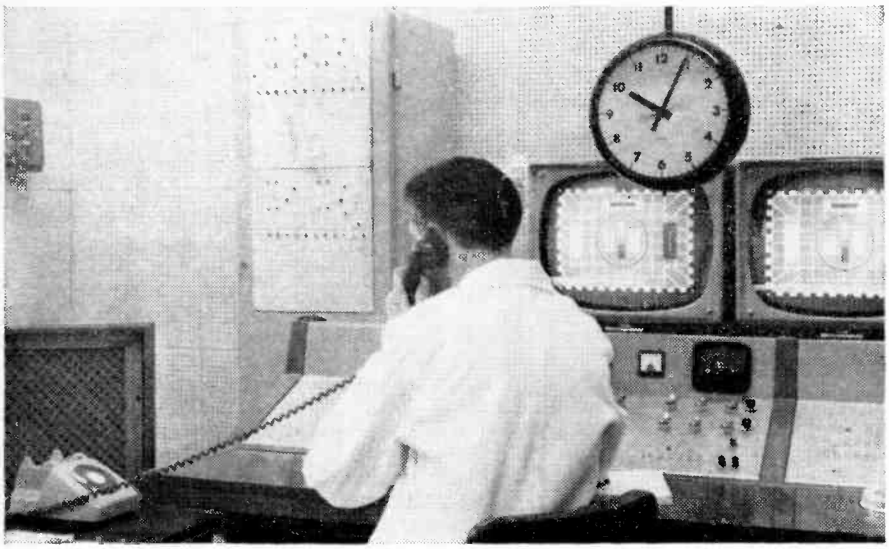
In accordance with the practice of the constituent institutions, the Council regards the qualification of a professional engineer as comprising three parts, namely academic education, training for the profession, and a period of responsible experience in the profession. The Council's plan for establishing the standard of academic education required of future Chartered Engineers is given in a booklet "Education and Training—Statement No. 1."

In this booklet, obtainable from the C.E.I., 2 Little Smith Street, London, S.W.1, details of Part I of the common examination are given with a syllabus and specimen papers. Part I of the examination will be held for the first time in October 1967, and and Part II (details of which are not yet published) in April 1968.

After a date still to be decided by the Privy Council it will be obligatory for all who wish to be registered as Chartered Engineers to pass Parts I and II of the C.E.I. examination or have an approved exempting academic qualification and, of course, have completed the requirements regarding training and experience for corporate membership of a constituent institution.

* Including the I.E.E. and the I.E.R.E.

Plumbicon Team Honoured.—The Television Society's Geoffrey Parr Award, which is made annually to an individual or team "for an outstanding contribution to television engineering or an associated science" has been presented to the Philips team concerned with the development of the



Remote Controlled TV Stations

Two unmanned I.T.A. television relay stations, Great Massingham, Norfolk and Hameringham, Lincolnshire are controlled from Belmont, Lincolnshire. The two stations, equipped with G.E.C. Telecode and Teleshift time and frequency division multiplex equipment, are linked by G.P.O. tie lines to the control centre. The illustration shows a mimic diagram (on the door of a console) which gives engineers continuous indication of conditions at the relay stations and enables the monitoring and controlling of numerous functions to be effected. Signals are transmitted over the G.P.O. lines which can also be used for speech communication when service engineers visit the relay stations.

Plumbicon colour television camera tube. The names mentioned in the citation are Dr. H. Bruijning, director of research of the Philips Research Labs., Aachen, Germany, Dr. E. F. de Haan, assistant director of the Research Labs., at Eindhoven, and Dr. L. Heijne, research physicist at Eindhoven.

Lady Fleming, widow of Sir Ambrose, was present at the 17th **Fleming Memorial Lecture** of the Television Society on April 21st at the Royal Institution, London, when Professor W. D. Wright, of Imperial College, was the lecturer. His subject was "The implications for television of modern thinking on the visual process." Lady Fleming presented the Society's 1964/5 awards. E. J. Gargini of Rediffusion Research received the *Electronic Engineering* Premium for his paper "Colour television by wire"; H. Steele (A.B.C. Television) the T.C.C. Premium for "The transcoding of colour television signals"; J. Weltman (I.T.A.) the E.M.I. Premium for "Television university"; J. E. F. Voss and C. J. Paton (B.B.C.) the Pye Premium for "Television coverage of the Tokyo Games"; Dr. N. Mayer (Inst. für Rundfunktechnik, Munich) the *Wireless World* Premium for "The N.T.S.C. colour television system using additional reference transmission"; and J. D. Last the Mullard Premium for "Varactor diode parametric amplifier and harmonic generators."

Magnetic Cores for Matrix Stores.—The British Standards Institution has published a "Guide to the specification of magnetic cores for use in co-incident current matrix stores," B.S. 4010. The publication defines terms used to specify the properties of magnetic cores intended for use in coincident-current matrix stores having a nominal 2:1 selection ratio. Measuring methods, conditions of test, recommendations for the specification of cores and the correct presentation of core performance data are also included. Copies, price 12s 6d, are available from B.S.I., Sales Branch, 2 Park Street, London, W.1.

Ten more u.h.f. transmitting stations for BBC-2 have been approved in principle by the P.M.G. Six of these will be installed on existing sites, these are indicated by an asterisk in the following list. All transmissions will be horizontally polarized and channel numbers are given in brackets. Belmont* (28), Sandy Heath* (27), Londonderry* (44), Caradon Hill* (28), East Lothian (27), Moel-y-Parc* (45), Staffordshire (26), Angus* (63), Sussex (55), and North Hampshire (45). These ten stations will serve about 5.25 M people and together with the 18 stations already approved will make BBC-2 available to about 77% of the population.

The Society of Electronic and Radio Technicians and the Wolverhampton College of Technology are organizing a three-day symposium on **radio and television maintenance** to be held at the College of Technology on June 14th, 15th and 16th. Subjects to be discussed will cover education and training of radio servicemen, Television picture quality, Maintenance problems, Test equipment, Colour television and Programme distribution systems. Further information, including registration forms, may be obtained from W. J. Anderson, College of Technology, Wulfruna Street, Wolverhampton.

Speaking at the jubilee luncheon of the **Scientific Instrument Manufacturers' Association**, Mr. Edmund Dell, Joint Parliamentary Secretary at the Ministry of Technology, referred to the industry's increased exports from £27.5M in 1958 to £62.7M in 1964. He added: "Nevertheless, it would be a mistake to disguise the fact that there are question marks over the industry's future. Imports have been increasing twice as rapidly as exports. Whereas in 1958 about 11% of apparent home consumption was supplied by imports, in 1964 this percentage has reached almost 30%. Although our export record in the field of scientific instruments has been good it is still true that our share of world trade in scientific instruments has shown some tendency to decline."

The **Baird Travelling Scholarship** for 1966 has been awarded by the Television Society to John D. Penney who is in the Department of Electrical Engineering at University College, London, doing research work for a Ph.D. His work is concerned with tunnel diode amplifiers and is being supported by a Science Research Council grant. With the Baird Scholarship grant of £200 he intends to visit America this year where he plans to visit companies and technical institutes to study tunnel diode amplifiers.

New Radio-telephone Facility.—Thames Radio came into operation recently and provides an improved Post Office radio-telephone service for ships using the Port of London. With aerials near Sevenoaks it will cover an area roughly from Tower Bridge to beyond Canvey Island, including the Medway. It will be available to handle telephone calls with ships at anchor, in port, or anywhere in the Thames area. The service operates at v.h.f. with frequency modulation. The frequency, 156.8 Mc/s, is used for establishing communication in either direction, after which the working frequencies are: ships 157.35 Mc/s and Thames Radio 161.95 Mc/s.

Two-way personal radio for Police Constables has been introduced in six Divisions of the Metropolitan Police Force. The equipment, which weighs only two pounds, is worn strapped across the chest and consists of two units, a transmitter-receiver and a combined microphone and speaker attached by a flexible lead. The aerial is incorporated in this lead. By pressing a button on the microphone a signal is transmitted. At the receiving station the receiver energizes a bell on a special telephone handset and conversation is then carried on in a simplex mode.

Thin Films Conference.—A joint I.E.R.E./I.E.E. conference on "Applications of thin films in electronic engineering" is to be held at Imperial College, London, from July 11th to 14th. There will be sessions on the preparation of thin films; general applications; thin film elements and integrated circuits; magnetic films; and cryoelectric films. Registration forms (fee £13) are obtainable from the I.E.R.E., 8-9 Bedford Square, London, W.C.1.

This summer the new **remotely controlled P.O. radio station** at Leafield, Oxfordshire, becomes fully operational. The station has cost over £1M and is equipped with six 85 kW and 12 30 kW h.f. transmitters. Transistors and motorized switches have been incorporated to provide a very high degree of reliability. At present the station is controlled by an "on site" operator but eventually the operation will be remotely controlled from London.

The **Northern Radio Societies Association** is to hold its second convention during September 3rd and 4th at Belle Vue, Manchester. Further details are available from I. D. MacArthur, 55 Langdale Road, Bramhall, Cheshire.

BBC-2 test transmissions from Black Hill, Central Scotland, will start on Channel 46 on June 11th. The u.h.f. transmitter will provide BBC-2 programmes to about 2,300,000 people in Central Scotland, including Glasgow, and part of Edinburgh.

A one-day symposium, **Computers in Medicine**, is to be held on July 6th at Enfield College of Technology. Demonstrations of equipment will be given by selected computer manufacturers during the day. Further details are available from the Academic Registrar, Enfield College of Technology, Queensway, Enfield.

Correction.—In the news item on page 174 of our last issue regarding the new mast and aerial for Winter Hill we inadvertently gave the incorrect frequencies for channel 9. These should read 191.25 Mc/s sound and 194.75 Mc/s vision.

"**A.F. Cascode.**"—We regret that an ECC81 was indicated instead of an ECC83 in Fig. 7 of "A.F. Amplification with the Cascode" by G. A. Stevens in the last issue.

PERSONALITIES

H. E. Barnett, T.D., M.Sc., A.C.G.I., D.I.C., M.I.E.E, until recently assistant director of the Electrical Inspection Directorate of the Ministry of Aviation, has been appointed director of the British Calibration Service set up by the Minister of Technology (see "Editorial Comment"). For the past 11 years Mr. Barnett has been in charge of engineering services in E.I.D. which included the organization of the Inspectorate's electrical standards, metrology and materials laboratories and has been concerned with developing new methods of measurement at r.f. Mr. Barnett is also a member of the Radio and Electronics Measurement Committee of the Ministry.

Air Commodore J. C. Millar, D.S.O., M.I.E.E., has joined the London Office staff of the Marconi Company for special liaison duties with the Services, Government departments and other users, on behalf of the Marconi Aeronautical Division. Educated at Malvern and Trinity College, Cambridge, Air Cmdre. Millar served for 33 years in the R.A.F. He was for three years Command Signals Officer, Bomber Command and from June 1963 until his retirement was R.A.F. Provost-Marshal in the Ministry of Defence.

Air Cmdre. J. C. Millar

R. N. Barton, M.I.Mech.E., has joined Plessey as director and general manager of the Telecommunications Group. He was previously production director with Standard Telephones and Cables.

G. Ivor Thomas, senior design engineer of A. B. Metal Products Ltd. for the past 12 years, has been appointed quality manager, a newly created position covering all aspects of inspection and quality control.

W. A. Everden has been appointed head of the Passive Components Department of Mullard's Industrial Markets Division. Formerly the commercial product manager for ferrites, Mr. Everden, who is 37, joined the Mullard company in 1948. He spent six years in various production posts and a further year at Mullard Research Laboratories where he specialized in applications research on ferrites.

W. A. Everden

Francis Seely B.Sc., aged 39, has been appointed head of Market Departments in Mullard's Industrial Markets Division. The Market Departments are customer-orientated groups specializing in and serving various sectors of the electronics industry such as computing and telephone exchanges, telecommunications and radar, and instrumentation, control and power. Mr. Seely, who has been in the electronics industry for 21 years, was previously manager of the market department for instrumentation, control and power. The post will now be filled by **B. H. Penney,** Grad.I.E.E., formerly manager of the Division's Industrial Sales Department. Mr. Penney, has had seventeen years' experience in electronics, first with the G.P.O. and subsequently in the semiconductor industry. He joined Mullard in 1964. The new head of the Industrial Sales Department is **T. E. Days** who worked at the Mullard Research Laboratories on special types of valve from 1940 until he left in 1955. He rejoined Mullard in 1961 and has been concerned with the supply of specialized components to universities and research laboratories.

F. C. McCrea, after 37 years' service with the Dubilier Condenser Company, has relinquished his executive duties but is remaining as chairman of the Board. He is succeeded as managing director by **J. H. Cotton** who has been with the company since 1930 and joined the board as works director in 1947. The new assistant managing director is **J. Goodman.**

Colonel J. S. Vickers, B.Sc.(Eng.), A.M.I.E.E., who joined the British Standards Institution in 1961, has been appointed head of the Planning Group set up to co-ordinate the Institution's increasing volume of work. He trained as an electrical and mechanical engineer, serving his apprenticeship at the Rugby works of British Thomson-Houston. Early in 1939 Colonel Vickers took a Regular commission in R.A.O.C. from which R.E.M.E. was formed in 1942. During the past four years at B.S.I. Colonel Vickers has been primarily concerned with U.K. participation in the work of the International Commission on Rules for the Approval of Electrical Equipment.

John Lawson, who joined Feedback Ltd. in 1961 as a development engineer, has been appointed to the company's technical sales staff with specific responsibilities in exports. He served for several years in R.E.M.E. and was in the Test and Development Department of Servomex Controls before joining Feedback.

F. Seely

B. H. Penney

T. E. Days

G. C. Gaut, M.A., B.Sc., research director of the Plessey Company, has been appointed by the Minister of Technology as a part-time member of the National Research Development Corporation. Mr. Gaut has been with Plessey since graduating at University College, Oxford, in 1934, and has been an executive director since 1951. He was responsible for setting up in 1937 the company's first laboratory for research and development on technical processes for the manufacture of electronic components. The laboratory, which was started at Ilford, is now at Caswell, Towcester. Mr. Gaut is also a director of the Plessey subsidiary Semiconductors Ltd. The N.R.D.C. was set up in 1949 by the Board of Trade to secure "in the public interest, the development and exploitation of inventions resulting from public research or other inventions where these are not being sufficiently exploited." N.R.D.C., which has been the responsibility of the Minister of Technology since 1965, has eight part-time members and three full-time members including the managing director **J. C. Duckworth,** who was for some years with Ferranti and was in charge of the development of the guidance and control system for "Bloodhound" guided missile.

Ian D. Davie, A.M.I.E.R.E., has joined Kent Precision Electronics Ltd. as chief engineer. Mr. Davie, who is 31 and was awarded the City and Guilds of London Institute Full Technological

I. D. Davie

Certificate in Telecommunications Engineering in 1959, was formerly with Roband Electronics Ltd. as manager of the power supply department.

J. S. Lasenby has joined Kent Precision Electronics Ltd. as sales manager. He held a similar post with Everett Edgcumbe & Co. before joining K.P.E.

B. J. Nearn has been appointed group sales manager in the S.T.C. Components Group. A former Signals Officer in the Technical Branch of the Royal Air Force, he joined S.T.C. in 1948 and has held a number of executive posts. Initially in the Rectifier Division, he subsequently became marketing manager, Magnetic Materials Division, and later, marketing manager Rectifier Division. Since 1963 he has been general sales manager, Components Group. **D. R. Salmon** has become home sales manager in the company's Components Marketing Division. Aged 39, Mr. Salmon joined the company as a student in 1944. After National Service in the R.A.F., he joined the Capacitor Test Department (then at North Woolwich) in 1948. Becoming interested in the suppression of radio interference, he took part in setting up the first radio interference suppression service in 1950 and for some years was engaged on the design of interference suppression devices. He has been product sales manager, Capacitor Division, since the end of 1962. **G. Thornton,** who is 28 and joined S.T.C. in 1962, was initially engaged on production control of transistors, and has been head of market research since 1963.

B. J. Nearn

D. R. Salmon

G. Thornton

R. B. C. Copsey, A.M.I.E.E., who joined Redifon in 1949, has been appointed chief engineer, Redifon Marine, at the company's Wandsworth headquarters. Mr. Copsey, who is a member of the Ships' Wireless Working Party Radio Technical Committee, will control both development and project engineering for Redifon's marine operations. Designer of many of Redifon's marine communications equipment, Mr. Copsey led the Redifon team which designed the drive and frequency synthesis equipment for the recently completed NATO high-power v.l.f. station at Anthorn in Cumberland. Prior to his present appointment he was engaged in research on aerial systems.

R. B. C. Copsey

A. W. Cross, B.Sc., who has joined Abbey Electronics and Automation Ltd., of Cheshunt, Herts., as sales manager, was previously senior engineer, then sales manager of W. H. Sanders (Electronics) Ltd. He gained a B.Sc., in mathematics and a B.Sc., honours in physics at Hull University and is author of the book, "Experimental Microwaves."

OBITUARY

William Henry Eccles, F.R.S., "the first of the radio physicists" died on April 29th in his 91st year. In our issue of last September we published a tribute to him on the occasion of his 90th birthday. In it our contributor "H.F.S." wrote "It would hardly be too fanciful to put forward Dr. Eccles as the grandfather of the transistor. In 1909 he demonstrated oscillating crystal detector circuits and developed the general theory 'that under certain conditions a rectifying detector could become a generator of oscillations and conversely a generator of oscillations could be used as a rectifier'." What was however, his most significant work was on radio wave propagation. In 1911 he published a Royal Society paper explaining and expanding the theory put forward ten years earlier by Heaviside. Dr. Eccles was for about two years with Marconi's but in 1901 went into the academic world and in 1916 was appointed to the chair of electrical engineering and applied physics at the City and Guilds of London Institute. For a short time during the First War he was director of the Admiralty Electrical Engineering Laboratory. He was elected a Fellow of the Royal Society in 1921.

THE MONTH'S CONFERENCES AND EXHIBITIONS

Further details are obtainable from the addresses in parentheses

LONDON

June 6-8 — Brunel College
Integrated Circuits in Electronic Equipment
(Brunel College, Woodlands Avenue, W.3)

June 6-8 — Savoy Place
Design and Construction of Large Steerable Aerials
(I.E.E., Savoy Place, W.C.2)

June 20-25 — Central Hall
Automatic Control (I.F.A.C. Congress)
(Congress Secretariat, U.K.A.C., c/o I.E.E., Savoy Place, W.C.2)

WOLVERHAMPTON

June 14-16 — College of Technology
Radio & Television Maintenance
(W. J. Anderson, College of Technology, Wulfruna St., Wolverhampton)

OVERSEAS

June 6-10 — Prague
Interkama Symposium
(Ing. J. Moravek, Plzenska 66, Prague-5-Smichov)

June 15-17 — Philadelphia
International Communications Conference
(A. E. Joel, Bell Telephone Labs, Holmdel, N.J.)

June 15-20
Scientific Congress on Electronics
(Rassegna Elettronica, via Crescenzio 9, Rome)

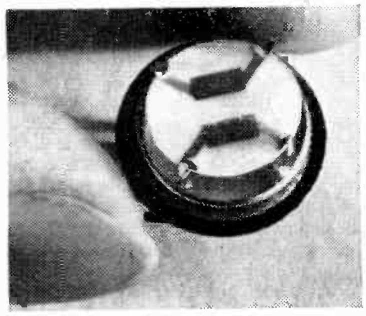
June 21-23 — Colorado
Precision Electromagnetic Measurements
(J. Cronland, Bureau of Continuation Education, University of Colorado, Boulder)

June 21-24 — Chicago
Data Processing Conference & Exhibition
(Data Processing Management Assoc., 524 Busse Highway, Park Ridge, Ill.)

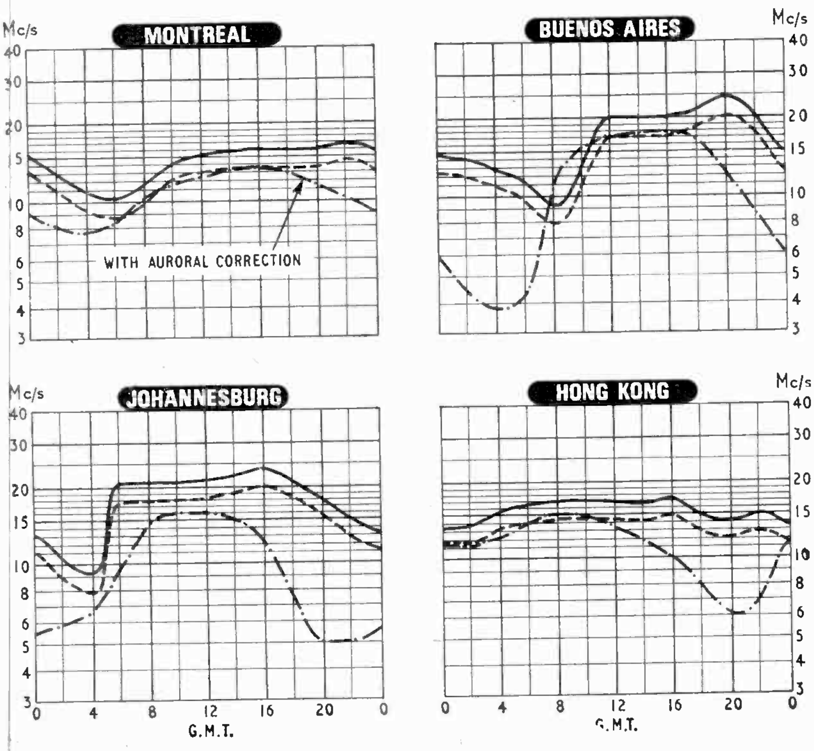
June 22-24 — Pasadena
Electron Devices Research Conference
(S. J. Buchsbaum, Bell Telephone Labs., Murray Hill, N.J.)

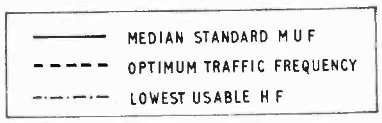
Quartz Bandpass Filter

CONVENTIONAL bandpass crystal filters normally require a network of capacitors, transformers and crystals. To replace these components, Bell Telephone Laboratories have developed a filter consisting of a single wafer of quartz. The device is made from a wafer of quartz 10 mm dia. and 1 mm thick on which four rectangular electrodes are deposited, two on each side. When the device is used as a filter, the crystal resonates at two different frequencies, above and below the normal quartz resonant frequency. This property of dual resonance is due to mechanical coupling between the resonators, the couplings depending on the mass of the electrodes and the distance between them.



The two resonant frequencies determine the pass band of the filter, the bandwidth being about 0·1% of the mid-band frequency (which can be between 1 and 150 Mc/s). Modifications can be made to the filter, e.g., more electrodes can be added giving greater selectivity and addition of a thin film capacitor would improve the loss characteristics. The filter exhibits a "constant-*k*" type impedance and will give up to 80 dB of attenuation. The filter has uses in many fields including narrow-band f.m. systems and carrier telephone systems (e.g., the new coaxial cable system referred to on page 283).





H. F. PREDICTIONS JUNE

A marked increase in sunspot activity was noted during the months of March and April. Several large active sunspot groups were apparent during this period. Solar flares resulted in a number of Dellinger-type fadeouts. Such a high measure of solar activity, during the early years of the sunspot cycle, is comparatively rare.

The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable frequency (LUF) for reception in this country. Unlike the standard MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, and the type of modulation. The LUF curves shown were drawn by Cable & Wireless Ltd. for commercial telegraphy and assume the use of transmitters of several kilowatts and rhombic aerials.

LC NETWORKS IN TO-5 CASE

TUNED CIRCUITS JOIN THE COMPONENTS NOW AVAILABLE IN TRANSISTOR CASES

INTEGRATED circuits have been produced in TO-5 transistor cans for some time. More recently, relays and potentiometers have appeared in TO-5 cans, and have been described in previous issues. An American company, JFD Electronics Corporation*, has now developed a tunable *LC* filter network in a TO-5 enclosure, and was exhibited at the I.E.E.E. International Convention and Show in New York.

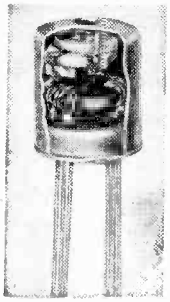


Fig. 1. A typical example of an LC network enclosed in a TO-5 case. The particular item is a phase detector circuit.

The construction is shown in Fig. 1 and a typical filter comprises a toroidal transformer, a fixed ceramic capacitor and a variable ceramic capacitor. A range of filters are available with centre frequencies from 3 to 250 Mc/s, which can be varied by about 10%. 3 dB bandwidths range from 40 kc/s to 4 Mc/s with unloaded Q's of about 60 to 100.

The tuning capacitors used in these networks measure 0.21 × 0.28 × 0.12 in and seven capacitance ranges are available from 1.6-9 pF to 8.5-50 pF.

Some of the circuit configurations possible with these networks are shown in Figs. 2 and 3.

*Represented in the U.K. by S.T.C., Capacitor Division.

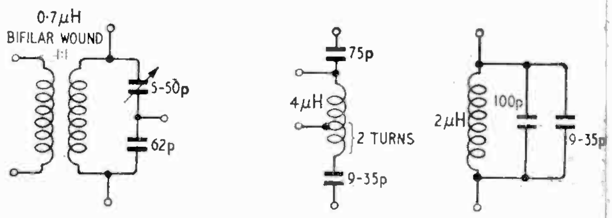


Fig. 2. Three of the many variations possible with the LC networks.

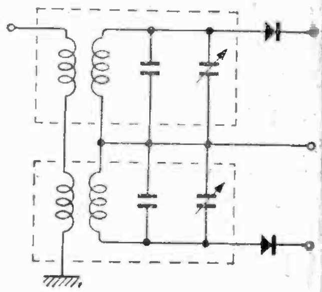


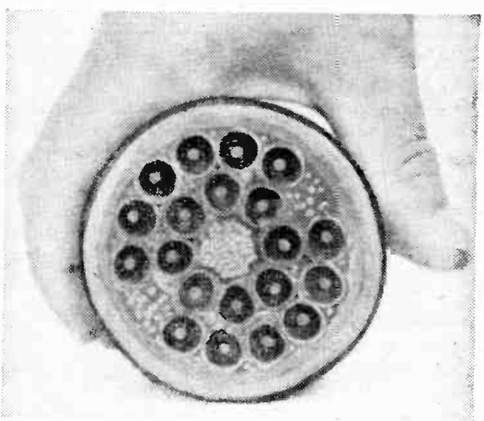
Fig. 3. A 5 Mc/s discriminator using two of the networks in TO-5 cases.

High-Capacity Coaxial Cable

FIELD trials are in progress in Ohio of a coaxial cable system with a capacity of 32,400 voice channels. The cables for the system have been developed by Bell Telephone Laboratories and contain 20 copper coaxial conductors (10 for each direction) each about ⅜ in dia.

The capacity is much higher than normal cables because of the increased number of conductors and also because the frequency of operation is about 0.5-17.5 Mc/s, each coaxial pair carrying 3,600 voice channels. (A previous Bell cable system operated from about 0.3 Mc/s to 8.3 Mc/s with a capacity of 1,860 channels per pair.)

Three types of repeater are used in the system, which uses specially developed silicon transistors. In addition to the basic repeaters located at intervals of 2 miles, there are regulator and equalizing repeaters. Regulator repeaters are placed every 14 miles and their function is to compensate for cable losses caused by changes in temperature. The remotely controlled equalizing repeaters are at intervals of 50 miles and intended to compensate for changes in gain due to various unpredictable effects that occur in cables and equipment. Additional repeater stations occur at intervals of 160 miles. The repeaters are checked by test signals whose levels are monitored at a main repeater or receiving station.



Coaxial cable developed by Bell with a capacity of 32,400 voice channels.

Demonstrations at V.L.F.

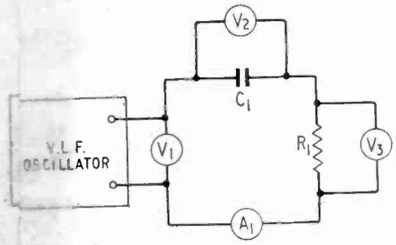
SERIES CIRCUITS AND PHASE-SHIFT OSCILLATORS

By T. PALMER,* B.A., Grad.I.E.E., Assoc.I.E.R.E.

A DEMONSTRATION of the phase difference between the currents flowing in parallel branches containing resistance and capacitance respectively, was described in *Wireless World*, p. 515, October, 1963. The present demonstration begins with the phase difference between the voltages across a resistor and across a capacitor connected in series to the output of a v.l.f. oscillator. In the final example of the phase-shifting properties of a series CR circuit, a ladder network of four CR sections is connected in a v.l.f. phase-shift oscillator circuit.

* Acton Technical College.

Fig. 1 shows the first part of the demonstration. The v.l.f. oscillator should have a frequency of the order of 5 cycles/minute. Suitable v.l.f. oscillators were mentioned in the previous article. In view of the use we shall make of the circuit later, it is convenient to let C1 be 27 μF and R1, 67 kΩ, but the values are not critical. Voltmeters V2 and V3 should be high input impedance valve or transistor voltmeters giving readings on centre-zero meters. Suitable circuits are given in the Mullard Reference Manual of Transistor Circuits (Page 271, Fig. 4) and Application Note 8, issued by Texas Instruments (Fig. 3). A feature of the demonstration is that it is possible to make a mistake in the connection of the voltmeters: this draws attention to some of the conventions associated with phasor diagrams. If the meters are not connected according to a consistent pattern, the indications on them do not conform to our theories. Before connecting C1, it is worth while arranging a circuit with a resistor R8 in place of C1. When the voltmeters are correctly connected, the pointers of all of them should swing from side to side in synchronism. The pointer of the centre-zero microammeter A1 should swing in phase with them. Note that the sum of the voltages indicated by V2 and V3 equal that of V1. After this has been arranged, C1 in inserted in place of R8. We now see that the pointers of the voltmeters no longer swing in step.

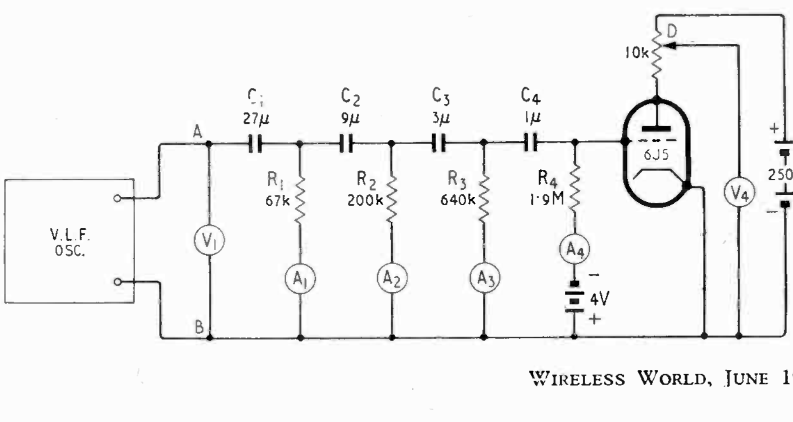


The pointers of the various meters indicate the phase relation in the circuit; V3, measuring the voltage across R1, leads V1; V2, measuring that across C1, lags V1, and the current indicated by the pointer of the microammeter A1 is in step with that of V3. Although the maximum readings on V2 and V3 added up to the maximum reading on V1 when we had R8 in series with R1, we now see that this is no longer so. Instead we have a relation of the form:—

$$(V_{2max})^2+(V_{3max})^2=(V_{1max})^2$$

We can next try the effect of varying the frequency of the oscillator; since the effects are in accordance with theory, we shall not mention them here. At a frequency of 5 cycles/minute, V3 leads V1 by about 45°.

The next step is to modify the circuit to the form shown in Fig. 2. The values shown on the circuit give a phase shift of approximately 45° in each CR stage, at a frequency of 5 cycles/minute. It was decided to reduce the shunting effect of each CR stage on the resistor of the previous stage by increasing the impedance of the different stages as we go from the input towards the output. (See Summary note 2.) With the values chosen, at a frequency of 5 cycles/minute, the voltage at the output is about 0·15 of that applied across the input at AB. But again it is, of course, necessary to connect the meters according to a consistent pattern; here, also, it may be worth while, before connecting C2, C3, C4, to connect suitable resistors in their place, to show that all the meters, when connected according to a consistent pattern, swing in step. When we revert to capacitors, the phase shift in each stage is apparent. It can now be seen that, at a frequency of 5 cycles/minute, the pointer of A2 leads that of V1 by 90°; that of A4 leads by 180°. Since the valve introduces a phase shift of 180°, V4, measuring the voltage from anode to cathode. now swings in phase with



V1, when the input frequency is 5 cycles/minute. V4 is a moving-coil voltmeter of the usual type, with a full scale deflection of 300 V. It gives its highest reading at the instant when V1 shows that A has its maximum positive voltage with respect to B. When the oscillator generates frequencies other than 5 cycles/minute, V4 and V1 are not in phase.

The oscillator is now disconnected from the input AB and a lead from the output, D, of the triode amplifier is now connected to terminal A. If a sufficient fraction of the output voltage is fed back to the input, we now see that the system has finally become an oscillator working at 5 cycles/minute. If the fraction of the output voltage is too small, oscillations will not be maintained (they may take some time to die away in this circuit with its long time constants). If too large a fraction is fed back, the voltage at the output is not sinusoidal. By considering the swings of the pointers of A1, A2, A3 and A4 the phase shift in the different stages can still be appreciated. If the values of the resistors (or the capacitors) are multiplied by a suitable factor, students can see the effect this has on the frequency of the oscillation.

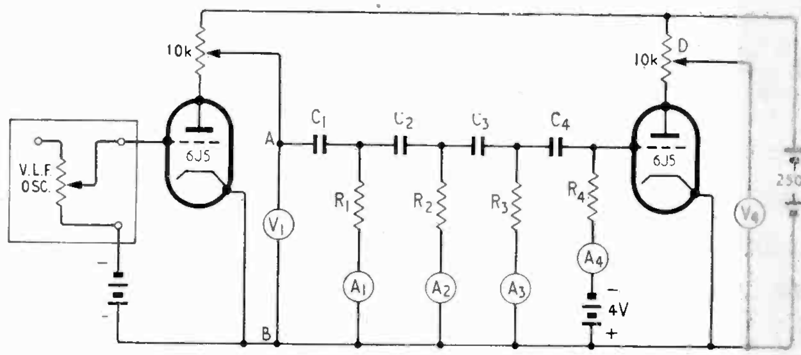
Summary

1. The oscillator I used in Fig. 2 gave an output of about 1 volt, peak, which gave small deflections on the microammeters. I amplified the output by a simple triode, as shown in Fig. 3. The arrangement has the advantage that, when we are considering whether V1 and V4 are in phase or not, we are concerned with the swing of pointers on similar instruments. The voltages are in phase if the two meters give maximum deflection at the same instant.
2. The advantage of increasing the impedance of the CR stages as we go from input to output, is that we do not have to take the loading of one stage on the previous stage very seriously. It has the snag, however, that with R4 equal to 1·9 MΩ, a very sensitive meter, rated at, say, 10-0-10 μA, is required to show the swing on A4, which may be of the order of 2 μA. If you prefer, all the CR stages can have the values of the first stage. (The frequency will not be 5 cycles/minute but it may be suitable; also, a larger fraction of the output voltage must be fed back to maintain oscillation.)
3. There is no reason why this technique should not be used with a transistor amplifier which turns into a v.l.f. oscillator when the output is returned to the input. The circuit of Fig. 15 of the article by Mr. F. Butler, (*Wireless World*, p. 588, December, 1962) is suitable for this demonstration. I prefer not to use it for an elementary class because:

(a) there is some uncertainty about the input resistance of the transistor amplifier; it is possible to measure this experimentally, but this detracts from the basic simplicity of the demonstration;

(b) it is more difficult for elementary students to understand how the output is fed back to the input.

4. When a class had seen the demonstration, a student who had seemed to understand how the system oscillated, wanted to know why anyone should want to make an oscillator.



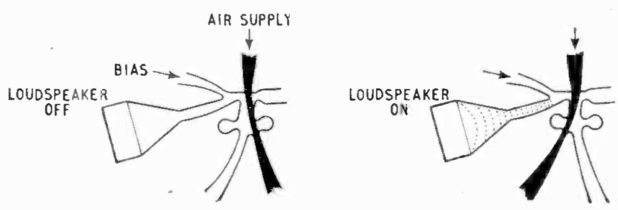
When I explained that if we chose suitable CR values and threw in a few switches, we could play pop music on it, the raison d'être of an oscillator was, of course, fully appreciated. If an epidemic of electronic organs breaks out, I hope I may be forgiven. This would be too high a price to pay for an understanding of phase-shift oscillators.

Transducers for Fluid Logic Systems

ATTENTION has been paid to logic gates operating with fluid because it is felt that such might form the basis of low-cost low-speed digital logic systems. To enable electronic signals to be converted to pneumatic signals devices are required which are capable of operating up to several hundred pulses per second. Often solenoids are used as transducers but these are limited in speed of operation. I.C.T. demonstrated a faster method using a pressure type loudspeaker at the Physics Exhibition held recently (reported in the May issue).

A fluid logic OR/NOR gate was shown operating with an input data rate of 300 pulses per second. The electrical input triggered an 8 kc/s multivibrator, and the resultant modulated a.f. signal was then amplified to 3 W and fed to the loudspeaker. A convergent cone coupled the acoustic output to the logic element, the presence or absence of the acoustic signal switching a fluid jet into one of two positions. Pressure signals at various points of a logic network could be displayed on an oscilloscope and small piezoelectric transducers were used to extract the signals.

Another demonstration showed that line matching is not only an electrical problem—interconnections in fluid systems exhibit characteristic impedance. A mismatch was caused by an open-ended tube and the pressure signals near the end of the tube could be compared to that of a matched line. By altering the size of the open-ended line between fully open and fully closed the signal could be seen to reach an optimum between the two extremes.



Transistor Electronic Organ—2

Semiconductors in Electronic Organs

By T. D. TOWERS, M.B.E.

THE first article in this series (May 1966 issue) examined in broad terms the principal features of electronic organs. The present article shows in some detail how such principles are reflected in actual circuits from what is now the commonest class of commercial instrument—the non-mechanical, transistorized, all-electronic organ.

Fig. 1 illustrates in block diagram form the main sections of a complete electronic organ. Transistors are

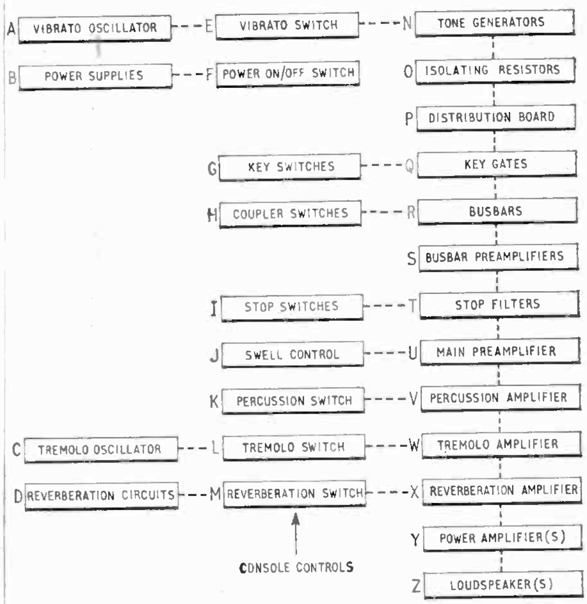


Fig. 1. Block diagram showing main sections of complete electronic organ.

often used in (1) *oscillators* as source for tones (N), vibrato (A) or tremolo (C); (2) *dividers* as sources for tones (N); (3) *gates* controlled by playing key switches for tone transmission (Q) or percussion (V); (4) *modulators* for applying vibrato (N) or tremolo (W) drive; (5) *preamplifiers* (S, U, W); (6) *power amplifiers* (Y); and (7) *power supplies* (B).

OSCILLATORS

The electronic organ uses two quite distinct classes of oscillators: (1) an audio-frequency type to generate tone signals, directly or indirectly, and (2) a subsonic type to provide drive for vibrato or tremolo effect in the generated tones.

Tone-generator oscillators.—Tone-generator oscillators are usually LC-tuned, because you can achieve the required frequency stability more easily with LC tuning than with, say, the resistor-capacitor network controlling an RC oscillator.

As to the level of frequency stability required, it is not commonly realized that there is a subjective element in this. In the equal-tempered scale (to which electronic organs are normally tuned) the frequencies of notes a semitone apart are in the ratio of $2^{1/12}:1$, i.e. 1.05946:1. For non-mathematicians this means that a semitone corresponds to about 6% difference in frequency. Hearing varies, but most people can distinguish a pitch difference of the order of $\frac{1}{2}$%, i.e. about a tenth of a semitone. (Although I once played in a group with a trumpet player who had to appeal to me to tell him when he had managed to set his tuning slide to bring him to the tuning "A." I reckoned he could not distinguish much better than a quarter tone!) The $\frac{1}{2}$% discrimination of normal subjects suggests that an organ should be capable of being tuned (and of holding its tuning) to something well down on this, say at 0.1%. However, experience has proved that too exact tuning can destroy to some extent the fine musical qualities of an organ, and that an instrument deliberately mistuned randomly at between one-fourth and one-half per cent of perfect pitch receives better customer acceptance on listening tests than one with perfect pitch. This still calls, however, for something of the order of 0.1% oscillator stability, if the deliberate mistuning is to be held over a period.

Another approach is to accept a less stable oscillator, tune it as nearly as possible to perfect pitch and be confident that the inevitable frequency wandering will produce the same effect as a deliberate controlled mistuning of a higher-stability oscillator.

Free-phase LC oscillators for direct tone-generation.—Historically, the first organs to use *LC* tone generators were the "free-phase" type. In these, a separate oscillator was used for each tone frequency required. Fig 2(a) gives a typical circuit. The oscillator is the Hartley type, normally used for this application because of its good frequency stability and its harmonic-rich sawtooth output. The inductor, *L*, is a ferrite pot-core with an adjustable slug permitting some ±4% variation of inductance. One standard pot-core assembly with a range of coil inserts can be used to cover the whole organ gamut, say from 64c/s to 4,080c/s. The playing key switch in the d.c. supply is the hallmark of the "free-phase" tone-generator oscillator. An uncommon refinement is that the d.c. supply can be set to 3V for "soft" or 9V for "loud." This illustrates the good frequency stability of the oscillator under changing supply voltage. The 100kΩ resistor in the output line isolates the oscillator from others connected to the same output busbar.

Master LC oscillators for divider organs.—The commonest type of LC oscillator in electronic organs nowa-

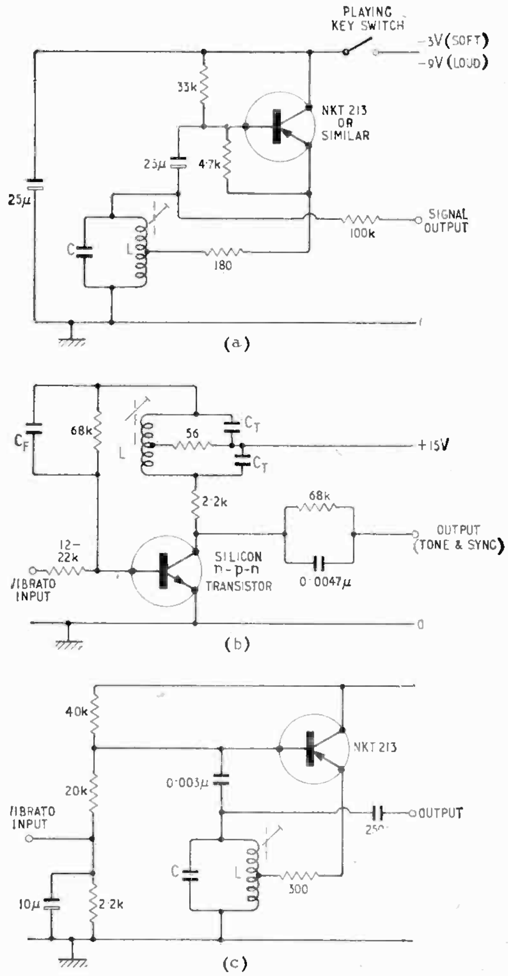


Fig. 2. Tone-generator LC oscillators: typical transistorised circuits used commercially for direct generation of tone signals ("free-phase") or for providing master synchronising frequencies ("divider"): (a) free-phase, emitter-coupled, Hartley (L, C = 3H, 2µF at 64 c/s to 30 mH, 0.05µF at 4,080 c/s) (Gulbransen); (b) master, collector-coupled, modified Hartley (L, C_T, C_F = 0.9 H, 0.1 µF, 0.047 µF at 740 c/s to 0.4 H, 0.066 µF, 0.033 µF at 1397 c/s) (Heathkit); (c) master, emitter-coupled, Hartley (L, C = 350 mH, 0.016 µF at 2 kc/s to 350 mH, 0.004 µF at 4 kc/s((Kawai).

days is the master oscillator in the divider type of organ. A set of twelve of these is required, each producing a frequency corresponding to one note in the chromatic scale in the highest octave of the instrument keyboard. The master oscillator not only generates a tone of its own frequency, but also provides synchronizing pulses to a string of divider circuits. Each divider produces in turn an output one octave lower than the one above it. Almost always the master oscillators are some form of Hartley circuit, with either collector-base or emitter-base feedback.

Fig. 2(b) gives a representative example of a collector-base feed-back master oscillator. This one is designed to provide chromatic frequencies from F ≈740 c/s to F 1,397 c/s by selecting suitable values of the split tuning capacitors, C_T, the feedback capacitor, C_F, and the inductance, L. For any selected frequency, the final exact tuning is effected by adjusting the slug inside the ferrite pot core. The rail voltage of 15 V is typical of the range of 15-18 V normally used with mains-operated instruments. The transistor used illustrates the trend towards silicon n-p-n devices. The overcoupled oscillator feedback gives a non-sinusoidal waveform rich in upper harmonics. (The "vibrato input" will be explained later below.)

Fig. 2(c) gives a typical example of the emitter-coupled master oscillator, which tends to be more common than the collector-coupled one. The example shown is designed to work in the frequency range 2-4 kc/s. For traditional C-to-C organ manuals this is the most common range for master oscillators to be set in. In economy organs, however, the oscillators may be found set from 1-2 kc/s, and in some specialized organs with wider tonal range 4-8 kc/s is used.

Although most organ designers now use some form of Hartley, there is wide variation in tank circuit L, C values. At 2 kc/s, the bottom end of the normal master oscillator compass, inductance values from 20 mH to 350 mH will be found. This wide design variation can be explained by the conflicting requirements of the tank circuit. First, to keep the organ reasonably in tune, it is best to have as high a Q as possible; but not so high as to make it difficult to frequency-modulate the oscillator for vibrato. The tendency nowadays is towards lower L and higher C. The higher capacitance tends to swamp out the effects of varying transistor junction shunt capacitances and makes the oscillator stability relatively independent of the transistor. Miniature low-voltage polystyrene capacitors are becoming standard in the tank circuit, because they have a negative temperature coeffi-

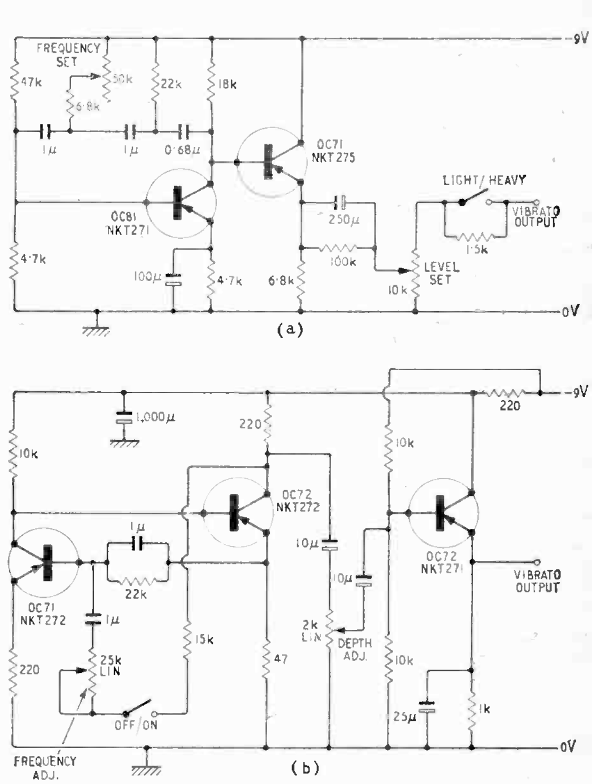


Fig. 3. Vibrato-tremolo RC oscillators: typical transistorised circuits used to provide modulating voltage for vibrato (frequency modulation) or tremolo (amplitude modulation) variation of tones at approximately 6 c/s: (a) RC phase-shift circuit (Watkins Electric Music); (b) Wien-bridge (Jennings Musical Industries).

cient offsetting the positive coefficient of the ferrite pot-core inductance.

Oscillators for vibrato or tremolo drive.—In a pipe organ, the "tremulant" stop induces a cyclic variation of both the pitch and the loudness of a speaking pipe at a rate of about 6 c/s. This is simulated in electronic organs by applying "vibrato" (subsonic modulation of the tone frequencies) or "tremolo" (modulation of the amplitude), or both combined. The modulation drive is usually provided by some form of *RC* oscillator which we will in future refer to as the vibrator oscillator, although tremolo drive is provided by the same sort of oscillator). This oscillator has to provide several volts r.m.s. of pure sinewave from an impedance low enough to be able to drive a number of loads. The pure sinewave is necessary because distortion can give rise to an unpleasant roughness in tone.

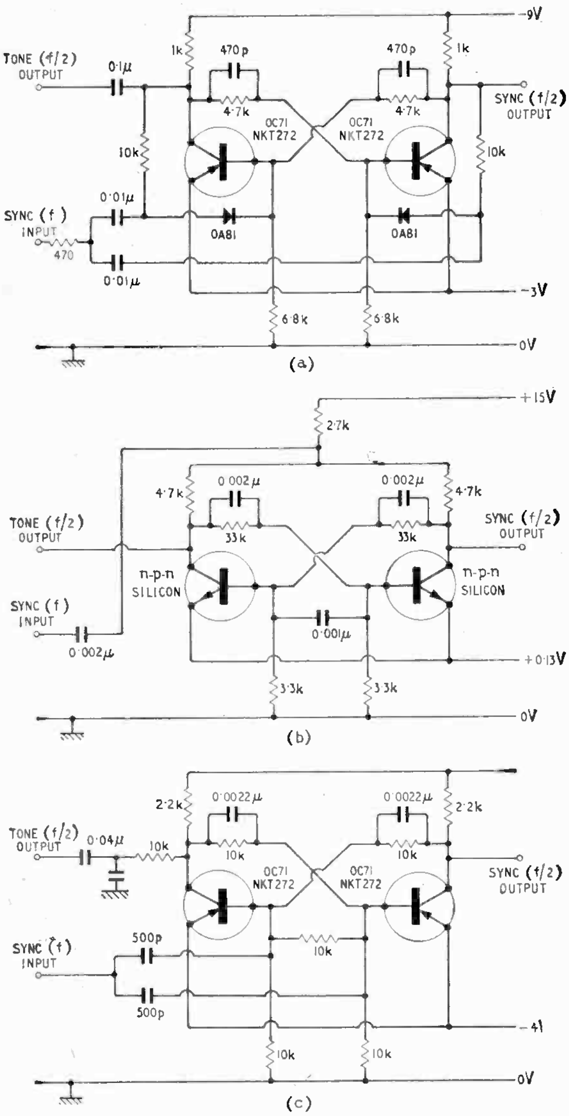


Fig. 4. *Square-wave dividers: selection of commercial transistorised bistables: (a) diode-triggered (Watkins Electric Music); (b) collector-resistance-triggered (Heathkit); (c) base-resistance triggered (Jennings Musical Industries).*

For low distortion, most vibrato oscillators use either an *RC* phase-shift or a Wien-bridge type of oscillator. For low output impedance, they usually have a buffer stage following the oscillator proper. Fig. 3(a) illustrates a typical *RC* phase-shift circuit employing only two transistors, while Fig. 3(b) shows a Wien-bridge circuit using three. Both include an emitter-follower output buffer stage and have potentiometer provision for presetting frequency in a range around 6 c/s and for adjusting the output level.

DIVIDERS

In divider-type organs, the master oscillators discussed earlier control a string of dividers, each giving a frequency one-half of that above it in the string. There are two main types of such dividers: "square-wave" and "sawtooth," characterized by their output waveshapes. Sawtooth dividers are more versatile in terms of their harmonic content, but nowadays most commercial organs use square-wave dividers. This is because they are cheap and convenient in manufacture, since the divider circuits are all identical wherever they lie in the divider string, and do not require any setting up by adjustment or selection of component values. With sawtooth dividers, component values change as frequency changes along the string, and most designs call for setting up each divider individually.

Square-wave dividers.—Almost without exception, the square-wave divider used in an electronic organ is some form of bistable multivibrator. The main variation between different designs lies in the method of trigger pulse steering. The normal computer-type diode steering is illustrated in the example given in Fig. 4(a). Fig. 4(b) illustrates the other main trigger-steering method used, the common collector resistor. A third variant also used is the divider of Fig. 4(c), where the trigger pulses are steered to the appropriate base with the aid of a 10 kΩ cross-coupling resistor between the bases. (Interested readers will find explanations of these and other pulse circuits described in this article set out in full in "Elements of Transistor Pulse Circuits" by T. D. Towers, Iliffe Books, Ltd., 1965.)

Sawtooth dividers.—Designers aiming at sawtooth output from their dividers usually adopt a blocking-oscillator divider of the type shown in Fig. 5 (a). An alternative sometimes used is to start with a square-wave divider and convert its output into a sawtooth with the circuit of Fig. 5 (b). Both the direct sawtooth divider and the converted square-wave circuit call for setting up by selection of the integrating capacitors used for different frequencies as indicated in the caption under Fig. 5.

Organ designers divide themselves firmly into "square-wave" or "sawtooth" proponents. An interesting compromise is the Heathkit (Thomas) arrangement whereby the square-wave output at any frequency is mixed with 50% of the octave above before passing to the key-switches and tone filters. This produces a staircase waveshape which partakes of some of the character of both square-wave and sawtooth.

GATES CONTROLLED BY KEYSWITCHES

As semiconductor devices get cheaper, designers are making more and more use of diode or transistor gates to route tone signals after they leave the generators.

Transmission gates.—When you use an ordinary key-switch to make and break an a.c. signal path from the

I.E.A. EXHIBITION GUIDE

SPONSORED by four trade associations* the sixth International Instruments, Electronics and Automation Exhibition opens at Olympia, London, on May 23rd for six days. More than 850 firms are listed as participating and almost a third of these are from overseas. Many are, of course, represented on the stands of their U.K. agents and others, e.g., from U.S.A. and France, are participating in composite national exhibits.

With so many exhibitors, the large majority of whom will be showing equipment, devices, components or materials of interest to readers of *Wireless World*, it is impossible to deal adequately with so vast and varied a display of products. In this supplement, however, we have endeavoured to give readers a brief preview of the exhibition compiled from information which exhibitors were invited to supply; although not all exhibitors responded to the invitation. Many of the exhibitors are sharing stands and it has been necessary, therefore to group them together stand by stand. To facilitate the location of references in this preview we have included in the list of exhibitors (at the end of this supplement) the name, in square brackets, under which the report on the stand is listed. We have also appended to each report a number for use on the reply card by professional readers requiring further information on manufacturers' exhibits.

Admission to this biennial exhibition, which, as will be seen from the plan on pages 308-9, occupies the Grand, Empire and National Halls at Olympia, costs 5s, or 10s for the week. It will be open daily from 10 a.m. to 6 p.m.

* British Electrical & Allied Manufacturers' Assoc., Electronic Engineering Assoc., Radio & Electronic Component Manufacturers' Assoc., and Scientific Instrument Manufacturers' Assoc.

Preview of Exhibits

A.K. FANS

Forced-cooled heat sink assemblies for semiconductors, which are produced in collaboration with Marston Excelsior Ltd. and are called Marex, are among several new products to be exhibited. There are also the Boxer tube-axial fans, which are only 1$\frac{1}{2}$ in deep, and the Warrior 2$\frac{1}{2}$ in deep centrifugal fan.

WW 311 for further details

A.P.T. ELECTRONICS INDUSTRIES

Among its exhibits the company will be showing its latest 'APTEC' Transcoder which can be used for reading, typewriting and punching information in any specified tape code. Editing features include special code behaviour controls, mode controls and auxiliary code generating switches. Other exhibits in the data processing field will include the 'APTEC' Tape Comparator Model AT 9102. In the range of power supplies, the TCU 1050 transistor stabilized power supply will be seen. Output is variable over the range 0 to 50 volts, with a load current of 10 A. The protection system is designed to prevent damage to the unit under overload conditions by limiting the current drawn and, after a delay, clamping the output to zero.

WW 312 for further details

AIRMEC

The main exhibit by Airmec will be the sweep signal generator type 352, which has a frequency band 20 c/s to 200 kc/s; swept in two ranges 20 c/s to 20 kc/s and 200 c/s to 200 kc/s, by a variable speed motor drive. There will also be a crystal controlled frequency standard type 311, the N375 series of proximity switches, and a time interval meter type 369.

WW 313 for further details

ALMA COMPONENTS

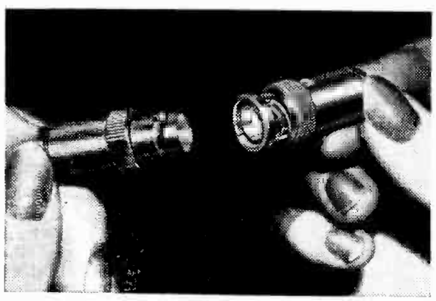
A 24 hour digital clock with progamming facilities is displayed with a uniselector demonstration unit and the full range of reed relays including the new miniature type DPRM, moulded for printed circuit applications. The full range of Alma precision wirewound and metal film resistors is exhibited including the loose wound J range of resistors having long term stabilities of better than ± 0.003% per year.

WW 314 for further details

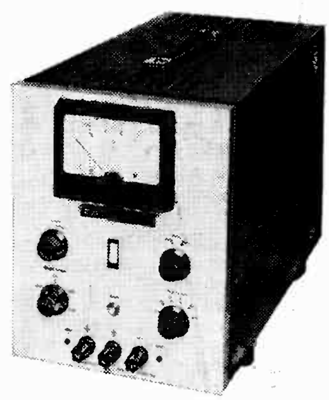
AMPHENOL

New products on display for the first time include the range of Delevan fixed r.f. inductors and tunable inductors now marketed by Amphenol under an agreement with Delevan Electronic Corporation, a subsidiary and export agent of American Precision Industries Inc. New connectors on show for the first time include the 75 Ω BNC range, with an upper frequency limit of 3 Gc/s.

WW 315 for further details



▲ *75-Ω BNC connector with an upper frequency limit of 3 Gc/s (Amphenol).*



▶ *The TCU 1050 stabilized power supply from A.P.T. incorporates an overload protection circuit.*

ANALYTICAL MEASUREMENTS

Of interest to industries required to install effluent plants under the new laws, and for process control where pH is an important factor, is the new range of industrial pH controllers and electrodes that will be shown. A new range of laboratory pH meters and pH recorders with expanded scales and solid state circuitry will also be displayed.

WW 316 for further details

ANTEX

A do-it-yourself "soldering bar" is a feature of this stand. A complete range of miniature soldering irons and accessories, including de-soldering tools will be shown. A selection of soldering irons, designed for the electronics industry and the amateur will be placed on benches at either side of the stand. Here, soldering and de-soldering can be undertaken by visitors, who can also, if they wish, bring along soldering problems for solution on the spot.

WW 317 for further details

APPLIANCE COMPONENTS

A range of Unimax micro switches, with ratings up to 25 A at 250 V, and a variety of shaded-pole synchronous hysteresis motors are to be shown. The new Bristol d.c. motor with solid-state control module is for 1.5 to 12 V supplies.

WW 318 for further details

ARKON INSTRUMENTS

The Model 63 recorder for pressure and draught measurement incorporates a number of improvements including a redesigned exterior and a reduction of overall dimensions to save space. The Model 1600 recorder will be shown working on an effluent measurement application, using the dip tube/air reaction principle, with the "V" notch weir technique. Also on display will be the Arkon Audible Gauge which gives an audible and visible check on storage tank level with oil fired central heating systems.

WW 319 for further details

ARROW

A new self-illuminated rocker switch will be shown for the first time. Subminiature switches, in both lever and push-button versions, together with the very comprehensive range of toggle and lever switches, in both two- and three-position types, especially suitable for instrument control, are also featured.

WW 320 for further details

AUSTEN PUMPS

This company will be showing a range of small oil-free diaphragm pumps for both pressure and vacuum applications. Also a small commutatorless d.c. motor with a transistorized switching circuit driving a pump designed as a small portable sampling unit which can run continuously for eight days on a lead-acid car battery.

WW 321 for further details

AUTOMATIC PUNCHED TAPE

A range of tape punches, readers, input keyboards and associated equipment made by the company and by the Tally Corporation (U.S.A.) and SAGEM (France) will include punches with speeds of 30, 60, 120 and 150 characters/sec., readers with speeds of 25, 60, 75 and 150 characters/sec. and teleprinters (using solid-state circuitry) with speeds of 50 or 75 bauds.

WW 322 for further details

AVELEY

The company's newly developed products on show will include a voltage and frequency monitor alarm, a crystal-controlled 2.5-28 Mc/s transmitter drive unit and a polaroid camera for large (14-23 in) c.r. tubes. The associated company Avel Products specializes in toroidally wound components. Aveley will also be showing equipment from several German and American instrument manufacturers for whom they are agents.

WW 323 for further details

AVIATION, MINISTRY OF

Techniques to be demonstrated will include the "Application of Fibre Optics," "The Transferred Electron (Gunn) Effect," "A Simple Semiconductor Microwave Source," "Formation of Thin Films in the Flow Discharge," "A C.R.T. Type Electron Beam Machine," "The 'Touch' Display" (a novel input/output device for computers) and a "Diode Bridge Hygrometer."

WW 324 for further details

AVO

Among new Avo Instruments shown will be a valve characteristic meter (VCM 163), which is simpler to use than earlier models; a transistor tester (TT 164) which can measure leakage currents down to 5 nA; and a Mk 3 version of the Model 8 Avometer giving increased sensitivity and improved frequency response. The Taylor l.f. oscillator Model 192A, which is now in production, will be exhibited. It has a thermistor controlled output, providing a stable source (in frequency and amplitude) and ranges from 10 c/s to 100 kc/s. Other exhibits include multi-range meters, transistor testers, signal generators, panel meters and the recently introduced Model 45D valve tester.

WW 325 for further details

B.F.I. ELECTRONICS

American equipment from the following firms will be shown: Digitronics (paper tape readers), Royal (paper tape punches and readers), Cimron (digital voltmeters), TRG (ballistic thermopiles), C.I.C. (d.c. differential amplifiers), Airpax (choppers, magnetic amplifiers, monitoring and control equipment), Magnetics (tape-wound cores), Universal (Uniac component insertion and component taping machine), and Preco (bonders, scribers and probers).

WW 326 for further details

B.I.C.C.

Telcon Metals Ltd. will be featuring their latest developments in the fields of soft magnetic high permeability alloys, thermostatic bimetals, beryllium copper and controlled expansion alloys. Magnetic & Electrical Alloys Ltd. will display a wide range of transformer, transductor and choke laminations in various grades of cold reduced oriented and non-oriented silicon-steel and high permeability nickel-iron alloys. Telcon-Magnetic Cores Ltd. will have on show their new Temcore construction, which reduces all losses to an absolute minimum. These cores are available both in grain-oriented silicon-iron and non-oriented materials. Temco Ltd. will exhibit a wide range of precision stainless steel wires, both diamond and tungsten carbide drawn, nickel-chrome and copper-nickel resistance wires, Pyromic, Calomic, Telconstan and Telcalloy, and beryllium copper wire in various tempers including the pre-tempered condition.

WW 327 for further details

BARDEN CORP

Examples of bearings in instrumentation equipment for aircraft, missiles, control devices, computers, synchros and servos are being featured by this company who are specialists in the production of precision ball bearings. They are also showing instruments they have developed for assessing the performance characteristics of ball bearings.

WW 328 for further details

BELIX

Two new ranges of power supply modules will be shown. The R.S. series consists of dual-mode constant-voltage constant-current units covering the range 0-30 V and 0-10 A. This series has reverse current, reverse voltage and over-voltage protection fitted as standard. Also on show will be a comprehensive range of silicon sub-units and cabinet models.

WW 329 for further details

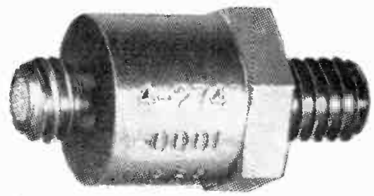
BELL & HOWELL

This company has introduced a small, light-weight piezo-electric accelerometer with a "compliant rod" compression design which mechanically isolates the sensing system from the housing. This mechanical isolation provides maximum shielding from the blast of rocket engines and thermal transients. The accelerometer is suitable for operation in severe humidity because of its all-welded construction. The 70-kc/s mounted natural frequency allows a frequency response of ± 5 % from 2 c/s to 12 kc/s.

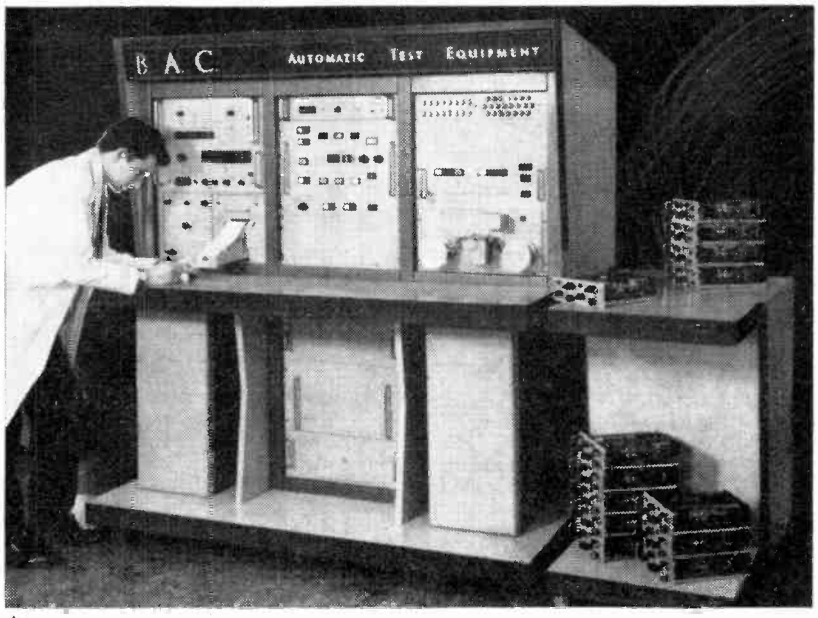
WW 330 for further details

BELLING-LEE

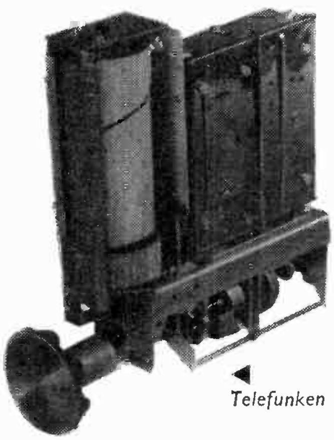
New designs at the show include the 12-way Flexipad terminal block (L 1639/B), three-pole power supply connector (L1722/P & /S)—a larger version of the L1436, sub-miniature pattern 17 coaxial connectors (L1565 & L1566 series), B.N.C. adaptors compatible with



▲ *Bell & Howell piezo-electric accelerometer with isolation between system and housing.*



▲ *Automatic test equipment controlled by a 16-hole punched tape (British Aircraft Corp.)*



◀ *Telefunken Multimat rotary assembly for use in v.h.f./u.h.f. tuners (Britimpex).*

pattern 15, tape cable connectors (8, 12 and 18-way), and the recently announced miniature circuit breakers. R.F. shielded enclosures and television distribution equipment will also be shown.

WW 331 for further details

BERCO

An addition to the "Regavolt" range of variable transformers, the 20B, will be exhibited. Apart from its main application as a 100 W dimmer on 400 c/s supplies it can also be used as a voltage regulator for 20 to 25 V transistor circuits operating from 50 c/s supplies.

WW 332 for further details

BRADY

W. H. Brady Co. of Ruislip, Middlesex (associate of American and Canadian companies of the same name) are exhibiting their range of self-adhesive identification materials. A prominent feature will be wire markers in various materials and sixteen background colours. Self bonding nameplates for various purposes will be shown.

WW 333 for further details

BRITIMPEX

Both the valve and semiconductor and components divisions of Telefunken are represented. A new subminiature gas-filled number indicator is shown (ZM 1120) with numbers of 8 mm in height. New semiconductor devices are AC117/AC175, AC178/AC179, AC131/AC186, BF 173, BF 184, BF 185, AAY 46, BAY 77 and BAY 78. A u.h.f./v.h.f. tuner (type 144) will be shown which uses either push-buttons or the Multimat rotary assembly (illustrated).

WW 334 for further details

BRITISH AIRCRAFT CORP.

The main exhibits are the Corporation's Automatic Test Equipment and the Electrolevel level sensing device. The test equipment developed at the Guided Weapons Division at Stevenage, can conduct automatically a long sequence of tests on a wide variety of equipment. It is controlled by a 16-hole punched tape and can handle the following types of signal: a.c., d.c., audio, video, radio, radar, etc.

WW 335 for further details

BRITISH PHYSICAL LABORATIES

The company will be displaying many new developments which have evolved since the 1964 I.E.A. Exhibition. Several of these will be shown for the first time and include: A d.c. Wheatstone Comparator Bridge with digital readout, the bridge being suitable for resistance measurement (or comparison) in the range 1 MΩ to 10 MΩ with 0.1% accuracy; a transistor tester for carrying out quick but accurate checks on transistors and diodes; a three channel component grader suitable for grading components into three tolerance bands; a new multi-range test set and an extended scale electrically-suppressed voltmeter, suitable for measuring voltages over a limited range, with an accuracy comparable to that of digital voltmeters.

WW 336 for further details

BRITISH RESISTOR CO.

Exhibits will include typical substrates for resistor-capacitor modules, magnesium oxide swaging tubes, NTC thermistors, PTC thermistors, high temperature thermistors, single crystal thermistors, together with a selection of varistors and resistors.

WW 337 for further details

BRITISH ROTOTHERM

In addition to a wide range of thermometers, Rototherm will also be exhibiting temperature and pressure recorders.

WW 338 for further details

C & N ELECTRICAL

The company announce a new modular data processing system details of which will not be released until the show opens. They will also be showing the R7020 h.f. communications receiver, which is now in production, and two new co-ordinate marking-out tables for metal work.

WW 339 for further details

CADMIUM NICKEL BATTERIES

Typical applications of the company's products in electronics and aerospace will be presented. The nickel-alkaline batteries manufactured include the Voltabloc rechargeable cells (1.2 V) and accumulators, which are hermetically sealed and pressure protected and have especially thin sintered-plate electrodes (made under licence from the French company S.A.F.T.). Cell capacities range from 0.45 to 6 Ah.

WW 340 for further details

CALLINS INTERNATIONAL

This company from Ireland are makers of aluminium foil electrolytic capacitors. Ratings range from 3,250 μF at 3V d.c. working to 17 μF 350V d.c. working.

WW 341 for further details

CAMBRIDGE CONSULTANTS

The company provides contract research and development services in mechanical, chemical and electronic engineering. Assistance is given in setting up licence agreements between individuals and manufacturing organizations and in company diversification programmes. The company has on its staff specialists in most scientific and engineering fields with computing services available.

WW 342 for further details

CHART-PAK

The Trans-Pak method of making printed circuit masters will be demonstrated. Trans-Pak die-cut symbols are used together with Chart-Pak crêpe paper tapes. The method eliminates hand drawing and consequently speeds up the process of making printed circuit originals.

WW 343 for further details

CIBA (A.R.L.)

CIBA will be showing how "Araldite" epoxy resins are being used in the electronics industry for impregnating, sealing and encapsulating electronic components and assemblies. Applications of Araldite moulding powders will be illustrated by a variety of miniature connectors and transformers. The E-Pak system for high-speed encapsulation using preformed pellets of Araldite will also be shown.

WW 344 for further details

CLARE INTERNATIONAL N.V.

A range of Clareed relays, suitable for direct mounting on printed circuit boards will be exhibited. The power dissipation capabilities have been improved, thereby increasing the operating voltage range. Forms A, B and C are available up to 12 contacts, with a rating of 15VA max. 1A, 250V.

WW 345 for further details

COBHAM ENGINEERING

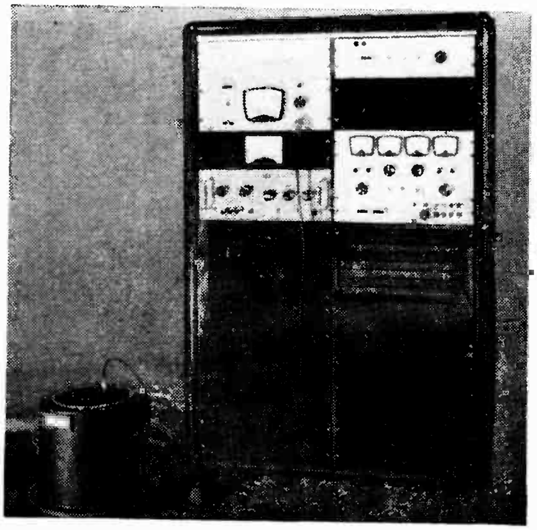
Several types of float, flow and proximity switches will be shown together with gauges and pressure transducers. A radio-control system for the remote operation of valves to control the flow of liquids is to be featured.

WW 346 for further details

CONTRAVES AG

The main exhibit of the Company will be a programme-controlled Co-ordinatograph which automaticaly plots data from punched tape or cards. Some of the applications of the equipment are for plotting ground registers, transverse and longitudinal profiles and polygonal curves.

WW 347 for further details



Derritron random noise equalizer analyser for vibration testing.

CONTROLS & AUTOMATION

The display will include working examples of electronic timers for machine and process control, also the new series HST7 modular electronic timers. Shown for the first time in the U.K. will be items from the Industrial Timer Corporation (U.S.A.) range of timer products, including punched tape programmers, cam timers, interval and delay timers, and time measurement devices.

WW 348 for further details

C. A. COOK

This company will show a 60 kc/s pilot selection filter (crystal) having a 3 dB bandwidth of 20 c/s with 75 dB discrimination at the ± 300 c/s points. Also being shown is a 7 Mc/s low pass filter (LC) with 60 dB stop band attenuation, miscellaneous delay line assemblies, and various wound components.

WW 349 for further details

CROMPTON PARKINSON

The main feature of the stand will be a display of "Unifix" switchboard instruments with standardized fixing dimensions. There is one common drilling plan for 3½ in, 4 in or 6 in dial instruments with short or circular scales. Also a range of a.c. transducers for the measurement of watts and power factor.

WW 350 for further details

CROUZET

The wide range of products includes micromotors, timers (electromechanical and electronic), relays (including delay and pneumatic types), switches (micro-switches and illuminated push-button switches), starter contactors, impulse counters, elapsed time indicators, temperature controllers (thermocouple, Pt resistance and proportional types), turntables, proximity switches, reed switches and fan motors.

WW 351 for further details

DAYSTROM

On display will be a selection of equipment from both the Industrial Products and Heathkit departments of the company. Of major importance is the "X-act Ray" non-contact thickness gauge, for operation on fast-moving strip materials. Details are available on the stand of Microlimit non-contact optical diameter gauges, the accuracy of which is greater than 1% over a thickness range of 0.001 in to 2 in.

WW 352 for further details

DERRITRON

Shown for the first time will be an automatic random noise equalizer/analyser, Type ARN 2. It is used in conjunction with a power amplifier and vibrator system generating random motion. An accelerometer may be mounted on the table, and the equipment then analyses the random motion, displaying the analysis on an oscilloscope and a valve voltmeter. The equipment can also control the spectral distribution of the wave form at the accelerometer mounting point to a predetermined spectral programme, at the same time equalizing for non-linearities in the amplifier vibrator system.

WW 353 for further details

DIAMOND H CONTROLS

A universal switch indexing device, the Unidex, is available for use with Oak

(*Continued on page* 295)

rotary switches F, H and JKN Series and soon for Series A. Smooth torque is provided by two independently sprung steel balls, allowing positive indexing in the range of 8 oz-in to 60 oz-in and even higher to suit customers' requirements. The device is claimed to provide an operational life surpassing that of conventional indexes by several thousands of cycles of operation.

WW 354 for further details

DUBILIER

The company is featuring polyester film/foil tubular capacitors in solid-sealed, shock-proof, drip-proof polypropylene containers. This "monolithic" construction makes them suitable for use in severe conditions of vibration and shock. Two types are available:—film/foil up to 400 V d.c. and mixed dielectric up to 1,500 V d.c. working. Also shown are resistors, interference suppressors and delay and pulse forming networks.

WW 355 for further details

DUKES AND BRIGGS

In addition to their own products, this company will be showing equipment they market or manufacture under licence by arrangement with several German, Dutch and Japanese companies. The exhibits will include closed circuit television, a.c. and d.c. network analysers, decade units, stroboscopes and control devices.

WW 356 for further details

DYMAR ELECTRONICS

Dymar will be exhibiting what is believed to be the world's first range of analogue measuring instruments utilizing "plug-in" techniques. The basis of the Dymar System is the Type 70 Meter Unit, which is available in either bench or 19 in rack-mounting versions. The Meter Unit will accept any one of the 700 series of Plug-In Instruments, which include a.c. and d.c. voltmeters, signal generators, distortion and wave analyzers, noise factor meters, etc.

WW 357 for further details

DYNAMCO

Dynamco Instruments (incorporating Digital Measurements) will be highlighting two new digital voltmeters. Also on display will be the a.c./d.c. digital voltmeter (DM2470), a very stable low distortion (0.005%) sine wave generator (D3100), 0.1% a.c. calibration equipment, and additional modules giving extended range and true r.m.s. reading characteristics to the DM2140 a.c. converter.

WW 358 for further details

E.M.I. ELECTRONICS

A magnetic thin film store which has read-rewrite cycle time of 300 nanoseconds will be on show. The techniques can be extended to reduce these times to 100 nanoseconds and the present capacity range of 6,400 to 51,200 bits is to be extended shortly to 800,000 bits in a second generation of stores. The Valve Division of E.M.I. will have in operation a cascade image intensifier capable of giving a light gain up to one million, and will give demonstrations of this device, together with examples of applications. The Automatic Division of E.M.I. Electronics will be showing the new high-performance transistor Oscilloscope 101, which has stable triggering up to 30 Mc/s. The Y-amplifier bandwidth of 15 Mc/s, coupled with a maximum sensitivity of 50 mV/cm, ensures that waveforms are faithfully displayed on the new 3-inch cathode ray tube, type MX 54, specially developed by E.M.I. for the 101.

WW 359 for further details

EAST GRINSTEAD ELECTRONIC COMPONENTS

A wide range of potentiometers will be shown. This will include components with linear, logarithmic (valves) logarithmic (transistors), inversed logarithmic and special logarithmic laws. Switched versions will be included together with miniature variable resistors for circuits where precision is essential.

WW 360 for further details

EDLON MACHINERY

The following Gravel machinery will be shown, Model RG/4—3-colour Offset Press with infra-red drying track. RG/4-K for rectangular or flat components. RG/3 Offset Printer for cylindrical objects. B3/M Semi-automatic Single Colour motorised Offset Press. B3 Hand Operated Offset Press. B2/3F Three Colour Hand Operated Offset Press. R1-MF Offset Press specially designed for single colour printing of dials/scales, etc.

WW 361 for further details

EFCO

The Processmaster diffusion furnaces, which have been designed to give accurate and repeatable control of the semiconductor manufacturing process will be exhibited. These furnaces are intended for the solid diffusion process, and furnaces for vapour diffusion have an additional low temperature source chamber. Multi-chamber furnaces can be supplied.

WW 362 for further details

EKCO

An auto-standardizing Beta Gauge will be displayed together with an accurate wall gauge (N711). New transistor equipment driven from load-cells will also be shown. The portable weighing equipment uses a resistive strain gauge load cell followed by a transistor amplifier and loads from 200 lb to 2,000 tons can be measured.

WW 363 for further details

ELCOM

Components on display include the miniature multi-bank type 142 switch accommodating 1 to 6 banks with one or two poles per bank and incorporating adjustable stops and nylon click wheel action. The sound equipment division of the company has on show a selection of amplifier modules designed to meet broadcasting and recording standards.

WW 364 for further details

ELECTRICITY COUNCIL

The exhibits include a system for telemetering performance data such as stresses, strains, temperatures and vibrations in rotating machinery; a radio transmitter with a sensing head used for sending "distress" signals from remote or unattended stations; an electronic boiler-water level gauge; an instrument for measuring the magnitude and frequency of voltage surges in a circuit; an instrument for detecting the symmetry of a conductor joint core; and an instrument for measuring the dust level in flue gases.

WW 365 for further details

ELECTROLUBE

The range of electrical and mechanical lubricants, and the recently-introduced Aerosol 2A-X will be exhibited. Electrolube Aerosol 2A-X is completely compatible with plastics such as polystyrene, polyvinyl chloride, polyvinyl carbazol, Makrolon, etc., and can therefore be used effectively on components and equipment incorporating such plastics and as a lubricant for all natural and synthetic rubbers.

WW 366 for further details

ELECTROPRINTS

Examples of the Electroprint system of flexible printed wiring, will be shown. This consists of copper foil etched to any circuit or harness pattern or in the form of in-line cable sealed within two thin flexible layers of insulating film of a variety of materials to suit different environmental conditions.

WW 367 for further details

ELECTROSIL

In addition to showing their ranges of glass-tin-oxide, high power and low temperature coefficient resistors, Electrosil will also exhibit glass capacitors, delay lines, and laboratory resistor kits. The Micro-electronics Division will exhibit a wide variety of digital and linear ranges of integrated circuits for military and industrial applications. A new, completely automatic tester for integrated circuits, capable of performing both d.c. and a.c. tests, will be shown working.

WW 368 for further details

ELECTROTHERMAL

A new range of "Flat-Pak" encapsulated dry reed relays, which incorporate single or multiple replaceable switch capsules in various configurations, is exhibited. Also on show will be the series G101 precision wire-wound resistors in values up to 10 MΩ which have a tolerance of 0.01%.

WW 369 for further details

ELESTA ELECTRONICS

New counters to be demonstrated will be a bi-directional position indicator for use with Rotax encoder or Ferranti digitizer, backward scaling counter with pre-batch output signal before final batch signal at zero, bi-directional counter for counting and batching in a negative and positive sequence, three output pre-selections, and a 24-hour digital clock displaying hours, minutes and seconds. .1 second pulses and B.C.D. outputs. 100 kc/s crystal reference.

WW 370 for further details

ENGLISH ELECTRIC

A fully transistorized f.m./a.m. general-purpose modulation meter is being shown. The carrier frequency range is 4 Mc/s to 1,000 Mc/s. Five deviation ranges, from 5 kc/s to 500 kc/s, are provided with modulation frequency range from 30 c/s to 150 kc/s. For audio band measurements the modulation frequency range may be restricted to 15 kc/s. Two ranges of a.m. depth measurement are provided, 0 to 30% and 0 to 100%, at fundamental modulation frequencies in the range 30 c/s to 15 kc/s. (Marconi Instruments.)

WW 371 for further details

ENGLISH ELECTRIC VALVE

Among the many power triodes and tetrodes available from E.E.V. is the new ceramic tetrode type CY 1170J. This new tube, with an output power of 82.5kW at frequencies up to 30 Mc/s, combines ceramic construction with the recently developed "built-in" method of vapour cooling. Several new types of high quality c.r.t. will be seen:—the T98OH 5in instrument tube developed for use with transistor circuits; T96OD 12-in and T97OZ 16-in high brightness tubes for processed read-out displays and the T96W high brightness monitor tube for use in TV cameras without the necessity for viewing hoods. These are but a few of the very many new valves and tubes to be exhibited.

WW 372 for further details

ERG

The recently released range of axial lead vitreous wire wound resistors approved to specification DEF.5115-2, will be shown. Also on show will be three new ranges of encapsulated dry reed relays, two of which are suitable for direct printed circuit board mounting and are fully protected against adverse ambient conditions.

WW 373 for further details

ETHER

Equipment shown will include the well-known range of temperature measuring instruments, notably the new transistorized potentiometric "Xactline" Series 7000 recorder. Also shown for the first time will be a ten point alarm scanner Type 12-70, which is exhibited with a 12-93 controller in a demonstration scanning the high and low limits on all set points. A feature of the General Products Division display will be an extended range of variable and fixed d.c. power supplies, together with examples of relays, solenoids, thermostats and low inertia and integrating motors, including the new Series 1210 integrator. Among new components shown by the Connector Division will be crimped connectors for film wire strip.

WW 374 for further details

EUROGAUGE

The range of tank-contents gauges and level indicators and controllers shown by this firm will include several all-electronic instruments—the EFT and ENT series—working on the capacitance probe principle and therefore suitable for both conducting and non-conducting materials. Solid-state circuitry, printed circuits and replaceable block units for easy servicing are features.

WW 375 for further details

EVANS ELECTROSELENIUM

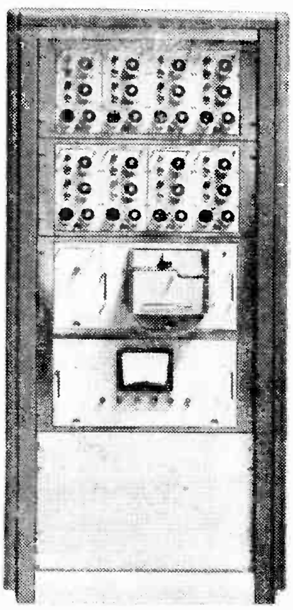
Among the new instruments to be shown is the Unigalvo 100 which gives f.s.d. with as little as 0.35 μA and has a range of eight different suspensions. Evans are also showing a new instrument for determining the presence of sodium and potassium in solutions.

WW 376 for further details

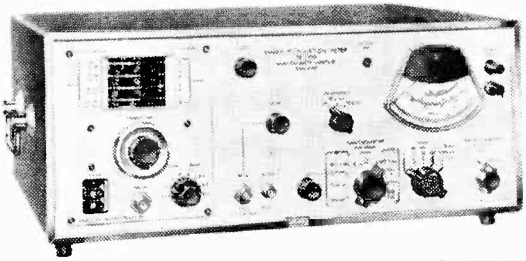
FARNELL INSTRUMENTS

Farnell Instruments will be exhibiting many additions to their well-known range of stabilized d.c. power supplies and oscillators. A new instrument on display will be an e.h.t. solid state power supply designed primarily for supplying photomultipliers. A preset output voltage with approximately 5% adjustment is available within the range 500 volts at 10mA and 5kV at 2 mA. For the first time the products of the Farnell Digital Control Division are being featured. One of the instruments on display will be a digital logic simulator system designed to familiarize engineers with logic techniques and also to simulate control problems.

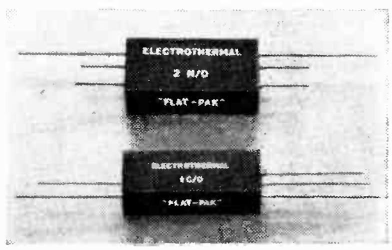
WW 377 for further details



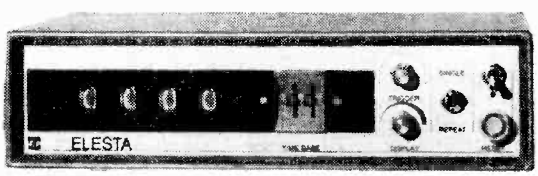
A Fairey vibration system used for environmental tests.



Marconi Instruments f.m./a.m. modulation meter, TF 2300.

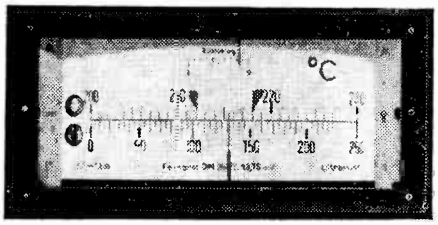


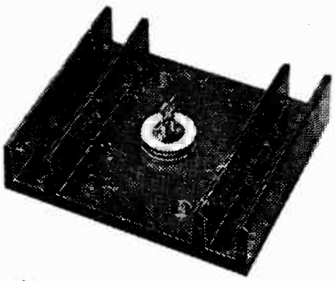
Miniature reed relays from Electrothermal.



A typical counter from the Elesta instrument range.

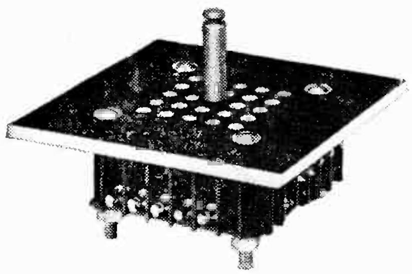
Indicator of the Ultrakust temperature controller (Headland). ▶





▲ *Triac bi-directional switch from G.E. of America (Jermyn).*

Matrix switch programming board made by Hatfield Instruments. ▶



FAIREY SURVEYS

Three hydraulic-powered vibration test systems, demonstrating respectively force, displacement, and acceleration control, will be shown. The force controlled system is supplied for fatigue testing while displacement and acceleration controlled systems find wide application in environmental tests. The systems are typical of the smaller equipment employed extensively for component testing, pre-production evaluation, and for laboratory use.

WW 378 for further details

FEEDBACK

On this stand there will be a logic primer for schools and colleges LK255, a digital encoder SE254, a system response analyser SRA225 including display unit DU224, a pneumatic control teaching mechanism, designed to demonstrate the principles of feedback control and a modular servo system MS262 for use in technician training.

WW 379 for further details

FENLOW

The new digital voltmeter (type 301A) is shown and uses a new strobe-locked integration technique. The oscillator is servo controlled by means of an early and late strobe principle. The effect is to reduce the effects of series mode signals (without the use of filters) by about 100 times over conventional systems when the mains frequency deviates.

WW 380 for further details

FIELDEN

Recently introduced temperature, level and pressure measuring equipment will include the Bikini 6000 series, a comprehensive range of inexpensive potentiometric indicator / controllers. Working models of two- and three-zone instruments with on-off, anticipatory proportional or time proportioning operation will be shown. Models are included for use with thermocouples and resistance bulbs, as well as for level, pressure, flow, weight, pH, CO_2 and smoke density transducers.

WW 381 for further details

FILHOL

This company's stand will be devoted to a display of examples of their synthetic sapphire bearings for instruments and a selection of the wide variety of small metal parts they produce.

WW 382 for further details

FISONS SCIENTIFIC APPARATUS

On display will be a comprehensive range of the company's environmental test cabinets including humidity ovens, high temperature ovens and low temperature cabinets.

WW 383 for further details

FOXALL

A new range of instrument housings will be shown. To provide increased impact strength without adding weight, housings are built on a 10 gauge (⅛in thick) aluminium alloy body. This has enabled the makers to turn structural properties to visual advantage, and a feature of the housings is that they have been styled to present appearance in keeping with modern, international marketing trends.

WW 384 for further details

FOXBORO-YOXALL

The theme of the Foxboro stand this year will emphasize the Company's technical capability to assume total process control responsibility. Five double-sided displays will be grouped around a central column of light and backed by a presentation serving to show how the same technical ability can be harnessed for a simple single indicating controller, a complex control room of Consotrol instrumentation, or the latest Foxboro computer control system, the PCP 88 parallel cascade processor.

WW 385 for further details

GENERAL RADIO CO. (U.K.)

A number of new instruments will be displayed including a series of solid state, modular constructed frequency synthesisers operating up to 70 Mc/s; pulse generators that include a high rate unit operating up to 100 Mc/s, with a rise time of less than 2 ns, a fore-burst generator; an automatic capacitance bridge, a high speed stroboscope, and a digital time comparator.

WW 386 for further details

GRESHAM LION

The MS.1 random noise measuring set for television testing has been designed for 625-, 525- and 405-line networks and permits measurement of random noise in the presence of a television signal. It operates over the range 20-60 dB signal/random-noise ratio. No ancillary equipment is required. An 8-track recording head for ¼in tape and a 9-track dual gap read-after-write head will be shown. The full range of high track density heads providing 33 tracks on 1 in tape, 16 tracks on ½in tape and 8 tracks on ¼in tape will also be on view for the first time.

WW 387 for further details

HASSETT & HARPER

A new standard cabinet is to be shown. Six-foot high it is available either 19in or 24in deep and the side panels are of the lift-off type to facilitate multiple side-by-side mounting.

WW 388 for further details

HATFIELD

Among the instruments shown will be a matrix switch programming board for use in process control, computer programming, data processing, etc.; a psophometer; a v.h.f. attenuator which gives a total attenuation of 1.1 dB in eleven steps; and a solid-state single-phase power supply unit, Type 594, which with the three-phase unit, Type 595, replaces the previous range of valve operated units.

WW 389 for further details

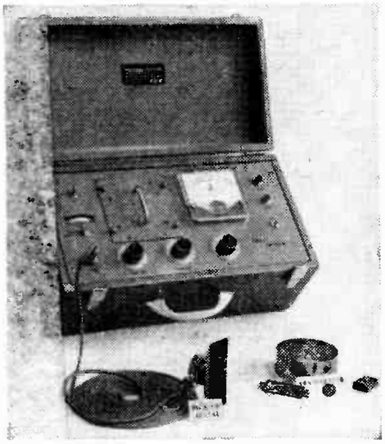
HEADLAND

The main exhibits will centre round the Ultrakust range of temperature controlling, measuring and recording equipment and the new Electrosonic range of ultrasonic cleaning equipment. Using PZT transducers, the equipment operates at 40 kc/s and the main advantage is that the temperature of the liquid in the tank can be up to 100° C without damaging the transducer.

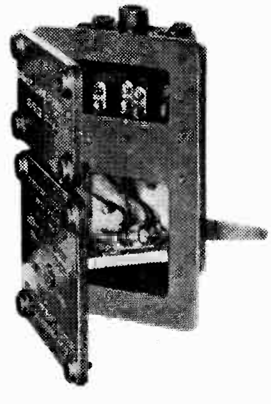
WW 390 for further details

HELLERMANN

Products from four Hellermann companies will be on show. They include a wide variety of cable accessories (markers, sleeving, clips, etc.), components and chassis fittings. Among



▲ An I.E.C. information link between transmitter and transducer.



▲ Mercury limit switch (Hendrey Relays).

the new products are the Tyton cable binding tool and flexible braid connectors.

WW 391 for further details

HENDREY RELAYS

Features on the stand will include a mercury vapour concentration meter; single channel spark recorder incorporating a unique 20 channel scanner and miniature general purpose high-speed reed relays switching 10 watts at 0.5 A, 30 V d.c. maximum.

WW 392 for further details

HESTO (HENKELS-STOCKO)

Exhibits will include small, intricate pressed, stamped and drawn parts for electronic and other industries. Pins and sockets for printed circuits. Solderless terminals, plain or pre-insulated in chain form or loose. Transistor caps and base eyelets in special alloys. Injection moulded products including multi-pole connectors for printed circuits, film and tape spools and storage boxes.

WW 393 for further details

HEWLETT PACKARD

Hewlett Packard will present a number of new instruments including the HP 3733A Power Unit, whose primary function is to provide a housing and power for the HP 5263A Time Interval Plug-In for use with the HP 3734A 5 Mc/s, and the HP 3735A 10 Mc/s Electronic Counters. Also to be shown are the HP 5090B/5091A Standard Frequency Receivers, the HP 1417A Logarithmic Response Unit for swept frequency displays and the HP 3710A Mobile Communications Calibrator.

WW 394 for further details

HUNT

The new Polymite ranges of metallized film (Melimet) capacitors, covering capacitances from 1,000 pF to 2.2 μF, are being featured. Their small size has been made possible by the use of polyethylene film and dispensing with conventional housing. The "professional" ML 30 series uses metallized polycarbonate and covers the range 0.5 to 10 μF. Hunt's will also be showing their ranges of electrolytic, mica, ceramic, foil and paper capacitors.

WW 395 for further details

I.E.C. (ELECTRONICS)

The "Tele-Meter" is designed to act as a link betwen a small transmitter and a read-out unit, and permits signals from strain gauges or similar transducers to be picked off from inaccessible or moving machinery, without the necessity for slip rings, sliding contacts, or trailing wires.

WW 396 for further details

IMHOFS

Prominent among the new items being shown will be the Brick Chassis designed to be accommodated in various models of their modular chassis systems. The prototype of a new racking system is being shown which consists of top and bottom frame extrusions and standard 4 ft, 5 ft, 6 ft and 7 ft vertical members that are pre-punched to accept panel mounting captive nuts.

WW 397 for further details

INDUSTRIAL INSTRUMENTS

The range of Transipack power supplies and static inverters will include a new sinewave static inverter, the 606/ST/300 which provides up to 300 VA (continuous rating) at 240 V with an input of 24 V d.c. The latest Mercron elapsed time indicator (electro-plating principle), the Mk. VIA, is more robust and has an integral scale (ranges: 0-10 hrs to 0-10,000 hrs according to external resistor), facilitating its use on printed circuits.

WW 398 for further details

INSTRON

Two additions to their range of universal testing instruments and accessories are being introduced by Instron. These are the load/strain control system and the incremental data system. The latter has been designed to improve efficiency for analyzing large numbers of repetitive tests and is a punched-tape, digital recording facility.

WW 399 for further details

JD ELECTRONICS

A comprehensive display of transformers, chokes, coils and other types of wound components illustrating the wide range of manufacturing capabilities to customers own specification will be seen. Complete units in the form of d.c. power supplies, constant potential power supplies, isolating transformers, and welding transformers will be on the stand.

WW 400 for further details

JERMYN INDUSTRIES

New components to be shown will include three terminal devices (Triacs) equivalent to two SCR's back-to-back suitable for mains operation. Epoxy encapsulated silicon controlled rectifiers which exhibit extreme gate sensitivity. Miniature 50A surge rectifiers which are protected against transient reverse voltages, and will dissipate 1,000 watts in the reverse direction. Low cost general purpose silicon diodes priced as low as 1s 3d each.

WW 401 for further details

JOSEPH ELECTRONICS

Will be exhibiting automatic gauging and sorting machines for Ge and Si dice to measure thickness or resistivity. A new fully automatic high speed lead welding machine for capacitors, resistors, and sub components. Glass-metal seals and ceramic-metal seals, and sub components in precious and semi-precious metals for the semiconductor and quartz crystal industry.

WW 402 for further details

K.G.M.

One of the K.G.M. companies is A.I.D.S. Ltd., who will be showing their closed-circuit monitoring television system. Other companies in the group are showing data logging equipment, digital indicators, and indicator and control panels.

WW 403 for further details

K & N ELECTRONICS

A wide range of instruments for microwelding diffusion bonding, multiple lead soldering and welding through insulation will be displayed. Included will be the new 700 Polytionic welder an a.c. powered console that will do 5 kinds of microwelding and microsoldering for work on wire or ribbon up to .005 in × 030 in.

WW 404 for further details

(Continued on page 299)

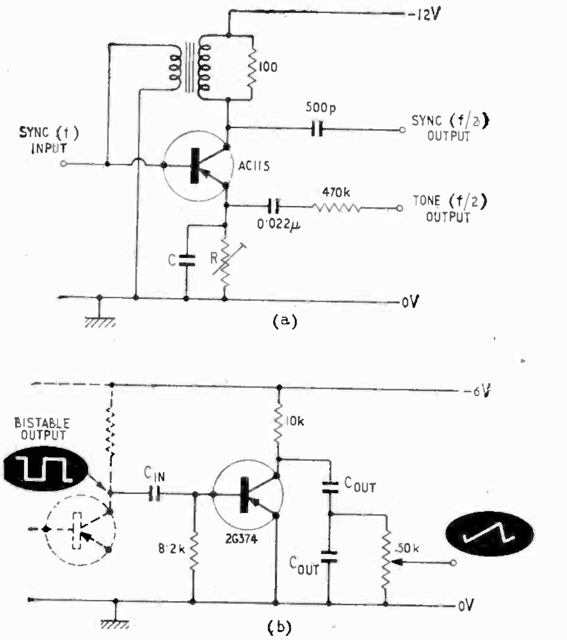


Fig. 5. Sawtooth dividers: transistorised circuits used commercially: (a) monostable blocking-oscillator triggered to run at half-frequency of next higher frequency oscillator ($C = 0.01$ μF at high to 0.047 μF at low frequency) (Harmonics); (b) integrator used to convert square-wave output of bistable to sawtooth at same frequency (C_{in}, C_{out} = 0.001, 0.022 μF at high to 0.047, 1.0 μF at low frequency) (Livingston-Burge).

generators, you run head on into the problem of objectionable keyclicks. The tendency nowadays is not to feed the signal to the keyswitch but to a semiconductor transmission gate which is controlled by the keyswitch. Click filter networks can be included quite simply in such gates, as indeed can arrangements for varying the rate of turn-on and turn-off of the signal. Moreover, such gates can easily be paralleled so that any number of signal lines can be switched on and off with one switch contact.

The best known example of this type of transmission gate is that given in Fig. 6 (a). In this, for ease of illustration, the single keyswitch is shown controlling only two signal lines, f_1 and f_2, but there is virtually no limit to the number of lines that can be so controlled. Consider the f_1 signal line. When the keyswitch is off, the key busbar is at zero volts d.c., and diodes D2, D4, being silicon diodes and not forward biased, present a high impedance in the signal line, so that there is no f_1 output. When the keyswitch is closed, the voltage on the key busbar rises towards +15 V with a time constant approximately equal to $R_1 C_1$ (7.5ms in this case). A positive voltage on the key busbar forward-biases the diodes D2, D4, and permits the f_1 input to pass through to the output. When the keyswitch is released, the key busbar voltage drops towards zero with a time constant roughly equal to $R_2 C_1$, if the decay busbar is set to its +OV "normal" position. This delays the switch-off of diodes D2, D4, according to a 50ms time constant in this case. If the decay busbar is set to +15 V, however, the diode D1 remains reverse biased and the capacitor C_1 can discharge only through the network of 47 kΩ resistors across the signal lines. This gives a length "sustain" before diodes D2, D4 eventually cut off and the signal output ceases.

Percussion gates.—The other type of key-controlled gate circuit is the percussion amplifier, of which a typical example is given in Fig. 6 (b). In this, when the key switch is open (off), transistor Tr1 is on and Tr2 off, with the result that Tr3, Tr4 are biased off and no tone passes through to the output. When the keyswitch is closed, the charged capacitor C applies a +ve pulse to the base of Tr1 which switches over the monostable circuit Tr1-Tr2, and biases Tr3, Tr4 on for a length of time set by the monostable recovery time. At the end of this time the monostable switches back and the amplifier is cut off again. A variety of percussion effects can be achieved by switching in different values for the monostable timing capacitor C_T, or by cross-coupling feed-back to make the monostable run as an astable.

MODULATORS

The gates described above can be regarded as forms of signal modulators. Semiconductor signal modulators

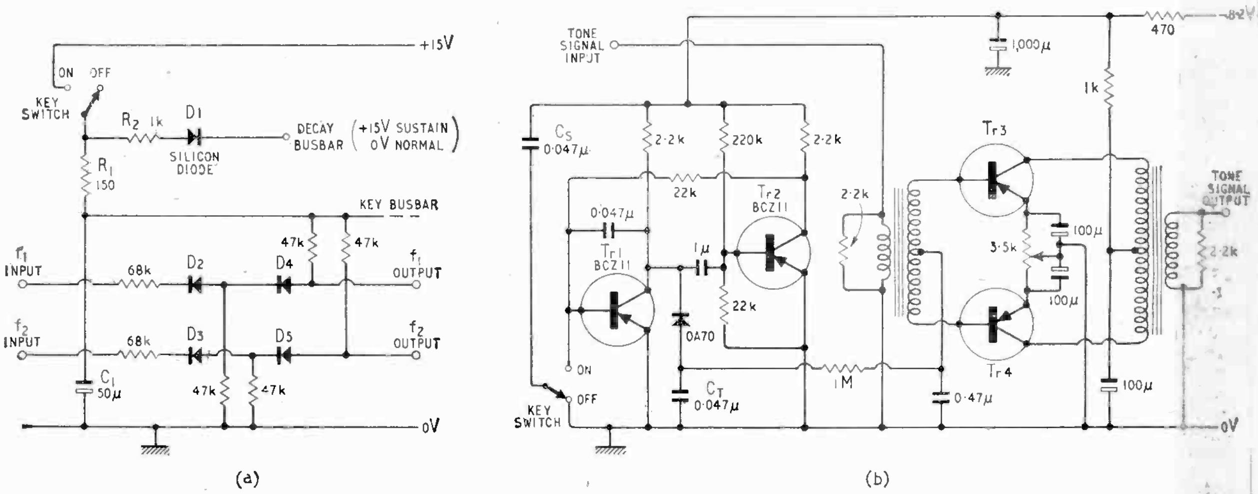


Fig. 6. Semiconductor gating circuits controlled by keyswitches: (a) diode transmission gate controlling tone generator outputs (Heathkit); (b) percussion transmission gate controlling composite tone transmission through a transformer-coupled amplifier after tone forming (Jennings Musical Industries).

are also used for various other purposes in electronic organs.

Swell control.—The simplest way to control the volume output of an organ is with a foot-pedal controlled potentiometer, but this gives rise to such difficulties of hum and noise that many designers use something more refined. With present day low-voltage organs, the tendency is to use a light-dependent-resistor (l.d.r.) circuit. Fig. 7(a) gives a typical example of this. The l.d.r., type ORP12, is inserted in the signal line and illuminated by a lamp through a shaped shutter. The shutter is controlled by a foot pedal. As the pedal is depressed,

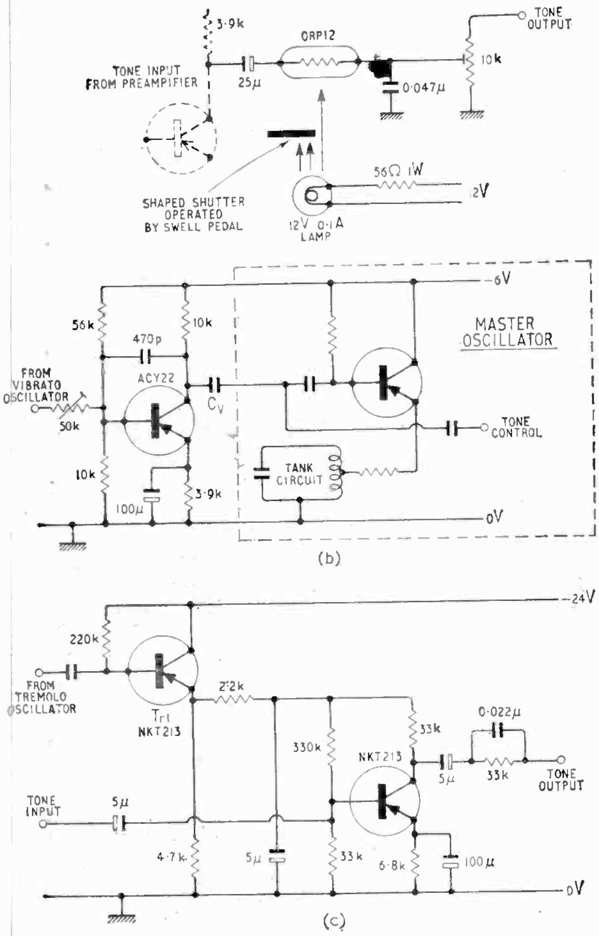


Fig. 7. Transistorised swell, vibrato and tremolo control circuits: (a) swell (volume) control by varying resistance of light-dependent-resistor with light beam (Livingston-Burge); (b) vibrato frequency-modulation of tone generator oscillator by means of special "reactance" modulator transistor stage (Livingston-Burge); (c) tremolo amplitude-modulation of amplifier stage gain by modulating supply voltage to stage (Orn s on-Burns).

the shutter allows more and more light to fall on the l.d.r., and its resistance falls from several megohms to several hundred ohms. Also the series resistance of the ORP12 falls, the attenuation on the signal line decreases and the signal output rises correspondingly.

The other common way to use the l.d.r. is to set it at a fixed distance from the lamp and vary the light intensity

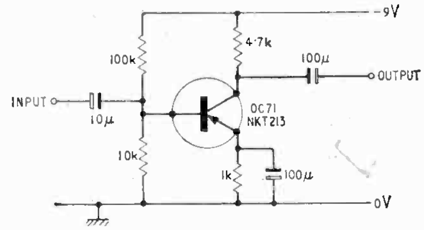


Fig. 8. Transistor general-purpose low-level preamplifier. (Jennings Musical Industries).

by varying the voltage across the lamp with a foot-controlled potentiometer.

Vibrato modulation.—Earlier we discussed the design of the vibrato oscillator. Now we consider how it frequency-modulates the tone signal. In the simplest arrangement, the vibrato drive voltage is applied through an isolating resistor to some point in the oscillator circuit, usually the transistor base (as in Figs. 2(b) and 2(c) above). Some designers interpose a modulator amplifier between the vibrato oscillator and the tone-generator oscillator; Fig. 7(b) gives an example of this.

Tremolo modulation.—Where tremolo (amplitude modulation) is used, some such arrangement as Fig. 7(c) is common. The d.c. supply to an amplifier stage in the main signal path is varied at the tremolo oscillator subsonic frequency through an emitter-follower modulator stage, Tr1. This causes the gain of the amplifier stage, Tr2, to vary correspondingly, and gives a tremolo effect in the tone output.

AMPLIFIERS

Apart from the special circuits discussed above, electronic organs use fairly conventional preamplifiers, power amplifiers and power supplies.

Preamplifiers.—To make up the signal losses incurred in the various switching and tone-forming circuits, most electronic organs use a number of preamplifiers. Fig. 8 shows a typical design.

Power amplifiers.—Electronic organ power amplifiers generally give between 10 W and 100 W output. They fall into two classes, mains and battery driven. Mains amplifiers tend to work across high (24-48 V) positive and negative d.c. rails, with a driver transformer and direct-coupled transformerless output. Battery/mains types tend to work from a lower voltage single-sided supply, usually 12 V, with both a driver transformer and an output transformer or choke to enable a standard 15-ohm speaker to be used with the low voltage d.c. supply.

FUTURE DEVELOPMENTS

The various circuits described above are taken from current models of commercial organs, but recent developments are pointing to the likelihood that many of these will be superseded soon by integrated circuits, and new devices such as field-effect transistors. The time is not far distant when a five-stage divider, which can now occupy a 5in × 3in printed circuit board, will be produced commercially in a block circuit smaller than a sixpence.

KENT

Lea Recorder Co. and Record Electrical Co., members of the George Kent group, will show recording and indicating instruments. Various meters (mainly for fluids) will be shown by Kent Meters and Leeds Meter Co. Pneumatic instruments will be featured by both George Kent (Petrochemical) and Kent Industrial Instruments.

WW 405 for further details

KERRY'S

A 20 W ultrasonic metal microwelder is being demonstrated. It incorporates a power generator, type W-260-A, which has a visual resonance indicator for correct work set-up. Precise regulation of ultrasonic energy delivered to the weld area is accomplished by a manual power control, adjustable over both a high and low range. Step switches control power and weld time to prevent their accidental change and to provide reproducible set-up adjustments. Also shown will be ultrasonic cleaning, machining and plastics welding equipment.

WW 406 for further details

KEYSWITCH

Specially designed for use with automated industrial production machinery is a highly sensitive transistorized single plug-in relay unit operating from an input of 5-10 μA, and stabilized with a Zener diode. It has built-in neons giving visual indication of the state of the relay; a sensitivity control is also provided.

WW 407 for further details

KISTLER INSTRUMENTE AG

The company specializes in the manufacture of quartz transducers and charge amplifiers. Among the new instruments which will be exhibited are new acceleration compensated pressure transducers that eliminate the influence of shock and vibration on pressure measurements; helium bleed pressure transducer for rocket motors and an electrostatic charge peak meter, a combination of a charge amplifier with a peak meter.

WW 408 for further details

KODAK

The range of photosensitive resist products to aid the manufacture of such items as printed circuit boards, nameplates and micro-miniature electronic devices will be featured. An automatic production unit using a photosensitive resist system and incorporating processes for the automatic cleaning of sheet metal, drying, coating and automatic photo-printing and development will also be on show.

WW 409 for further details

LAN-ELECTRONICS

Inductive proximity switches just introduced employ sensitive and stable silicon transistor circuits built into standard relay boxes with clear plastic covers. Ferrous and non-ferrous metals may be detected up to a distince of 3in from the miniature probe, which measure ⅜in diameter and 2in long. The Lan-Dec 20 integrated-circuit training computer and associated add-on logic units will be demonstrated. This is thought to be the only computer of its type in production using integrated circuits.

WW 410 for further details

LEMCO

Extensions to the range of electrolytic capacitors of the London Electrical Manufacturing Co. include the sub-miniature welded construction Lemcolytic types covering the range 0.25 μF 3 V to 200 μF 6 V. The miniature range now covers from 4 μF 50 V to 1,000 μF 15 V. The entire range is available with vertical mounting for printed circuit use.

WW 411 for further details

LEVELL ELECTRONICS

On display will be a transistor a.c. microvoltmeter TM 3A, for use as an a.c. voltmeter or a.c. amplifier, with 16 ranges from 15 μV to 500 V f.s.d. in 10 dB steps and a frequency response from 1 c/s to 3-Mc/s. Transistor a.c. amplifiers TA 401, TA 601, and TA 605 for increasing the sensitivity of oscilloscopes and electronic voltmeters will also be shown.

WW 412 for further details

LIPPKE

This West German company manufacture the Hygrotester moisture meter and they will be illustrating its use in measuring the moisture content in a variety of manufacturing processes.

WW 413 for further details

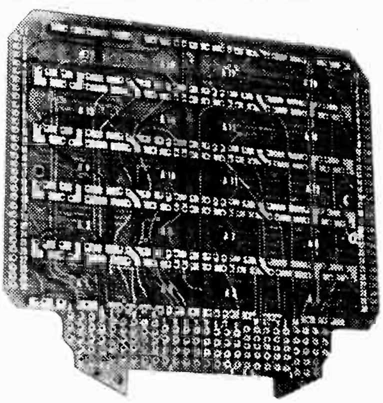
LITTON PRECISION PRODUCTS

New instruments and components to be displayed will include stepper motors, a miniature precise angle indicator, a miniature blower motor, a servo amplifier, tandem synchros, shaft encoders, precision potentiometers and a range of microwave components. In addition multi-layer circuit boards containing up to 12 circuit layers will be shown. These have been designed to allow for the complex interconnections in computer circuitry. Typical boards accommodate many flat packs or integrated circuits. Each layer is a discrete circuit etched on epoxy resin impregnated fibre glass. The layers are laminated under heat and pressure into a rigid circuit no thicker than a conventional single circuit board.

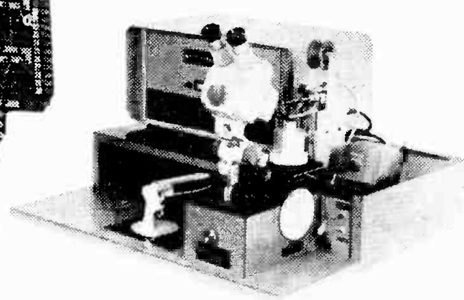
WW 414 for further details

LIVINGSTON LABORATORIES

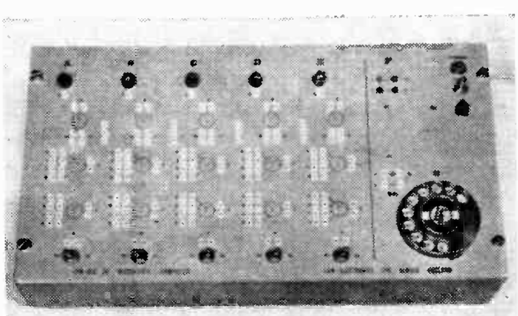
A new pulse generator EH 122 to be exhibited provides fast risetime pulses, with continuously variable repetition



◀ *Up to 12 circuits can be contained in the Litton multi-layer circuit boards; each layer contains a separate circuit.*



▶ *Kerry's W-260-A ultrasonic micro welder.*



◀ *Integrated - circuit computer, the LAN-DEC 20, made by Lan-Electronics.*

rates from 1 kc/s to 200 Mc/s. Pulse widths from 1 nanosecond to 100 microseconds with positive or negative outputs of up to 5 volts into 50 ohms.

WW 415 for further details

LUCAS

A new instrument recently developed by the Lucas subsidiary G. & E. Bradley, a nanosecond chronometer, which measures pulse lengths or time intervals with time threshold and time resolution of the order of 5 nanoseconds will be shown. It can be used to analyse "single shot" or repetitive events with a time resolution better than that of most high speed digital counters. The measuring range covers pulse lengths of intervals from 5 nanoseconds to 3 seconds.

WW 416 for further details

MB METALS

MBM 4000 data loggers will be shown with MBM 4500 data logging units, MBM "Film Wire," pressure diaphragms, and high temperature thermocouple connectors capable of operating up to 700 °C in a highly radioactive environment.

WW 417 for further details

M-O VALVE CO.

Prominent among the many new devices on show will be a rectangular face dual trace instrument cathode ray tube with mesh p.d.a. This compact high brightness tube, type 1300P, is the first of its kind in the world. It incorporates auxiliary electrodes for independent astigmatism correction on each beam and separate beam equalizing and blanking plates. New items in the range of ferrite and semi-conductor microwave components will include C-Band resonance isolators, and S-Band stripline isolators, S-Band "T" coaxial circulators and isolators, and C-Band band-pass filters and 3-port circulators. One item of particular interest in this new range is a step recovery diode source. This compact microwave power source uses only two active devices; a transistor multiplier giving an output at about 800 Mc/s, followed by a step recovery diode with a 12 times multiplication factor giving an output of 5 mW at any required frequency in X-Band. Quartz crystal units covering the frequency 200 kc/s to 200 Mc/s, will be shown by Salford Electrical Instruments with various sizes of thermostatically controlled crystal ovens. The latest types of quartz crystal controlled transistor oscillators cover a variety of frequencies. A wide range of types and sizes of capacitors will include polystyrene, polyester, teflon and polycarbonate. Selenium rectifiers covering a wide field of applications will be displayed with miniature contact-cooled types.

WW 418 for further details

MAINE-LEE

A new range of teleprinter and digital data test equipment and terminal devices produced by Atlantic Research Corporation of Virginia will be introduced. From the same firm will be their new remote control and telemetry system—Arctel-8—which continuously samples the state of up to eight functions.

WW 419 for further details

MALLORY

Highlight of the Mallory stand is a new cell that is only half the size of their previous "world's smallest." Measuring little more than 2/10ths of an inch in diameter and $\frac{1}{16}$ of an inch thick, it has a rated capacity of 16 mAh at 0.5 mA current drain.

WW 420 for further details

MARKOVITS, I.

One of the principal activities of the company is badgemaking and it manufactures nameplates die cast in metal with electro-plated finishes of bronze, gold and silver. Enamel work can also be applied. In addition, nameplates injection moulded in high impact polystyrene and high lights covered with anodised aluminium can also be supplied.

WW 421 for further details

MARRISON & CATHERALL

Permanent magnets and transformer cores made in grain oriented silicon iron are this company's speciality. In the display of cores is a new transformer clamping frame assembly and a new "C" core transformer strapping clip.

WW 422 for further details

MINIATURE ELECTRONIC COMP.

New M.E.C. items on show include the miniature potentiometers in TO-5 cases (*W.W.* Sept. 1965 p. 466) for both military and industrial application. Another recent item is the Curtis electro-chemical elapsed time indicator covering the range 2 to 25,000 hours. Multi-turn and Mecpot trimmer potentiometers and miniature switches are also shown.

WW 423 for further details

MODEL AND PROTOTYPE SYSTEMS

A system for making working models, prototypes, experimental and demonstration models is available in three forms: The Proto Structural System, mainly for building up frame structures; the Proto Construction System, comprising a wide range of parts (spur gears, worm gears, bevel gears, racks, ball races, shafts, sprockets, chain, etc.); and the Proto Major Construction System, which is similar to the last-mentioned but contains a greater quantity and assortment of parts.

WW 424 for further details

MOORE REED

The "Digikit" modular decimal digitizer, which does not require a decoder, is featured among the analogue and digital devices being shown. The company have a cross-licensing agreement with the Vernitron Corp., of the U.S.A., under which Moore Reed manufacture Vernitron analogue devices and Vernitron digital devices of M.R.

WW 425 for further details

MORECAMBE

The company have added to their range of "Meecostatic" contactless switching modules several new devices. These comprise diode matrix modules having in one case inverted outputs and in another binary coded outputs. These complement the true output 1-2-4-8 code matrix already in the series. Also shown will be solid-state drivers for numerical indicator tubes and three ranges of power supply units.

WW 426 for further details

MORGANITE

Under a licence agreement with Bechman Instruments of America, Morganite Resistors are producing a series of linear motion miniature rotary trimming potentiometers with Cermet resistance elements. A new and improved range of Filmet metal film resistors will also be seen at the show.

WW 427 for further details

MUREX

A comprehensive range of sintered permanent magnets of small shapes and intricate designs and examples of the refractory metals including fabricated components of tungsten, tantalum, molybdenum and niobium. The sintered magnets are suitable for a wide range of electrical and electronic applications including instruments, meters, relays, motors, switchgear, controllers, gauges, microphones, and loud speakers.

WW 428 for further details

N.S.F.

Two new switches will be shown for the first time. One, designated the MLA, is a lever-operated panel-mounting rotary switch of 2 or 3 positions and using a section of only 1 in diameter. It is available with locking and/or biased action. Rating, current breaking, is 50 mA at 300 V or 500 mA at 30 V. The other is a dual-concentric version of the well-known Model "A" 12-position multi-bank rotary switch. This also uses 1 in diameter sections with concentric $\frac{1}{4}$ in and $\frac{1}{8}$ in diameter shafts.

WW 429 for further details

NEGRETTI & ZAMBRA

The Conzel instrumentation system for measurement and control is an electronic modular system and provides "in-line" presentation and will be shown with the Conzair, a system of miniature pneumatics, also providing "in-line" presentation, consisting of a recorder, a control station, a set point station, an electro-pneumatic converter, differential pressure transmitter, the "*n*-cel" of titanium construction and an indicator.

WW 430 for further details

PACKARD

Laboratory instruments for assaying radioactivity are specially featured. They include the tri-carb liquid scintillation spectrometers which provide a manual, semi-automatic or fully automatic counting facility for assaying radioactive isotopes.

WW 431 for further details

PAINTON

Painton have recently entered into an exclusive licence agreement with Chauvin Arnoux, of Paris, to manufacture their entire range of OK relays in Great Britain and these are to be featured on the stand. They have a max. current rating of 10 A per contact and are built into a transparent dust-proof case. A feature of Painton's resistor display will be the Metlohm metal film type available in the range 50 Ω to 2 MΩ.

WW 432 for further details

PARKINSON COWAN

On show will be a wide range of liquid and gas meters, process and control equipment including electronic rate of flow indicators, industrial liquid meters, laboratory gas test meters and high pressure meters for industrial use. Displayed for the first time will be Dialarm, an automatic warning device of emergency conditions such as power failure, pump failure, water and sewage levels, pressure rise and fall or for burglar or fire alarm.

WW 433 for further details

PARTRIDGE, WILSON AND CO.

A series of low cost robust solenoids for domestic appliances, vending and amusement machines will be exhibited, also a new range of industrial solenoids for automation, machine tool operation, hydraulic and pneumatic valves. Power transformers designed and built for diverse climatic conditions to BS 2214 and BS 2011, and a static inverter of 1 kW output with near sine waveform complete with 50 V battery and charger, will also be seen.

WW 434 for further details

PEARSON PANKE

Amongst the photo-electric systems exhibited will be a Photo-electric guard with beam scanning an area approximately 1,100 mm high 100 times per second; the whole device tested fully-automatically 100 times per second. New register regulating device for high speed packaging machine synchronization. A correcting signal is obtained proportional to error.

WW 435 for further details

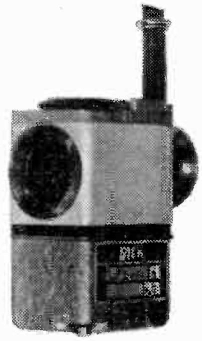
PEMCO

Two portable data tape recorders will be shown by this American company. One, announced last December, is the 110 which accepts up to 14 data channels and is battery operated. The new 120 has six speeds (up to 60 in/sec for 100 kc/s bandwidth) and will also cater for 14 channels. (Pacific Electro Magnetics Co. Inc.)

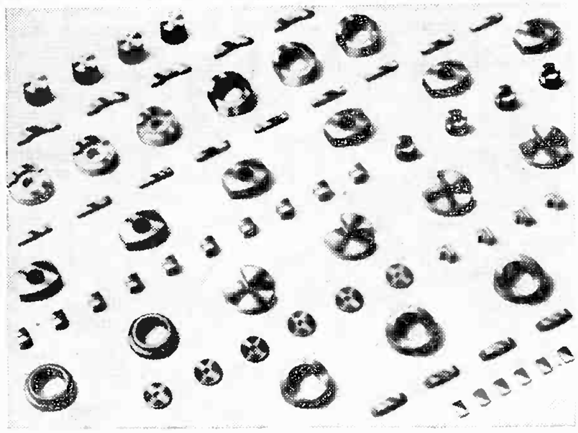
WW 436 for further details

PHOTAIN CONTROLS

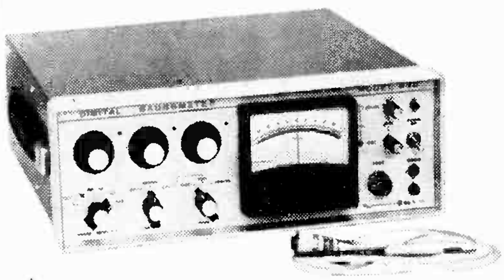
Among the new Photain exhibits will be a new regulated voltage (0-25 V) and variable current (0-100 mA) supply unit, called "Vibox." It is complete with a safety cut-out against overloading and will be shown with the well-known Photain a.c. and d.c. Variable Voltage



▲ *A photo-electric guard system, by Pearson Panke.*

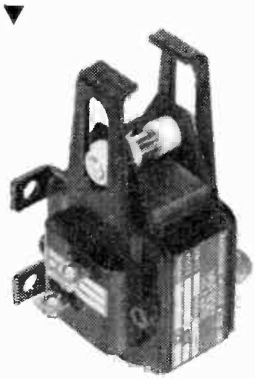


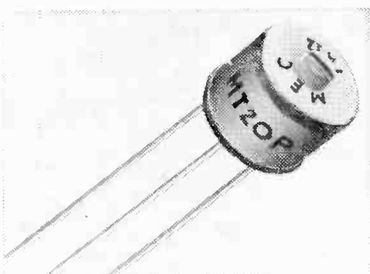
▲ *Murex sintered permanent magnets in intricate shapes and designs for a wide range of electronic and electrical applications.*



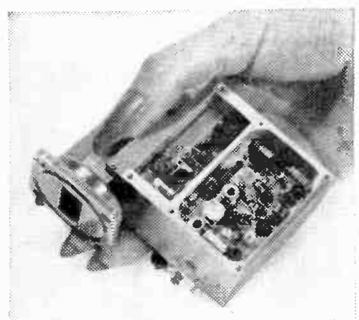
▲ *This "solid-state" digital gaussmeter, the Bell 660, is being demonstrated on Livingston's stand. It provides a resolution of better than 1 part in 1000.*

A low-cost Partridge, Wilson solenoid, for application in domestic, amusement and vending machines. ▼

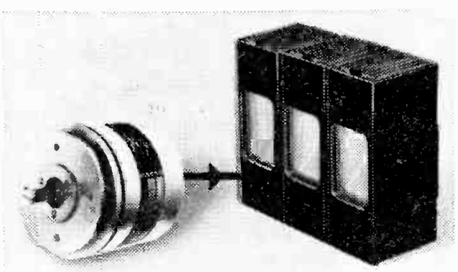




▲ *MT20P miniature potentiometer in TO-5 case (M.E.C.)*



▲ *The step recovery diode source from the M.O. Valve Co., has advantages over the more usual varactor diode chain, of reduced weight, size, cost and power consumption.*



◄ *"Digikit" modular decimal digitizer (Moore Reed).*

Power Supply Unit which attains an 0-20V a.c. or d.c. output at 0.5 amps. Thermocouple cartridges for measuring temperatures on all types of moving surfaces will also be on view, with a new pocket-size thermocouple. For industrial process controls, various electronic timers will be demonstrated as working exhibits, to include "plug-in" units, transistor solid state circuits and multiple-switching sequencing units.
WW 437 for further details

PHOTOELECTRONICS
Exhibits will include a micro-obscuration measurement panel displaying the non-colour-conscious "in-line" Haze Meter and Yeast and High Turbidity Meter. Also displayed will be a photo-electric dangerous-machine guard; a flame monitor giving gas flame protection by u.v. or probe sensing; and photo-electric devices, solid state switches, timers, etc. for use on production lines.
WW 438 for further details

PICARD & FRERE
Well-known as a supplier of precision tools to the watchmaking industry, this company will show the following items of interest: anti-magnetic heat-resistant tweezers; receiver repairing, testing and trimming tools; a new electroplating machine; automatic ultrasonic cleaning machines; a range of twelve electrical pliers; and a cutter which will slit a human hair.
WW 439 for further details

PLANER G.V.
A complete kit makes it possible to adapt all sizes of existing vacuum evaporators to the electron beam method of operation. The complete kit being shown consists of the ring assembly and power unit giving variable H.T. supply of up to 7kV, d.c., reversible polarity at 200 mA, and L.T. supply to heat the emitter filament and suitable surge and overload protection.
WW 440 for further details

PLANNAIR
Among the fans and blowers being displayed will be the 2½in centrifugal blower which is available for either 230 or 115 V a.c. supplies or for 12 or 24 V d.c. supplies. Its small size and light weight makes it particularly suitable for electronic equipment.
WW 441 for further details

PLESSEY
Pride of place on this stand is being given to the XL9 high-speed, random-access, real-time computer and the XL11 computer which is not much larger than a shoe-box. The **XL11**, which is not yet in production, uses monolithic integrated silicon circuits throughout. It has a basic store of 4,096 words of 16 bits. Also featured is the new **PR155** communications receiver, which covers the frequency range 60 kc/s to 30.1 Mc/s. A feature of the set is its frequency stability and the marine version of the receiver incorporates a digital frequency read out. The Plessey-Licon 01 series of illuminated push-button switches, made under licence from the Illinois Tool Works Inc. of Chicago, will be shown by the Components Group. These switches have been introduced to cut control panel costs by combining indicating and manual switching functions in a single compact component. These are but a few of the wide variety of products from the various sections of the company which will be shown.
WW 442 for further details

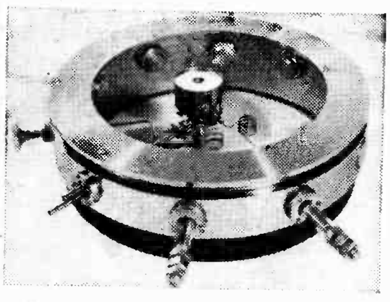
POTTER INSTRUMENT CO.
Exhibits will include a recently introduced off-line printer system model PS-6000, designed to relieve general purpose computers of the burden of routine printing operations. Also to be shown is the new single capstan digital magnetic tape transport, Model SC-1060, capable of bi-directional tape speeds of up to 200 i.p.s. at 800 b.p.i. with no programme restrictions. The transport can operate as a 7- or 9-channel system and can be adapted to all major computer formats.
WW 443 for further details

PYE GROUP
On view will be the W. G. Pye Modular Process Chromatograph; two of the 104 Gas Chromatograph series, and a Pye precision decade potentiometer. A portable thermocouple test set which includes a d.c. potentiometer, galvanometer, Wheatstone bridge, and potential source, with variable resistance load will also be shown. The full range of Pye micro switches and limit switches is shown. Also exhibited are a full range of Joystick controllers, incorporating squeeze-type control knobs of "fail-safe" design, for additional switching actions. The miniature heavy duty toggle switches can be fitted with locking action and Beta-lights can be incorporated in switch levers. The principal Pye Telecommunications exhibit will be a new data logger, specially designed to work into the latest IBM "golf-ball" printing machine. It prints at a maximum speed of 15 characters per second. Information from any number of sources can be tabulated periodically in pre-arranged sequence. Inputs can be either binary coded decimal information or transducer signals.
WW 444 for further details

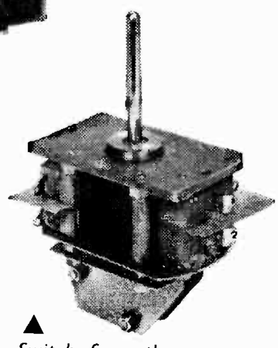
QUANTUM
Manufactured by Optimized Devices of the U.S.A., for whom Quantum

(*Continued on page* 303)

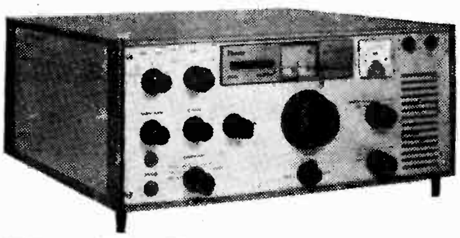
◀ *Integrated circuit analyser manufactured by Optimized Devices Inc. and shown by Quantum Engineering.*



▲ *The ring assembly for adapting vacuum evaporators to the electron beam method, by G. V. Planer.*



▲ *Switch from the range manufactured by Pye Switches.*



▶ *PR155 transistor communications receiver introduced by Plessey.*

Engineering are U.K. representatives, the integrated circuit analyser, model IC-101, provides a rapid means for testing and analysing monolithic and discrete components. It incorporates several unique features to facilitate the rapid testing of devices.

WW 445 for further details

QUICKDRAW CO.

The Quickdraw Technical Drawing Device will be the main exhibit and will be shown in two models. Also on show will be a range of drafting machines using the well-known principle of parallel motion together with one unit which has a transparent board enabling a light source from behind to be utilized for tracing work, etc.

WW 446 for further details

RADIATRON

This company will be exhibiting Kienzle fast digital printers, a Jacquet miniature potentiometric recorder, and electrically operated laboratory stopwatches, ECMA single decade read-out counters and digital modules. Also to be shown will be operational amplifiers, five channel tape punch and tape recorder, radiation measuring instruments and pocket type dose-meters.

WW 447 for further details

REDIFON

The Redifon-Astrodata Ci-5000 computer will be on view. Typical applications for the Ci-5000 include space flight simulation; photo-chemical nuclear process, process control simulation and engineering or scientific computation. Two or more Ci-5000 computers can be slaved together to assist in the processing of unusually large amounts of data.

WW 448 for further details

RESEARCH ELECTRONICS

Research Electronics Ltd. are exhibiting on the Recording and Nucleonic Instrumentation Group stand and are demonstrating transistorised nucleonic instruments for elementary teaching purposes and for advanced research work with radio-active isotopes; also digital counting timing and frequency measuring instruments and the new British-made Weyfringe Digital Voltmeter, the only one with integral printout.

WW 449 for further details

RESEARCH INSTRUMENTS

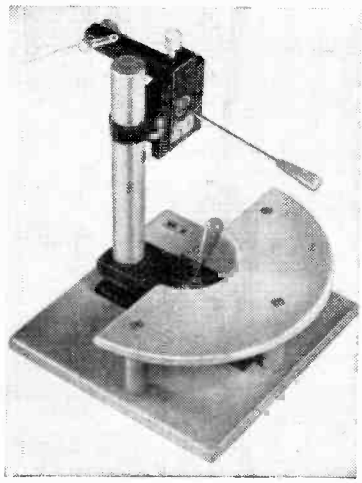
The Micromanipulator is the latest addition to the range of high-quality low-cost micromanipulators. The instrument and its component units provide more building blocks from which equipments can be assembled to meet every manipulating and positioning requirement. A new Multiprobe test equipment will be shown for the first time.

WW 450 for further details

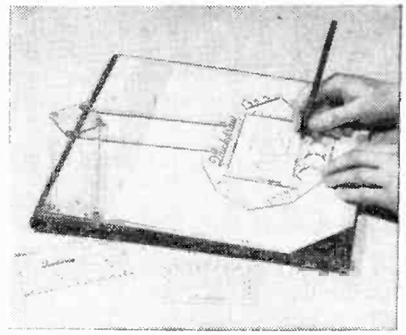
ROBAND

Stabilized power supplies, digital voltmeters and oscilloscope systems will be shown. A range of modular power supplies called REX offers, apart from 4-50V outputs and current ratings of 2-15A, standard 5in height detachable printed circuit board carrying a complete feedback amplifier; heat sinks situated at back of unit; and an instant release assembly.

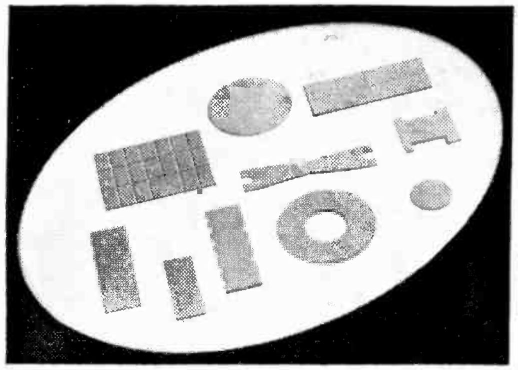
WW 451 for further details



▲ *A micromanipulator from the range by Research Instruments.*



▲ *The Quickdraw technical drawing device will be of interest to anyone involved in the preparation of illustrative work.*



▶ *Examples of Royal Worcester ceramic substrates for thin film circuits.*

ROSS COURTNEY PRODUCTS

A wide range of cable terminations including spades, flags hooks, caps, splices and high temperature terminals. Hand and power operated crimping tools will also be shown.

WW 452 for further details

ROYAL WORCESTER INDUSTRIAL CERAMICS

Royal Worcester is making ceramic substrates for thin wafer circuits in "Regalox," a high quality sintered alumina ceramic, offering mechanical strength and ease of manufacture in a variety of shapes most suitable for modular construction. "Regalox" is extremely hard and strong and this ensures freedom from scratches or other damage in processing. Being completely non-porous, there is no danger of migration of deposits as no moisture path exists, even in conditions of high humidity.

WW 453 for further details

S.E. LABORATORIES

An electro-medical multi-channel amplifier for the handling of physiological potentials and conversion of data from transducers into signals suitable for processing either on data loggers, computers, trace recorders or oscilloscopes is among several new products exhibited by this company and its associates. Three small plug-in pre-amplifiers are available which fit into the 3½in high housing of the main amplifier which also accommodates the electroencephalograph and electrocardiograph calibration selector.

WW 454 for further details

SGS FAIRCHILD

Among the range of semiconductor devices and integrated circuits an interesting new addition will be an n-p-n silicon planar transistor, the BFX42, which is guaranteed to maintain its performance after exposure to atomic radiation—actually a fast neutron flux dosage of 10^{15} neutrons/cm^2. It has a high current gain of 180. New micrologic elements include the DTμL 945 and 948 clocked flip-flops, improvements on the earlier 931.

WW 455 for further details

ALTERFIX
Exhibited will be metal fasteners, including external and internal circlips and push-on fasteners, moulded fasteners, including snap-in grommets, knock-in feet, zip-on nuts and knock-in screws, special parts, precision manufactured in large volume for particular applications and including complete components in metal or plastic. Impact assembled fasteners will be particularly featured.
WW 456 for further details

SANGAMO WESTON
The company will be showing a selection of meters ranging from laboratory standards to miniature panel instruments, a prominent feature of which will be the range of Clear Front instruments including the new Edgewise model. A notable feature will be the newly developed 4700 Series advanced magnetic tape instrumentation system. There will also be a representative selection of products manufactured by the systems and control subsidiary, Sangamo Controls Ltd.
WW 457 for further details

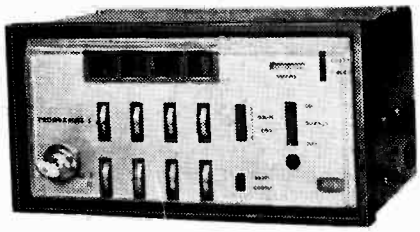
SEALECTRO
A new item is the space saving miniature, two-pole Jack-socket permitting single-hole mounting on ¼ in fixing-centres. The contacts are gold finished beryllium-copper. Other items shown are the Actan programming switches, sub-miniature co-axial connectors, magnetostrictive delay lines, press-fit transistor and integrated circuit holders, and Coaxitube semi-rigid cables.
WW 458 for further details

SENSITISED COATINGS
The Company will be displaying some of their range of recording charts, graphs, discs and sheets for use on pen and event recorders. These are produced in all forms of recording media including heat, pressure and electro-sensitive papers as well as normal "pen and ink" type chart papers.
WW 459 for further details

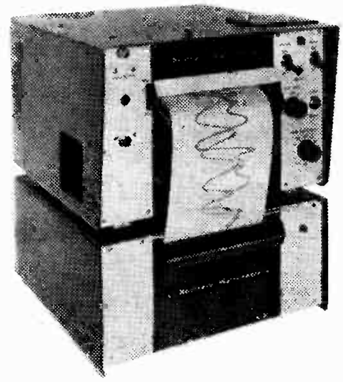
SERVICE ELECTRIC CO.
Displayed in the "Secomak" range will be axial fans designed especially for cooling a wide range of electronic equipment. Variable temperature control will be featured in the range of hot air blowers for drying processes, heat treatment and environmental test rig.
WW 460 for further details

SERVOMEX CONTROLS
The major exhibits will include a D.C.L. Servomex null-balance oxygen analyser type 83, a type GS.96 gas sampling panel and a D.C.131, stabilized power supply. Also to be shown is the portable instructional servo systems SS.132, for teaching the fundamental principle of control engineering.
WW 461 for further details

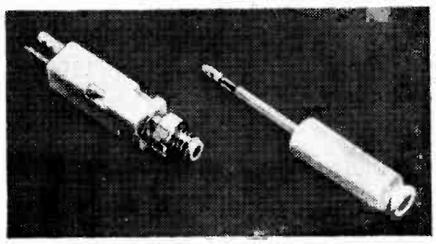
SETPOINT
Formed 2½ years ago, the company will show a 250-point computing data logger to enable a British ship to operate with



▲ *Smiths digital batch counter for up to 10,000 counts/second.*



▲ *The Southern Instruments M1300 ultra-violet recorder shown on the M1303 rewind unit.*



◀ *Miniature jack socket with gold plated beryllium-copper contacts (Sealectro).*

unmanned engine room. Steelworks automation equipment will be represented by hot metal detectors and thickness gauges using an optical scanning system. A system for weighing masses carried by cranes will also be shown.
WW 462 for further details

SIFAM
Samples and an enlarged demonstration model of instruments incorporating pivotless, taut-band (ligament suspended) movements, which the company plan to put into production soon, will be featured among the one hundred or more different types of instrument displayed.
WW 463 for further details

SIRCO CONTROLS
Pressure, vacuum and temperature control switches are this company's speciality. The latest 4,000 series pressure switches have ranges of 2-16, 10-100 and 30-300 p.s.i.
WW 464 for further details

SMITHS INDUSTRIES
The Industrial Instrument Division will show digital batch counters with an operating range of up to 10,000 counts/second. They have a choice of 8 standard combinations based on one or two programmes with or without visual indication and/or indication of total batching.

Exhibits of the Medical Equipment Company will include a re-styled version of the Dianoscope ultrasonic diagnostic device, with simplified controls, and the Pyrosan "heat camera."

The Kelvin Electronics Company will have two new ultrasonic flaw detectors, one of which, the Mk. 8, is portable, transistorized and has a built-in flaw alarm.

A synchro signal amplifier for driving up to 5 synchro control transformers from one synchro transmitter without intermediate gearing is among the items shown by the Aviation Division.
WW 465 for further details

SOUTHERN INSTRUMENTS
A new low cost Oscillograph Recorder type MRE.141 will be shown which is of particular use to the manufacturers of turbines, rotary and reciprocating engines of all types. Another new instrument to be shown for the first time will be the M.1310 ultra-violet recorder which accommodates from 1-50 channels and uses any paper width up to 12 inches. A new accessory to the M.1300 ultra-violet recorder is the rewind unit type M.1303 on which the M.1300 instrument can stand. Alternatively, the two units can be supplied for 19 inch rack mounting.
WW 466 for further details

SPERRY
A fully automatic sail trainer, which simulates sailing a 12-ft dinghy, is to be featured. Manufactured by T.P.I. Ltd., it uses both Sperry and Vickers Detroit servo hydraulic equipment. "Inspectron," which employs random signal testing and cross correlation techniques for automatically testing electro-mechanical servo systems giving a clear Go/No Go signal, is also to be shown. Industrial applications of Sperry's Airborne Data Acquisition System (SADAS) are being investigated.
WW 467 for further details

(*Continued on page* 305)

SPRAGUE ELECTRIC (U.K.)

Among the ranges of electronic components exhibited will be high reliability capacitors, metal film capacitors, subminiature capacitors, tantalum capacitors, ceramic capacitors, resistors and transistors. Various types of transistors will be shown; also integrated and thin-film circuits will be featured including a differential amplifier with current source, an operational amplifier and an analogue switch.

WW 468 for further details

STANDARD TELEPHONES AND CABLES

A recently introduced impulse noise counter, the 74258-A, intended primarily for determining the suitability of circuits such as telephone lines for data transmission will be on show. The instrument will record on an internal register all pulses exceeding a pre-set amplitude, which can be adjusted to any level between 0 and −60 dbm. The counting time can be adjusted in steps up to 60 minutes. The maximum count is 9999, with a manual reset, and all pulses separated by 125 milliseconds or more will be recorded.

WW 469 for further details

H. W. SULLIVAN

Will be showing precision decade capacitance bridge 0.01 % of new design, a precision Wheatstone bridge 0.003 %, a precision potential divider 0.001 %, and a decade inductance bridge 0.1 %—new design. Also being exhibited are decade resistance, capacitance and inductance boxes 0.01 %, together with a range of instruments suitable for educational laboratories—also of new design.

WW 470 for further details

SUPERIOR ELECTRIC

Unimatic Engineers are showing the American "Slo-Syn" digital indexing equipment for *x-y* positioning, machine-tool numerical control, welding, flame-cutting and similar applications. The indexer can be controlled manually from decade switches or automatically from 1-inch punched paper tape. Positional accuracy is ±3% of the basic 1.8° indexing motor step; with a 10 t.p.i. leadscrew this represents ±0.0003in.

WW 471 for further details

TANNOY

Exhibits will consist of examples of specialised audio communication systems. These will include flameproof systems for use in the petroleum and chemical industry, induction loop systems designed for inter-communication between large moving structures such as overhead cranes, coke pushers, etc., and high power loudspeaker systems suitable for areas of high noise level.

WW 472 for further details

TAYLOR INSTRUMENT COMPANIES

The pneumatic Quick Scan concept will be introduced for the first time in Europe. Servo powered recorders, deviation controls and process indicators will demonstrate the system. The electronic version of the Quick Scan concept and the new 235T liquid level transmitter will be shown for the first time.

WW 473 for further details

TECHNA SALES

Exhibits will include the E-T-A miniature circuit breakers rated from 0.5 A to 400 A with rupturing capacities up to 10,000 A and a new device for semiconductor circuit protection. "Arcex," a glass bonded mica insulating material for applications up to 500° C, will also be featured. A range of transistor timers and relays, manufactured by Solid State Controls Ltd. will also be shown.

WW 474 for further details

TECHNIVISION ENGINEERS

This company specializes in the manufacture of customer designed prototype electrical, electronic, pneumatic and hydraulic test fixtures, cabinets, consoles, etc., and the repair and calibration of all makes and types of electrical and electronic instruments. It will be exhibiting a Continuity Tester capable of checking up to 944 wires in a cable-form or electrical circuit. Its primary function is to indicate any open circuit in a cable form or similar wiring assembly immediately and automatically.

WW 475 for further details

THORN-AEI

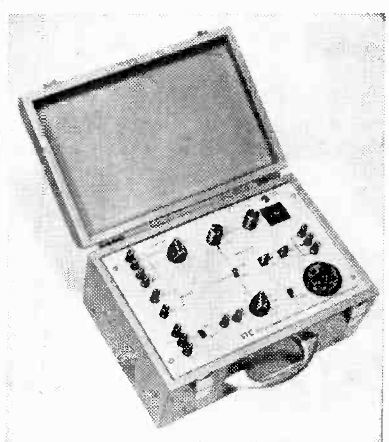
A new service to industry is the Brimar transistor "package." Individual transistors in any one "package" will be selected in order to reduce performance spread between one package and another, due to the performance spread of individual transistors. Brimar "packages" will be exhibited for linear amplifiers of ½ W to 8 W NPN audio output transistor for 32 V operation; a working prototype of the SA17 circuit design for a transistor educational tape recorder for headphone reproduction, industrial valves, and cathode ray tubes.

The Mazda development type V3503 colour tv tube 19 in, and 25 in versions will be demonstrated; a 12 in rectangular tv tube, a 19 in CME 1907 picture tube with Rimguard simplified implosion protection using a two-part metal frame, and Mazda tubes with "Sparkguard Base" for protecting associated circuitry from tube flashover at 20 kV operation, will also be shown.

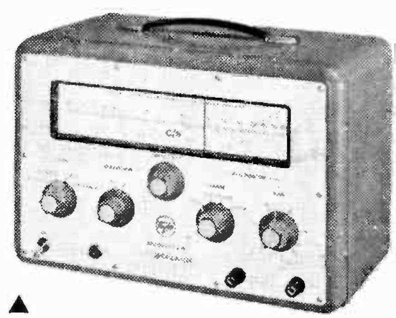
WW 476 for further details

TRANSITRON

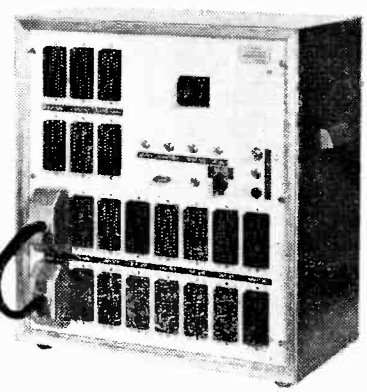
Transitron are exhibiting examples of their HLTTL (High Level Transistor Transistor Logic) circuits packed in the fully hermetically sealed 14 and 22-lead ceramic-glass flat packs, 14 lead dual in-line plug-in pack and an 8-lead low



▲ *Two input band-pass filters are incorporated in the S.T.C. 74258-A impulse noise counter. A recording milliammeter can be connected to provide a permanent record of the impulses against a time scale.*



▲ *Taylor 10 c/s-100 kc/s l.f. oscillator, Model 192A. (see Avo stand)*



▶ *In conjunction with suitable equipment the Technivision 944-line Continuity Tester can be used for checking resistance inductance and capacitance.*

height TO-5 package. Unsealed packages are also on display to show their internal construction.

WW 477 for further details

TYLORS

This company specializes in the production of meters for the handling of liquids under varying conditions of temperature, pressure and viscosity.

WW 478 for further details

U.K. OPTICAL BAUSCH & LOMB

Specialised optical assemblies are on on show, illustrating the applications of optical components to problems of measurement and control in automation and instrumentation. In addition to components and assemblies for visible light applications, specialised items include those manufactured from materials suitable for ultra-violet, and infra-red wavelengths up to 40 microns, demonstrating various surfacing techniques.

WW 479 for further details

U.S.A. EXHIBIT

In all, 72 American companies will be participating. Products will fall into two main categories: advanced components for the electronic equipment and computer manufacturing industries, and complete measuring, control and data processing instruments and systems for a wide range of specific industries. In the last-mentioned category are included devices for use in waterworks, purification plants, road transport organizations, electronics, television stations, marine applications, chemical plant and public health laboratories.

WW 480 for further details

ULTRA ELECTRONICS

A new range of printed wiring edge connectors is being manufactured. Pitched on 0.156 in centres, the range consists of 10-, 15- and 22-way connectors, fitted with floating bushes to accommodate 8 BA screws. Contacts are manufactured from phosphor bronze. Contact resistance is 10 milliohms maximum, and insulation resistance 5,000 megohms minimum under normal conditions. The mouldings, of diallyl phthalate compound, have a temperature range from -55°C. to 110°C.

WW 481 for further details

VACTRIC CONTROL EQUIPMENT

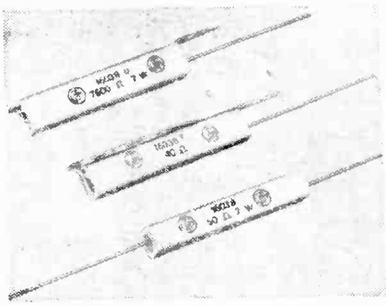
The Vactric electric flashing beacon is portable and has no moving parts. Also being shown is the $3\frac{15}{16}$ in diameter Vacsyn synchronous motor, which in standard form is wound for 115 V, 50 c/s, and the 08 gearhead with exact ratios up to 1,200:1.

WW 482 for further details

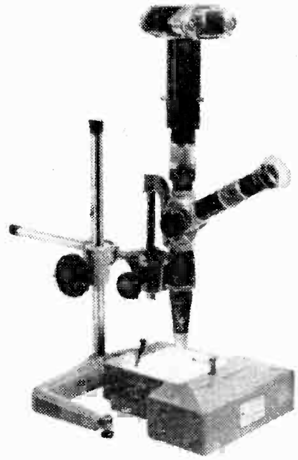
VENNER ELECTRONICS

On this stand, a frequency counter TSA 5536, operating up to 10Mc/s, and giving a 6-digit indication by gas-filled numerical tubes, will be shown. A 100 Mc/s counter TSA 5538 an 8-digit instrument measuring in excess of 100 Mc/s, and a TSA 3314 millisecond stopclock, will also be exhibited.

WW 483 for further details



▲ *Wirewound K-series power resistors (Vitrohm).*



▶ *The Vision circuit hole microscope for inspection of multi-layer printed circuits.*

VERO

Instrument cases, racking and the new Vero card frame for the mounting of printed circuit boards are to be shown. The card frames will carry 28 boards at a 0.6 in pitch or 56 at 0.3 in pitch.

WW 484 for further details

VIBRO-METER CORP.

Exhibits will include a wide range of transducers and electronic instruments designed for mechanical engineering research and development purposes.

WW 485 for further details

VISION ENGINEERING

On show will be an instrument that enables holes from between 0.002 in to 0.030 in to be examined quite comfortably. The instrument is available, either as a straightforward visual inspection instrument or with 35 mm or polaroid C.B.100 Camera attachment to provide permanent records. The operator receives a 360° view of the bore in question and by moving the zoom focus can examine the entire wall of the bore. The magnification provided is approximately ×40.

WW 486 for further details

VITROHM

Vitrohm Elektroteknisk Fabrik A/S of Copenhagen, manufacturers of fixed and variable resistors, are exhibiting the K-series wirewound power resistors (axial and "standee" types) which are rated up to 60 W. Miniature precision wire-wound resistors in all-welded construction, inexpensive $\frac{3}{4}$ in dia. preset wire-wound resistors and evaporated metal film types with a noise voltage below 0.1 μV per volt will be shown.

WW 487 for further details

WESTINGHOUSE

Silicon diodes ranging from 200 mA up to 370 amperes with voltages at 100-2,400 V, silicon thyristors ranging from 500 mA up to 250 amperes at 25-2,400 V selenium rectifier assemblies from milliwatts to kilowatts and supervisory and automation systems will be exhibited.

WW 488 for further details

WIRE PRODUCTS

This company specializes in the forming of miniature precision parts from wire or rod (the diameter of which rarely exceeds 0.25in), cold heading and the assembly and manufacture of glass to metal seals. Some 6,000 different components made for industry will be shown.

WW 489 for further details

WODEN TRANSFORMER CO. LTD.

This company will be displaying a complete range of high quality transformers and chokes for electronic application, including cast-resin and hermetically sealed components using "C" and toroidal cores, together with compound filled, potted and steel shrouded units.

WW 490 for further details

G. H. ZEAL

On show will be a variety of instruments illustrating the comprehensive range of thermometers and hydrometers available to industry. These will include mercury-in-steel, temperature controllers, vapour pressure, bi-metallic dial indicating thermometers and recorders, manometers and relay units, specification laboratory thermometers together with glass and metal hydrometers.

WW 491 for further details

A List of Exhibitors and Plans of the Exhibition are given on pages 307-310

LIST OF EXHIBITORS

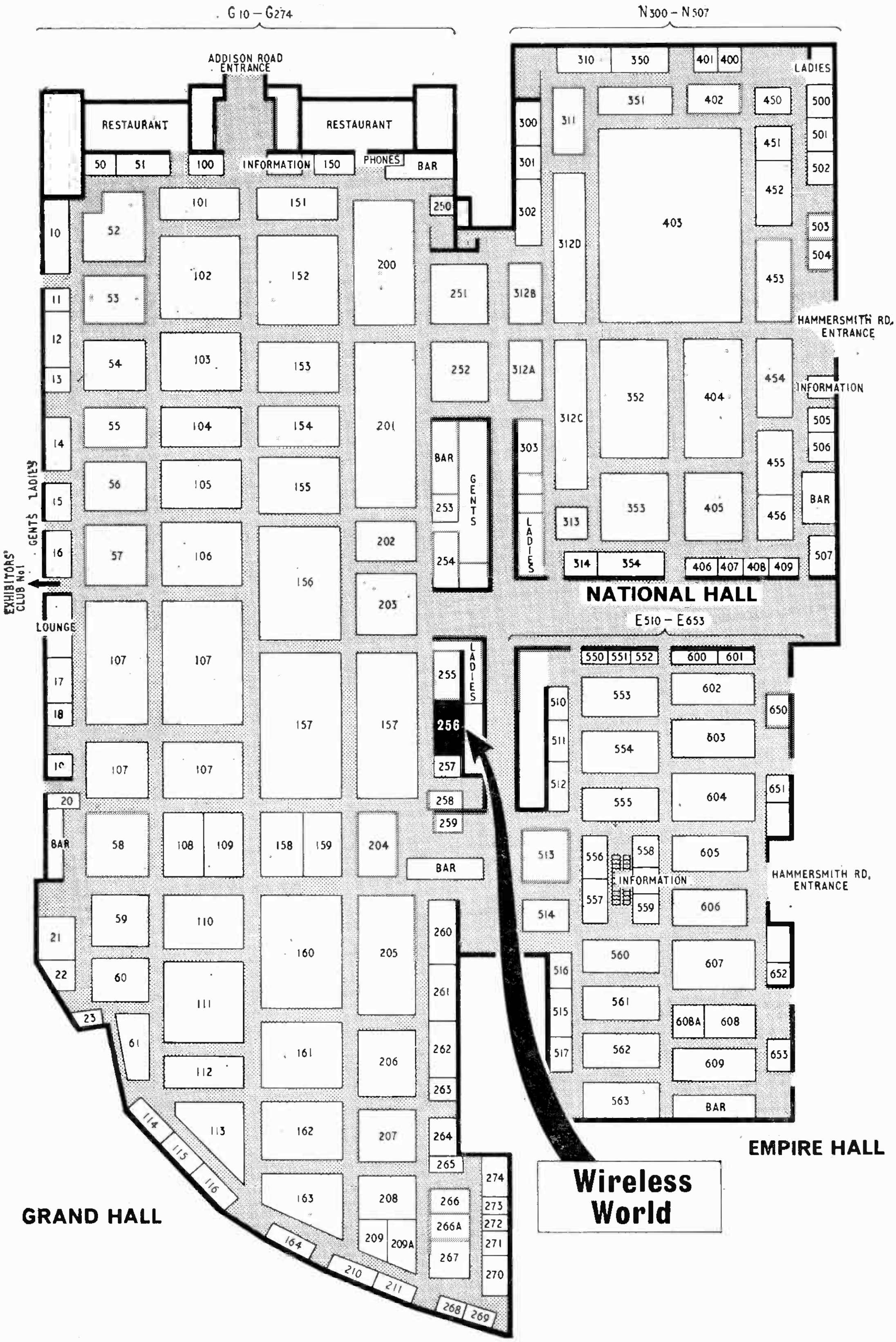
Exhibitor	Stand No.
A.B. Metal Products	G271
A.D.A.R.	N312D
A.E.G. (Great Britain)	G116
A.I.D.S. [K.G.M. Electronics]	N503
A.K. Fans	E510
A.N.T.E.X.	N812
A.P.T. Electronic Industries	G724
Acbars	G759
Accles & Pollock	E942
Ad. Auriema [Impectron]	G734
Addo	G758
Aircraft-Marine Products	G112
Airflow Developments	E650
Airmec	G102
Allen West Automation	E954
Allied International Co. [B. & K. Labs.]	G58
Allspeeds	G164
Alma Components	N314
Alston Capacitors [Alma Components]	N314
Amelco Semiconductor	G745
American Embassy	G107
Ampex Great Britain	E513
Amphenol	G21
Analytical Measurements	N819
Anderton Springs	N407
Andrew Corp. [U.S.]	G107
Anelex Corp. [U.S.]	G107
Antenna & Radome Res. Assoc.	G266A
Appliance Components	N820
Applied Microwave Labs.	G266A
Aqmel [Compagnie des Compteurs]	N303
Arkon Instruments	N310
Arrell Electrical [Permanoid]	N839
Arrow Electric Switches	G728
Associated Electrical Industries	G201
Assoc. des Ouvriers en Instruments [Lyons]	N456
Astralux Dynamics	G744
Astrodata [U.S.]	G107
Aumann KG [Cole Electronics]	G103
Austen Pumps	G771
Automatic Control Eng'g.	E924
Automatic Punched Tape	G753
Automatic Timing & Controls [U.S.]	G107
Autronic Developments [Newport Inst.]	N406
Avel Products [Aveley]	G206
Aveley Electric	G206
Aviation, Ministry of	E607
Avo	G60
B. & K. Laboratories	G58
B. & R. Relays	G764
B.F.I. Electronics	G274
B.I.C.C.	E932
Bailey Meters & Controls	N454
Bakelite	E935
Barbour Stockwell Insts. [Electrautom]	G735
Barden Corporation	G260
Barr & Stroud	N311
Behlman - Invar Electronics [Electrautom]	G735
Belix Co.	E945
Bell & Howell	G209
Belle Industries [Beulah]	G19
Belling & Lee	G252
Bendix Corp. (FieldTech)	G254
Bendix Electronics	N451
Benson-Lehner	N846
Berec International [Ever Ready]	G761
Besson & Partner [Vactric]	G262
Beulah Electronics	G19
Bishop Instrument [Lyons]	N456
Black Automatic Controls [Elliott]	G157
Blakeborough & Sons	E563
Bours (Trimpot)	E931
Bowmar Instruments [Reliance Controls]	N866
Brady, W H., Co.	N840
Bradley, G. & E. [Lucas]	E561
Bran & Luebbe	G18
Bribond Printed Circuits	E913
Brion Leroux & Cie [Leland]	E904
Britimpex	E601
British Aircraft Corp.	G910A
British Electric Resistance Co.	E901
British Ermeto Corporation	G263
British Physical Laboratories	G731

Exhibitor	Stand No.
British Precision Springs [Smiths]	N404
British Resistor Co.	G269
British Rototherm Co.	N818
British Watch Timers [Furzehill]	G773
British Wire Products	G781
Brown, S. G. [Hawker Siddeley]	G111
Brush Clevite Co.	G732
Brush Instruments [Aveley]	G206
Bryans	G14
Budenberg Gauge Co.	N302
Bulgin & Co.	G101
Burgess Products Co.	G255
Burr-Brown Research [U.S.]	G107
Bush Beach & Segner Bayley	E923
Butterworth & Co	G738
C. & N. (Electrical)	E609
CIM [Crouzet]	N817
C.R. [Compagnie des Compteurs]	N303
C.R.C. [Compagnie des Compteurs]	N303
C.Z. Scientific Insts.	N826
Cadmium Nickel Batteries	N800
California Computer Prods. [U.S.]	G107
Callins International	G268
Cambion Electronic Products	N836
Cambridge Consultants	E925
Camille Bauer [Kandem Electrical]	G153
Canon Electric	G713
Celdis [Motorola]	G155
Chance-Pilkington	E514
Chart-Pak	G13
Chesapeake Inst. Corp. [U.S.]	G107
Ciba (A.R.L.)	N854
Cie Crouzet [Crouzet England]	N817
Cie Petercem [Crouzet England]	N817
Clare International N.V.	G702
Clare-Elliott Ltd. [Elliott]	N452
Clarke & Co. (Manchester)	G10
Cleveland Electronics Inc. [U.S.]	G107
Cobham Engineering	N871
Coil Winding Equip. Co. [Kolectric]	N858
Cole, R.H., Electronics	G103
Colvern	N869
Compagnie des Compteurs	N303
Computer Control Co. [U.S.]	G107
Conklin Inst. Corp. [Electrautom]	G735
Constructions Radioelectriques et Electroniques [Lyons]	N456
Contraves AG	E562
Control Data Corp. [Electrautom]	G735
Controls & Automation	N838
Cook, C. A. [Cole]	G103
Copley Haddon & Co. [Photain Controls]	N859
CORECI [Crouzet]	N817
Cossor Communications	G207
Cossor Instruments	G207
Counting Instruments	N811
Cousino Electronics Corp. [Beulah]	G19
Coutant Electronics [Motorola]	G155
Creators Group of Companies	N807
Crompton Parkinson	G267
Crouzet England	N817
Croydon Precision Instrument Co.	G787
DAM [Crouzet]	N817
D.E.V. Eng'g. [Tylors]	G742
Data Device Corp. [Electrautom]	G735
Data Technology Corp. [U.S.]	G107
Datum Division of Bedco	G726
Davu Wire & Cables [J. Day]	N505
Day, J., & Co.	N505
Daystrom	G768
Degussa [Bush Beach]	E923
De La Rue Frigistor [Formica]	G158
Delta Controls	G261
Delviljem (London)	E937
Derritron	G16
Deuta-Werke GmbH	N808
Devices Sales	N829
Diamond H Controls	G729

Exhibitor	Stand No.
Di/An Controls Inc. [Electrautom]	G735
Digital Equipment Corp.	N852
Disa Elektronik A/S	G714
D-Mac	E512
Dodd Transformers [K. & N. Electronics]	G272
Drayton Controls	G163
Drayton Hydroflex	G163
Dresser-MMM	N822
Dual Components	E653
Dual Engraving Co.	E653
Dubilier Condenser Co.	G711
Duerrwaechter - Doduco K.G. [Joseph Electronics]	E911
Dukes & Briggs Engineering Co.	N870
Durant Mfg. Co. [U.S.]	G107
Dymar Electronics [Lan-Electronics]	E916
Dynamco Instruments	G723
E-A Technical Services [Elliott]	G157
EMI Electronics	N405
East Grinstead Electronic Components	N804
Eberle, Kohler & Co.	E558
EFFEN Elecktrotechnische Fabrik Otto Frees [Neoflex]	E558
Eddystone Radio	E917
Edlon Machinery	N400
Ekco Electronics	G701
Elcom	E915
Elcontrol [Bryans]	G14
Electrautom	G735
Electricity Council	E936
Electro Mechanisms	N863
Electro-Chemical Eng'g	E951
Electroglas Inc. [U.S.]	G107
Electrolube	E559
Electronic Applications [Furzehill]	G773
Electronic Associates	E555
Electronic Instruments	G718
Electronic Machine Co.	G204
Electronic Machine Control	G204
Electronic Measurements	G266A
Electronic Space Prods [Electrautom]	G735
Electronic Switchgear	G718
Electronic Development Corp [Electrautom]	G735
Electrons Inc. [Lyons]	N456
Electroprints [Painton]	E929
Electrosil	G61
Electrothermal Engineering	N507
Electrovac [Joseph Electronics]	E911
Elesta Electronics	N408
Elliott-Automation	G157 & N452
Elliott Brothers	N452
Eltromet [Kent]	G200
Engelhard Hanovia Lamps	E557
Engineering Review Publishing Co.	N813
English Electric Co.	N403
English Electric Leo-Marconi	N403
English Electric Valve Co.	G53
English Numbering Machines	G727
Epsylon Industries	G264
ERG Elektro-Rohren-Gesellschaft [Neoflex]	E558
Erg Industrial Corporation	G780
Erichsen GmbH [Pearson Panke]	E933
Ether	N352
Eurogauge Co.	N857
Evans Electroselenium	G777
Ever Ready Co.	G761
Eversheds & Vignoles [Kent]	G200
Facit-Odhner Electronics	E930
Fairchild Instrumentation [Aveley]	G206
Fairey Surveys	G253
Farnell Instruments	N867
Farris Engineering [Elliott]	G157
Feedback	N827
Fenlow Electronics	E918
Ferranti	N353
Fielden Electronics	G59
FieldTech	G254
Filhol, J. P.	E551
Fine Tubes	E939
Fischer & Porter	G113
Fisher Governor Co. [Elliott]	G157
Fisher Research Lab. [U.S.]	G107

Exhibitor	Stand No.
Fisons Scientific Apparatus	N500
Fleming Instruments	N501
Flight Refuelling Group	N872
Formica	G158
Foster Instrument Co.	E950
Foxall, T., & Sons	N855
Foxboro-Yoxall	G110
Furzehill Laboratories	G773
G.E.C. [M-O Valve]	G156
General Devices Co. Inc. [U.S.]	G107
General Electric, of N.Y.	G270
General Electronics Labs. [U.S.]	G107
General Precision Systems	E908
General Radio Co.	E554
Gesellschaft feur Elektrotechnik [Cole]	G103
Globe Industries Inc. [Lectropon]	G745
Gloster-Saro [Hawker Siddeley]	G111
Gloucester Controls	N455
Gloucester Instruments	N455
Graphic Instruments [Research Electronics]	G730
Graviner	G765
Griebach Instruments Corp. [Lyons]	N456
Gresham Lion Electronics	N843
Gresham Transformers	N843
Guest Electronics	N844
Guildline Instruments [Lyons]	N456
Gulton Industries [West Instrument]	N450
H.D.C. Research	E652
Haefner & Krullmann [Cole]	G103
Haddon Cables	E952
Haddon Electric Welding Machines	E952
Haddon Transformers	E952
Hahn Magnet [Neoflex]	E558
Haldor Topsoe	G786
Hallam, Sleigh & Cheston	N861
Hartmann & Braun A.G. [Kandem]	G153
Harwin Engineers	N803
Hassett & Harper	G210
Hatfield Instruments	N409
Hawker Siddeley Dynamics	G111
Hawker Siddeley Group	G111
Headland Engineering Developments Ltd.	G751
Headway Research Inc. [Electrautom]	G735
Heath Inc. [U.S.]	G107
Hellermann Deutsch	E934
Hellermann Electric	E934
Hellermann Plastics	E934
Hellermann Terminals	E934
Hendrey Relays	G22
Hengstler, J., Co.	G50
Henry & Thomas	G746
Hesto (Henkels-Stocko)	N805
Hewlett-Packard	G161
Heywood Temple Industrial Publications	N823
Highland Electronics	N841
Hird-Brown [Controls & Automation]	N838
Hirschmann Richard [Neoflex]	E558
Hoffmann, J. H.	G708
Holt Instrument Labs. [Aveley]	G206
Honeywell Controls	G205
Horizon House Inc.	G776
Hottinger Baldwin GmbH [Aveley]	N206
Hunt (Capacitors)	G203
IBM United Kingdom	N868
I.E.C. [International Engineering Concessionaires]	N873
Ide, T. & W.	G250
Iliffe Electrical Publications	G256
Imhof, Alfred	G741
Impectron	G734
Import Export Machines	E926
Industrial Electronics	G256
Industrial Instruments	N837

(Continued on page 309)


G 10 – G 274
N 300 – N 507
ADDISON ROAD ENTRANCE
RESTAURANT
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INFORMATION
PHONES
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LADIES
HAMMERSMITH RD. ENTRANCE
INFORMATION
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GENTS
LADIES
EXHIBITORS' CLUB No 1
LOUNGE
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NATIONAL HALL
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INFORMATION
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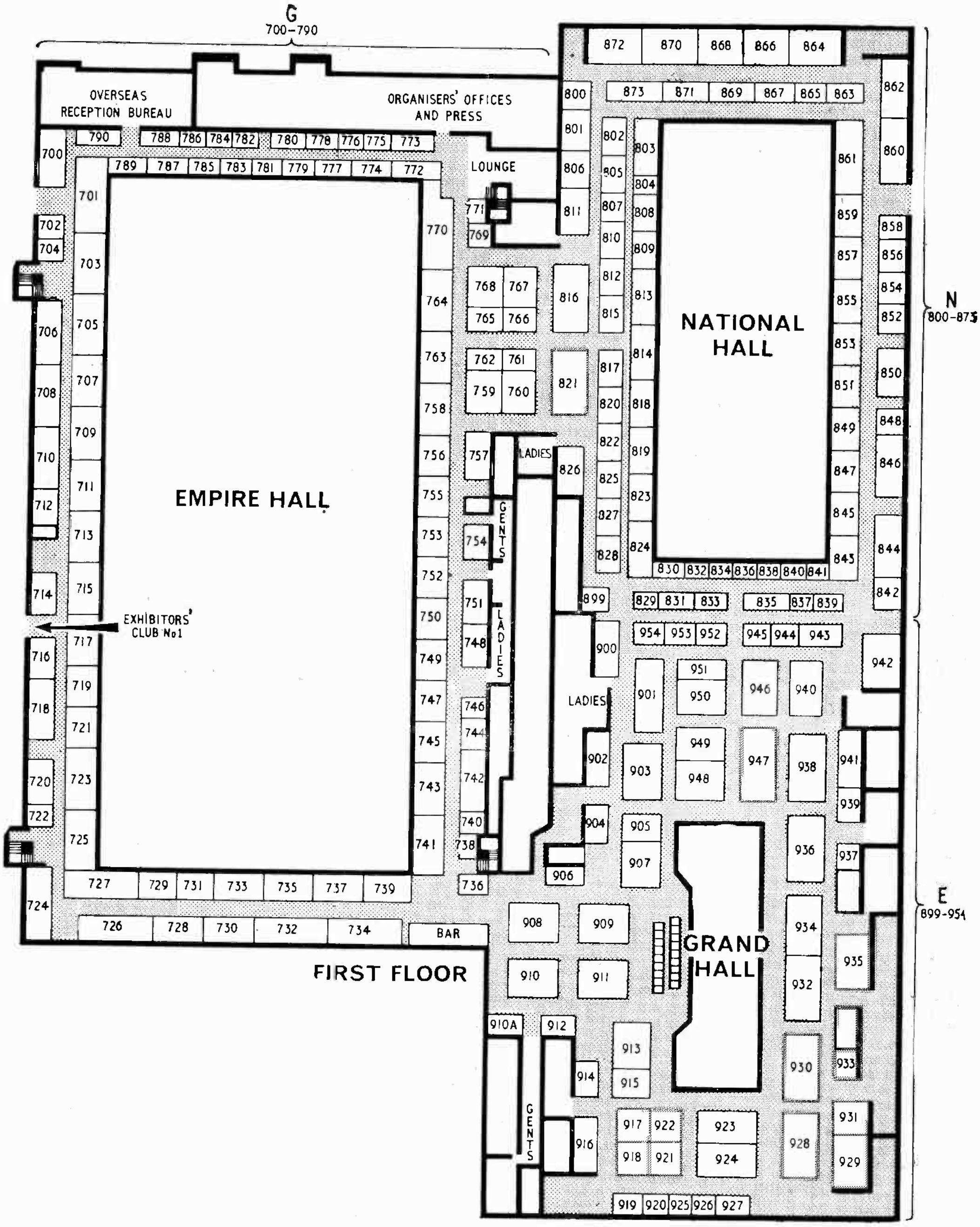
EMPIRE HALL
GRAND HALL
Wireless World



Exhibitor	Stand No.
Industrial Timer Corp. [Controls & Automation]	N838
Information Displays Inc. [Electrautom]	G735
Instrulab Inc. [Quantum Eng.]	N809
Infrared Industries [Cossor]	G207
Instron	E907
Instrumentation & Control Systems [Electrautom]	G735
Intercontinental Instruments [Lyons]	N456
International Electronics	G12
International Engineering Concessionaires	N873
International Instruments Inc. [Leland]	E904
Intersonde [Research Electronics]	G730
JD Electronics	N830
Janus Control Corp. [Electrautom]	G735
Jenaer Glaswerk Schott [Skan]	G767
Jermyn Industries	E944
Joseph Electronics	E911
K.D.G. Instruments	E947
K.G.M. Electronics	N503
K.M.C. Semiconductor Corp.	G266A
K. & N. Electronics	G272
Kandem Electrical	G153
Kelvin Electronics [Smiths Industries]	N404
Kennedy Co. [U.S.]	G107
Kent, George	G200
Kent, William (Porcelains) [Wade]	G784
Kerry's (Ultrasonics)	E511
Keyswitch Relays	G755
Kieler Howaldtrwerke [Aveley]	G206
Kistler Instruments AG	G114
Knick Elektronische Messgerate [Electrautom]	G735
Kodak	G262
Kolectric	N858
KOVO Foreign Trade Corp.	G709
Kumag, AG [Cole]	G103
Laboratoire Electro-Acoustique [Furzehill]	G773
Lancashire Dynamo	G762
Landis & Gyr	G707
Lan-Electronics	E916
Leach Corp. [FieldTech]	G254
Lectropon	G745
Leeds Meter Co. [George Kent]	G200
Leeds & Northrup	G55
Leland Engineering	E904
Leland Instruments	E904
Leland Leroux	E904
Lemo S.A. Electrotechnique	E912
Letchworth Sheet Metals [Bryans]	G14
Levell Electronics	N815

Exhibitor	Stand No.
Lippke, Paul, KG	G710
Litton Precision Products	N806
Livingston Components	G57
Livingston Electronics	G57
Livingston Laboratories	G57
Lloyds Bank	G17
Londex [Elliott]	G157
London Electrical Manufacturing Co.	E516
Lucas, Joseph	E561
Lund Brothers & Co.	E922
Lyons, Claude	N456
MB Electronics [B. & K.]	G58
M.B. Metals	G733
M.C.P. Electronics	E914
M.I.R.A	N873
M-O Valve Co.	G156
MSA Compaey	N300
Mackie, W., & Co.	E953
McMichael [M-O Valve]	G156
Magnetic Devices	E605
Magnetic & Electrical Alloys [B.I.C.C.]	G743
Maine-Lea [Sensitized Coatings]	E941
Mallory Batteries Ltd.	E905
Marchetti, Peter [Electrautom]	G735
Marconi Co. [English Electric]	N403
Marconi Instruments [English Electric]	N403
Markem Machine Co.	G774
Markovits, I.	G11
Marrison & Catherall	G772
Martin-Ivo	G778
Mathatronics Inc. [U.S.]	G107
Mawdsley's	N856
Maxam Power	N864
Measurement Research [Research Electronics]	G730
Mecanoplastique [Compagnie des Compteurs]	N303
Mec-Test [Miniature Electronic Components]	N350
Medistor Inst. Co. [U.S.]	G107
Melabs	G107
Mervyn Instruments [West Instrument]	N450
Messier S.A. [Electrautom]	G735
Metal Detection & Electroweighers [Lippke]	G710
Meter Flow [S.E. Labs.]	E603
Metex Corporation [U.S.]	G107
Mesucora	N312 & N303
Micro Instrument Co. [Lyons]	N456
Micromanipulator Co. [Electrautom]	G735
Micronia Corporation [Lyons]	N456
Microsen [Compagnie des Compteurs]	N303
Microwave Associates	N842
Microwave International Corp. [U.S.]	G107
Midland Bank	E948
Millivac Instruments [Lyons]	N456
Milton Ross Co.	G788
Milton Roy Co. [U.S.]	G107
Mimic Diagrams & Electronics	E924
Miniature Bearings [International Eng'g.]	N873
Miniature Electronic Components	N350
Mining & Chemical Prods. [M.C.P.]	E914
Model & Prototype Systems	E550
Moore Reed & Co.	G789
Morecambe Electrical Equipment Co.	G719
Morgan Brothers (Publishers)	N816
Morganite Resistors	E560
Motorola Semiconductor Products	G155
Mullard	G152
Murex	E600
N S F	G720
Nalder Brothers & Thompson	E909
Nanoseconds System	G266A
Narda Microwave Corp. [Aveley]	G206
National Cash Register	E927
National Provincial Bank	N862
Negretti & Zambra	G56
Nelson-Ross Electronics Inc. [Quantum]	N809
Neoflex	E558
New Western (Engineering) [Negretti & Zambra]	G56
Newmarket Transistors	G705
Newport Instruments	N406
Non-Linear Systems Inc. [Lyons]	N456
Nore Electric	G266A
Norma Gesellschaft [Croydon Precision Inst.]	G787
North Atlantic Industries [Aveley]	G206
Nucleonic Accessories [Research Electronics]	G730
Nutec	E912
Oerlikon Machine Tool Co. [Contraves]	E562
Officine Galileo [Leland]	E904
Officine Toscane Elettronecaniche [Leland]	E904
Oldenbourg, R., Verlag	G738
Oliver Pell Control	G716
Omron	G259
Optical Works	G722
Optimized Devices Inc. [Quantum]	N809
P. & H. Engineering Co.	G760
P.C.A. Radio	N865
P.M.F. Electronics [Electrautom]	G735
P.R.D. Electronics	G266A
P.S.B. Instruments	G779
Pacific Electro Magnetics Co. Inc.	N832
Packard Instrument	G700
Painton & Co.	E903
Palmer Aero Products	G750
Panax Equipment [Electronic Machine Co.]	G204
Parkinson Cowan Measurement	E602
Parmeko	G715
Partridge Wilson & Co.	G785
Payne & Griffiths [Smiths]	N404
Pearson Panke	E933
Pergamon Press	G740
Perkin-Elmer	E938
Permanoid	N839
Peto Scott	E608A
Photoain Controls	N859
Photoelectronics (M.O.M.) Holdings	G211
Picard, Henri, & Frere	G769
Pignone Sud S.p.A.	G208
Pitt & Underwood	G57
Planer G.V.	G704
Plannair	G15
Platon, G. A.	N354
Plessey Co.	G160
Polaron [Delviljem]	E937
Potter Instrument Co.	G115
Precimecanic [Electrautom]	G735
Precis S.A. [Electrautom]	G735
Precision Products & Controls [Platon]	N354
Precision Tool & Instrument Co.	G736
Process Control & Automation	E902
Pye, W. G. & Co.	N352
Pye Switches	N831
Pye Telecommunications	N352
Pyro-Werk GmbH [Kandem]	G153
Quantum Engineering	N809
Quickdraw Co.	G20
Quinton-Crane Electronics	G51
RCA Great Britain	G52
RHO Associates Inc. [Quantum]	N809
R.M.T.	N858
Racal	G154
Radiatron	E900
Radio Frequency Labs. [U.S.]	G107
Rank Organisation Ltd.	E604
Reach Electronics Inc. [Quantum]	N809
Record Electrical Co. [Kent]	G200
Recording & Nucleonic Inst. [Research Electronics]	G730
Red Valve Co. Inc. [Platon]	N354
Redifon-Astrodata	G747
Reliance Controls	N866
Reliance Gear Co.	G766
Research Electronics	G730
Research Instruments	G273
Reutlinger & Söhne [Cole]	G103
Rimbach Publications [U.S.]	G107
Rivlin Instruments	N301
Rixon Electronics Inc. [Electrautom]	G735
Roband Electronics	E928
Robinson, F. C. & Partners	G203A
Rockbestos Wire & Cable Co. [FieldTech]	G254
Roditi Purchasing Co.	N835
Rohde & Schwarz [Aveley]	G206
Rosemount Engineering Co.	N825
Ross, Courtney & Co.	N853
Ross & Co. (Foundry) [Marrison & Catherall]	G772
Rotameter Manufacturing Co. [Elliott]	G157
Rotax [Lucas]	E561
Rotron Europa	G734
Royal Worcester Industrial Ceramics	E906
Royce Electric Furnaces	E951
Royston Instruments	G51
S.E. Laboratories	E603
SESCO [M.C.P. Electronics]	E914
SGS-Fairchild	G54
S.T.C.	G106
Sage Laboratories	G266A
Salford Electrical Inst. [M-O Valve]	G156
Salterfix	N504
Sanders, W. H. (Electronics) [English Electric]	N403
Sangamo Weston	G151
Sanken Electric Co. [Photain Controls]	N859
Saxby Electronique [Electrautom]	G735
Schaevitz [Electro Mechanisms]	N863
Schnorr, Adolf	N873
Schuemann, Heinrich [Cole]	G103
Scientific Atlanta [Aveley]	G206
Scientific Furnishings [Research Electronics]	G730
Scottish Council	N847
Sealectro	G706
Seavom [Compagnie de Compteurs]	N303
Semikron Rectifiers & Electronics [H.C.D. Research]	E652
Sensitised Coatings	E941
Sensory Systems Inc. [Quantum]	N809
Serck Controls [Gloucester Controls]	N455
Service Electric Co.	N828
Servomex Controls	G251
Servo-Tek Products [U.S.]	G107
Servo Consultants	G257
Seti [Compagnie des Compteurs]	N303
Setpoint	G749
Shandon Scientific Co.	G725
Shaw Publishing Co.	N506
Sic [Compagnie des Compteurs]	N303
Sick, Erwin [Pearson Panke]	E933
Siemens [U.K.]	G103
Siemens & Halske AG.	G103
Siemens-Schuckertwerke AG.	G103
Sierex	G100
Sifam Electrical Instrument Co.	N821
Siliconix Inc. [Electrautom]	G735
Simplex Time Recorder [U.S.]	G107
Simplifix Couplings	G263
Singer Co. [Quantum]	N809
Sirco Controls	G265
Smart & Brown [A.B. Metal Prods]	G271
Smiths Industries	N404
Smiths Medical Equipment Co.	N404
Societe des Accumulateurs [Cadmium Nickel Batteries]	N800
Sola Basic Industries [U.S.]	G107
Solarton Electronic Group	G162
Sontranic [Research Electronics]	G730
Sorensen Products [Cossor]	G207
South London Elec. Equip. Co.	E556
Southern Instruments	N402
Sovirel	N848
Spear Engineering Co.	G775
Spectra-Physics Inc. [Lyons]	N456
Sperry Gyroscope Co.	159
Sprague Electric	E919
Standard Telephones & Cables	G106
Stéatite Insulations	N802
Steatite & Porcelain Products [Morganite]	E560
Stevens Mfg. Co. [U.S.]	G107
Stewart Aeronautical Supply Co.	N845
Stocko Metallwarenfabriken [Hesto]	N805
Stoddart Electro Systems [Aveley]	G206
Strumenti Industriali e Scientifici [Leland]	E904
Sullivan, H. W.	G752
Superior Electric Nederland N.V.	G23
Synthetic Jewels [Smiths]	N404
Systems & Communications	E899
T.R.G. Inc. [Lyons]	N456
TRW Semiconductors [M.C.P. Electronics]	E914
Tannoy Products	E940
Taylor Electrical Instruments [Avo]	G60
Taylor Instrument Companies	N453
Teb Huber [Aveley]	G206
Techmation	E943
Techna	G754
Technivision Group	N813
Technograph & Telegraph	G763
Technology, Ministry of	G105
Tectonic Industrial Printers	G757
Tektronix	E553
Telcon Metals [B.I.C.C.]	G743
Telefunken A.G. [Britimpex]	E601
Telequipment	E949
Temco [B.I.C.C.]	G743
Terminal Radio International [U.S.]	G107
Texas Instruments	N351
Thermal Syndicate	G717
Thermalloy	E914
Thermionic Products [Airmec]	G102
Thomas Electronics	G209A
Thorn AEI Radio Valves & Tubes	G109
Thorn Special Products Division	G104
Tinsley & Co.	G266
Tintometer	G258
Tiro-Clas	E552
Topper Cases	G782
Tothill Press	N860
Tracor Inc [Racal]	G154
Transistor Automation Corp. [U.S.]	G107
Transitron Electronic	G739
Trompeter Electronics Corp. [U.S.]	G107
Trumeter Co.	E651
Turner Electrical Instruments	G150
Turton Brothers & Mathews	N401
20th Century Electronics	G712
Tylors	G742
U.K. Optical Bausch & Lomb	G783
U.S.A. Exhibit	G107
Ultra Electronics	G770
Unimatic Engineers	G207
Union Carbide	N801
United Trade Press	G790
Uni-Tubes [Smiths Industries]	N404
Uptime Corp. [U.S.]	G107
VEB Carl Zeiss Jena	N826
Vactric Control Equipment	N849
Vacwell Engineering [Electronic Machine]	G204
Varian Associates	E554
Veeco Instruments	N834
Veeder-Root	N814
Venner Electronics	G748
Vermont Research Corp. [U.S.]	G107
Vero Electronics	N824
Vibro-Meter Corp.	N851
Victoreen Inst. Co. [U.S.]	G107
Vision Engineering	N810
Vitrohm Elektroteknisk Fabrik A/S	E921
Wade (Ulster)	G784
Ward Brooke & Co.	G202
Waters Mfg. Inc.	N873
Watson, John, & Smith [Platon]	N354
Waycom	E946
Weber	G103
Weinschel Eng'g Co. [English Electric]	N403
Weller Electric	N833
Welwyn Electric	G703
West Instrument	N450
Westinghouse Brake & Signal Co.	G108
Westland Aircraft	G721
Westminster Bank	E910
Westool	N313
Wetzer, Hermann, KG, [Counting Insts.]	N811
Whiteley Electrical Radio Co.	E606
Wilton Co. [U.S.]	G107
Wire Products & Machine Design	G756
Wireless World	G256
Woden Transformer Co.	N850
Zeal, G. H.	N502

LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

Attenuation in Coaxial Cables

MR. WADE'S article in the April issue was both interesting and informative. However, the graph he uses in Fig. 5 gives a rather pessimistic picture of the attenuation on a lossy line. A reflection coefficient of 0.6 measured at the transmitter end of a short-circuited line, would indicate a total attenuation over the forward and return paths, of 2.2 dB. This figure is actually twice the cable attenuation, and the values for attenuation given by Fig. 5 should be halved.

Chippenham, Wilts. D. P. GRAY

The author replies:—

May I draw upon Reference 4 mentioned in the article (i.e. "VHF Line Techniques" by C. S. Gledhill, pp. 14-17), where the theory associated with the graph of Fig. 5 is shown. Summarizing this theory, and modifying it for convenience to yield equations in terms of line *currents* instead of voltages (because we are considering a short-circuit termination), we can state the following.

If the forward current at the transmitting end of a cable of electrical length l is I_F, it will be attenuated by a factor $e^{-\alpha l}$ at the short-circuit end, so that the current flowing through the short-circuit is $I_F e^{-\alpha l}$. This current will be totally reflected, and again attenuated by $e^{-\alpha l}$ on its return to the transmitter. Hence the reflected current at the transmitter will be $I_R = I_F e^{-\alpha l} . e^{-\alpha l} = I_F e^{-2\alpha l}$.

The reflection coefficient k measured at the transmitter end of the cable is defined as the ratio I_R/I_F, from which it will be seen that

$$k = e^{-2\alpha l}$$

$$\therefore \alpha l = \tfrac{1}{2} \ln \frac{1}{k} \text{ neper}$$

$$\text{or } \alpha l = 10 \log \frac{1}{k} \quad \text{dB}$$

This last equation is the one from which Fig. 5 was plotted. It should be noted that αl is the attenuation over a length l, and not over $2l$; the fact that the signal has travelled over both the forward and return paths before the reflection coefficient is measured is allowed for in the index $-2\alpha l$.

If Mr. Gray still needs to be convinced on this point, let us calculate from first principles the reflection coefficient to be expected at the transmitter for the particular example quoted. If the cable has an attenuation of 2.2 dB and the magnitude of the forward current at the transmitter is, say, 100 mA, this current will be attenuated by 2.2 dB to 77.6 mA at the short-circuit termination, and after reflection the wave will be attenuated by a further 2.2 dB to 60.2 mA at the transmitter. Hence the reflection coefficient is 60.2/100 = 0.602, which to all intents and purposes is equal to the value of 0.6 stated in the article.

I understand Mr. Gray to imply that the cable attenuation for a reflection coefficient of 0.6 should be only 1.1 dB. If we now repeat the above example, assuming an attenuation of 1.1 dB, the short-circuit load current will be 88.1 mA, and the reflected current at the transmitter will be 77.6 mA, in which case $k = 0.776$; not 0.6 as stated by Mr. Gray. However, the value $k = 0.776$ (or shall we say 0.78) is in agreement with Fig. 5, and accordingly I maintain that this graph is correct. I wonder if Mr. Gray has confused current with power when using equations involving dB, remembering that the reflection coefficient is expressed in terms of a current or voltage ratio, and not a power ratio?

May I take this opportunity of drawing attention to three small errors which did find their way into the article. Two are concerned with the graph shown in Fig. 9. The word **LOAD** towards the bottom right-hand corner has become detached from **S.W.R.** at the top, i.e. each curve represents the s.w.r. at the load. Secondly, the horizontal and vertical dotted lines (corresponding to the numerical example given in the text) should intersect on the **LOAD SWR** = **10** curve, and not just above it as shown. Finally, my call-sign is G3NRW.

Chelmsford, Essex. A. I. H. WADE

Temperature Indicator

IN recent times it has become common to refer to all voltage regulator diodes which use reverse voltage breakdown as Zener diodes. A look at the graph in Fig. 1 will show that only those diodes which operate at the lower voltages are truly Zener diodes. Zener breakdown occurs in relatively highly doped junctions where

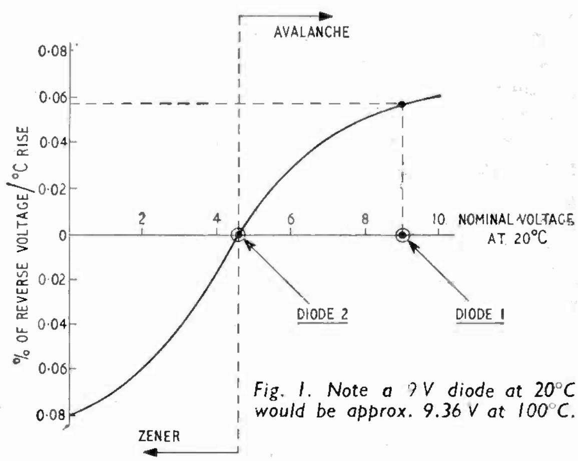


Fig. 1. Note a 9 V diode at 20°C would be approx. 9.36 V at 100°C.

the depletion layer is very thin, the electric field stress at this junction can be in the order of 500 kV/cm, this being the main cause of the breakdown, this occurs at lower voltages as temperature increases.

Avalanche breakdown occurs within the depletion layer when the current carriers forming the reverse saturation current reach a sufficiently high velocity to create other carriers by collision. In this type of breakdown the breakdown voltage rises as the temperature increases.

Readers may be interested in a temperature gauge developed in an attempt to use this increasing voltage as an indication of diode temperature (Fig. 2).

One side of the meter is held at 4.7 V by diode 2. The voltage of this diode being independent of ambient tem-

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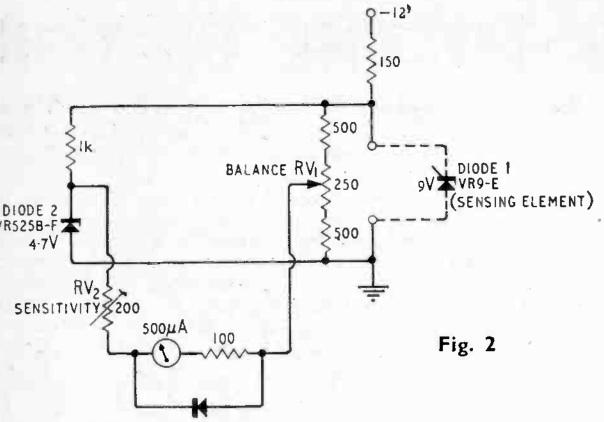


Fig. 2

perature changes. Diode 1, an avalanche diode, forms the temperature sensing element and as the temperature rises unbalances the bridge. The original gauge was required to read from 0 to 100°C. In setting up the gauge diode 1 was reduced in temperature to 0°C. With RV2 set for maximum sensitivity, the balance control RV1 was set for zero reading on the meter. Diode 1 was then increased in temperature to 100°C. and the sensitivity control adjusted for f.s.d.

The gauge has been used for several months as a water temperature gauge for a petrol engine.

The avalanche diode used was a 5 W stud mounted type, screwed into the thermostat housing by its 2 B.A. thread. Diode 3 was used for meter protection during starting conditions, where the battery voltage could possibly fall to a low value.

The gauge has been found to be accurate and linear, and also free from ambient temperature changes. The device has many possibilities, it can be set to give a positive or negative output about any pre-set temperature and should work well in a control system.

Preston, Lancs. J. B. LEIGH

Information Explosion

I AM deeply interested in the problem which you raise in your April editorial—"Can the Information Explosion be Controlled?" I nevertheless doubt whether this question is as crucially important as many people think. Let me elaborate.

An explosion is a transient phenomenon: this is not. Human society has been developing a long time, and the rate at which it has been changing has also apparently been steadily increasing. We have become worried because the rate of change is now severely taxing human adaptability and it may not be long before we cannot cope with it. This is the wider context in which the rapid proliferation of technical information must be considered: information of this kind is, in fact, only a single feedback path in the far larger and more complex closed-loop relationship between man and his culture. This overall system is the only one that really matters. To concentrate on the information problem alone is rather like tackling a runaway horse and cart by putting roller bearings on the wheels.

In these circumstances I am not clear what "control" really means. Of course we must try to *accommodate* this expansion, but control can only be effectively applied to our total, increasingly technically based culture. To restrain cultural development would, however, thwart the drive of human imagination and enterprise and we would be sure to suffer one way or another—perhaps in frustration and bloodshed, or less dramatically in complacency and decadence. If we are, in fact, more interested in reins than in roller bearings, we must shape our culture into a continuously expanding phenomenon which has intrinsically safe, self-adaptive, characteristics. Such a culture will, I believe, become an increasingly important concept in the next decade or so; but it will be a long time before we can realize a practical model.

I am sure that, in the detailed problems of information dissemination, computers and verbal techniques will, as you have suggested, become increasingly important. But literature of one kind or another has been with us a long time, and we have become used to the presentation of the printed word. In their own field engineers are now skilful at flipping pages, jumping paragraphs, extracting key data, and perhaps referring back to check earlier qualifications. In the 12th Graham Clark Lecture, Lord Snow pointed out that engineers as engineers can get on very comfortably without words, and that as students it doesn't matter if they mis-spell the vocabulary they use. All these considerations suggest to me that improved information paths may increase the quantity of material handled, but that the quality may seriously deteriorate. Perhaps, after all, our culture has some inherently stable characteristics. It may be able to sense when it is wise for the roller bearings to become clogged with sand!

Welwyn Garden City, Herts. CRAWFORD ROBB

Amplifier Noise Level

WHEN at the recent Audio Fair I requested a very well known person in the audio industry if he would adjust the volume and treble controls of a transistor amplifier he was demonstrating to maximum, and allow the audience to estimate the noise level it produced.

I was told that "this is meaningless" and that the volume control would never normally be in the maximum position.

I would like to suggest, in your columns, that there are very good reasons for this subjective test to be of value. Unless the noise figures are very good (better than 70 dB below 30 W r.m.s.), two comparable transistor amplifiers may give very different subjective impressions if in one, the effect is concentrated in the low frequencies, due to excess or flicker noise from transistors. And not all gramophone records have the ideal dynamic range (70 dB), or they may be undermodulated, or they may be recordings of solo instruments, played pianissimo with silent intervals (that is except for amplifier and tape noise), all requiring a higher setting of the volume control to maintain the same average listening level. If these conditions are not allowed for in design, then a higher power amplifier is not a higher quality amplifier as I believe it also should be. A maximum acceptable noise power delivered to the loudspeaker should be the aim, more difficult perhaps to achieve than a reasonable signal-to-noise ratio.

Decca Radio & Television, London, S.W.8. R. C. DRISCOLL

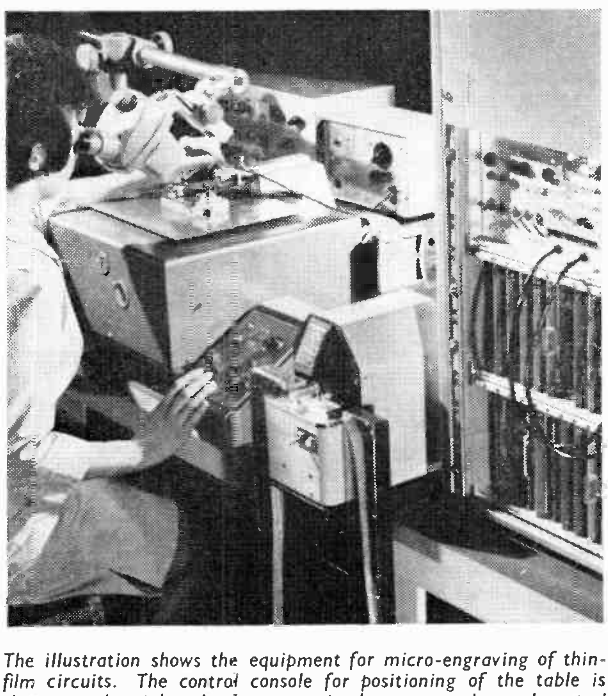
HANOVER FAIR

We regret it has not been possible for us to include in this issue a report on the Hanover Fair as we had planned.

A SPARK MICRO-ENGRAVING TECHNIQUE FOR THIN-FILM CIRCUITS

A SPARK micro-engraving technique for use in the production of thin film circuits has been developed by Standard Telephones and Cables Limited. The engraving equipment is positioned controlled from a digital punched paper tape programme, and a significant feature is that all the scaled-up draughting processes normally associated with thin-film circuit production are entirely eliminated because the programme can in fact be prepared from a simple dimensioned sketch drawn by the circuit design engineer on squared paper. The machine can engrave tracks down to 0.002in wide with a positional accuracy of 0.0003in. An important aspect of the use of punched tape is the possibility of tape preparation at a remote location—the digital information can be sent from one place to another over the telex system. The use of punched tape also suggests another interesting possibility—feeding circuit design parameters directly into a computer which will calculate the necessary dimensions of the circuit elements and control the action of the micro-engraving equipment.

Spark micro-engraving is a technique for cutting lines in thin films of electrically conductive material. Although a spark engraving probe or stylus, traversed while in contact with the film surface, does produce the required erosion effect the process applied in this way is unreliable because of the tendency to short-circuit the stylus to the film surface, which stops further erosion taking place. The method used by S.T.C. is to vibrate the stylus perpendicularly to the plane of the surface being engraved, so as to make and break contact with the film and produce momentarily critical gap conditions for spark breakdown during each half-cycle of movement. The spark energy is provided by a small capacitor placed across the gap and charged from a low voltage d.c. supply through a resistance which is large enough to prevent thermal damage to the film due to flow of d.c.



The illustration shows the equipment for micro-engraving of thin-film circuits. The control console for positioning of the table is shown on the right. In the centre is the tape reader and control box. The table with engraving head is on the left.

Optimum voltage and component values are dependent on type and thickness of the material being engraved. For example, typical values for nichrome films less than 100 Å thick are: 24 volts, 50 pF and 100 kΩ. The engraving is carried out under the surface of a dielectric fluid which provides high breakdown strength and restricts the breakdown to an area closely defined by the stylus diameter. Vibration of the stylus is effected by a piezo-electric element which is caused to vibrate in a longitudinally bending mode by the application of a driving voltage to metallized electrode areas. When energized in a resonant mode, e.g. 4.5 kc/s, a tip movement of approximately 25 μm is obtained with 100 volts a.c. input. One end of the transducer is rigidly clamped to a balanced arm and the stylus is mounted at the free end. The tip diameter is precisely controlled, and although any lateral movement of the tip affects positional accuracy, and hence the edge definition of the engraved line, some resilience is necessary in the stylus mounting to avoid deformation of the tip by continuous hammering action. The stylus is housed in jewelled bearings and a 1 μm radial clearance provides free longitudinal movement. The engraving speed which can be used is dependent on the volume of material to be removed. Typical values for a 50 μm wide track are: 1 cm/s for 70 Å thick nichrome and 1 mm/s for 3000 Å thick gold film.

Relative movement between the stylus and thin film substrate is effected by a two-axis numerically controlled table similar to that of a conventional machine tool. An open-loop control system is used incorporating a stepping motor as the drive element and precision leadscrews as the reference lengths. One electrical input pulse fed to the motor drive circuitry causes the motor shaft to make one step of rotation (equivalent to 1.8°). This rotates a leadscrew and moves the table a distance of 0.0005 in. (This is the resolution of the table.) The stepping motors have a strong in-built detent action, and provide an accurate step movement provided the frictional forces opposing the motion of the table are not larger than the detent force of the motor.

The data tape control system for the table consists of two registers, one containing the co-ordinates of the actual table position and the other containing the co-ordinates of the position to which the table must move. The motors and position register are pulsed until the two registers contain identical co-ordinates. This indicates that the table has reached the required position.

Preparation of the tape programme consists of punching the co-ordinates of the various change points in relation to a suitable origin. The origin must be in the extreme position in each axis to which the table is required to move during the engraving process because the control unit cannot handle negative co-ordinates as would be required if the table were to be expected to move past the origin. The origin must also be an easily identified point on the substrate so that the engraving head can be set in relation to the substrate before engraving is commenced. The data consists of groups of nine numbers punched in standard G.P.O. telex code; the first numeral controls the machining speed and energy input. The next four represent the Cartesian ordinate expressed in units of 0.0005 inch. The last four numerals in the group represent the Cartesian abcissa in the same units.

At present the process has two main applications to thin-film circuits. These are the machining of passive components to close tolerance values after deposition and the manufacture of photolithographic masters.

By direct machining, component tolerances which can be obtained are 0.1% for resistors and 0.5% for capacitors. For photolithographic masters, accurate artwork or photography is eliminated and a master can be engraved in a hard adherent metallic layer on a standard 2 in×1 in glass slide in about 10 to 15 minutes.

PICKUP ARM DESIGN—2

DESIGN AND MOUNTING OF ARMS FOR MINIMUM DISTORTION DUE TO LATERAL TRACKING ERROR

By J. K. STEVENSON,
B.Sc., Grad.Inst.P., Grad.I.E.E.

Concluded from page 218 of May 1966 Issue

In part 1, the author maintained that whilst distortions in disc reproduction are gradually being reduced, tracking error distortion has not been. It was pointed out that it is possible to design and mount an arm so that distortion due to lateral tracking error is less than 1%. After discussion of distortion due to tracking error, design formulae are derived for offset angle and overhang for minimum tracking error distortion.

In part 2, two designs are presented, one for 7in discs and one for 7, 10 and 12in discs. Tracking error is shown to be critically dependent on mounting errors, and in view of this, the author outlines two mounting procedures. Pickup arm shape and optimum tracking mass are also considered.

RECORD players may be considered as being of two types, those suitable for all diameter records, and those suitable for only 7in records. Design values are now given for both types.

Design values for 7in discs

x was measured at the start and finish of a number of records of different makes and the values obtained are given in Table 1. x_{outer}, which was measured for 7in and 12in discs, was found to be fairly constant and varied at the most by 1/32in. The values for x_{inner} are representative values for the minimum distance from the record centre and x_{min} denotes the minimum distance in exceptional cases, being the minimum value obtained for x_{inner} from measurements on a batch of records of different makes and different types of music.

Pickup arms have been designed using equations 6, 7, and 8. In the design of an arm restricted to 7in records, x_0 and x_2 were chosen as follows.

$$x_0 = x_{inner} = 2.125\text{in},$$
$$x_2 = x_{outer} = 3.281\text{in}$$

x_m^3, x_p, x'_0 and x_3 were then determined and the values are given in Table 2. Maximum distortion of a given modulation occurs at the start of a record, and also at $x = 2.49$in, and $x = 2.00$in. The distortion becomes zero at $x = 3.00$in. and $x = 2.13$in. In this design, the distortion is set to zero at the normal finish of a 7in disc (a desirable feature) and increases to the maximum value at $x = 2.00$in. However, it is unusual for the modulated section of a 7in disc to continue as far as $x = 2$in.

Design values for all discs

In the case of a record player suitable for 7in, 10in and 12in discs, the situation is more involved. In considering the distortions from 7in discs, it must be remembered that the turntable speed for these records is different to that for 10in and 12in discs. Three designs were obtained as shown in Fig. 6, and as the offset angle and overhang vary fairly linearly between them, the extreme designs 1A and 1C provide limits for overhang and offset angle between which any value of either of these parameters may be chosen, and the value for the other immediately given. With the smaller offset angle (design 1C), the maximum harmonic distortion for 7in discs tracking at 45 rev/min is less than that for long-playing records, as seen from Fig. 7. As the angle increases,

TABLE 1
Extreme values of x obtained from measurements on discs (x in inches)

x_{min}	x_{inner}	x_{outer}	Discs considered
$2\frac{1}{2}$	$2\frac{5}{8}$	$5\frac{23}{32}$	10″, 12″ ($33\frac{1}{3}$ rev/min)
2	$2\frac{1}{8}$	$3\frac{9}{32}$	7″ (45 rev/min)

TABLE 2
Values of x used in pickup arm design (x in inches)

Design	Design values		Zero distortion	Maximum distortion (also at x_2)		Maximum tracking error		Application
	x_0	x_2	x'_0	x_3	x_f	x_m	x_m^3	
1A	2·500	5·719	4·684	2·279	3·260	3·422	11·710	7″, 10″, 12″ discs
1B	2·375	5·719	4·606	2·158	3·134	3·307	10·939	
1C	2·250	5·719	4·522	2·038	3·005	3·190	10·175	
2	2·125	3·281	3·001	2·004	2·488	2·525	6·379	7″ discs

In a design, the distortion of a given modulation is maximum at the largest value of x (x_2) and set to zero at x_0. Then:—

x'_0, x_0 are the values at which the distortion is zero

x_2, x_p, x_3 are the values at which the distortion is maximum, where $x_2 > x'_0 > x_p > x_0 > x_3$, as shown in Fig. 5 (last month).

then provided the overhang is adjusted accordingly, the maximum distortion for long-playing records gradually reduces, and the maximum distortion for 7in discs increases.* For the larger offset angle (design 1A), the maximum distortion for 7in discs is about $2\frac{1}{2}$ times as great as that for long-playing records. However, it is still less than 2% second harmonic even for an 8in pickup, and in view of the fact that other forms of distortion will be lower for 7in discs at 45 rev/min than for 10in or 12in discs at $33\frac{1}{3}$ rev/min, the design is still suitable. The values used in these designs are given in Table 2. Note that for designs 1A to 1C the tracking error changes from positive to negative for a long-playing record, and changes from negative to positive for a 7in disc. If we had disregarded 7in discs and obtained a design with minimum distortion for long-playing records, i.e. one for which the distortion changes from positive to negative and back to positive again, the improvement would be very small but the distortion from 7in discs would by comparison be enormous.

The intermediate design 1B is recommended although, as mentioned earlier, provided that the offset angle lies within the given range, the mounting may be considered as optimum with the smaller angle slightly favouring 45 rev/min records and the larger angle favouring long-playing records.†

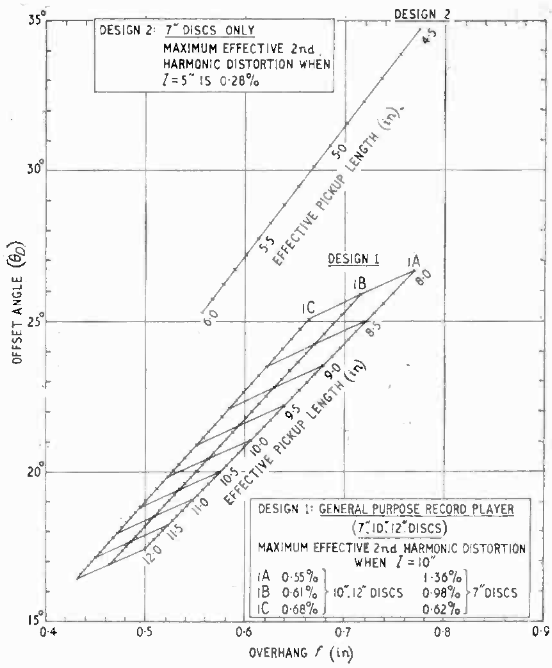
45 rev/min records are slightly favoured insofar as most forms of distortion are inversely proportional to the groove speed or a power of the groove speed i.e.:—

$$\text{distortion} \propto \left(\frac{1}{u}\right)^n \propto \left(\frac{1}{sx}\right)^n, \text{ where } n \geqslant 1.$$

The maximum distortion of a given modulation (the total

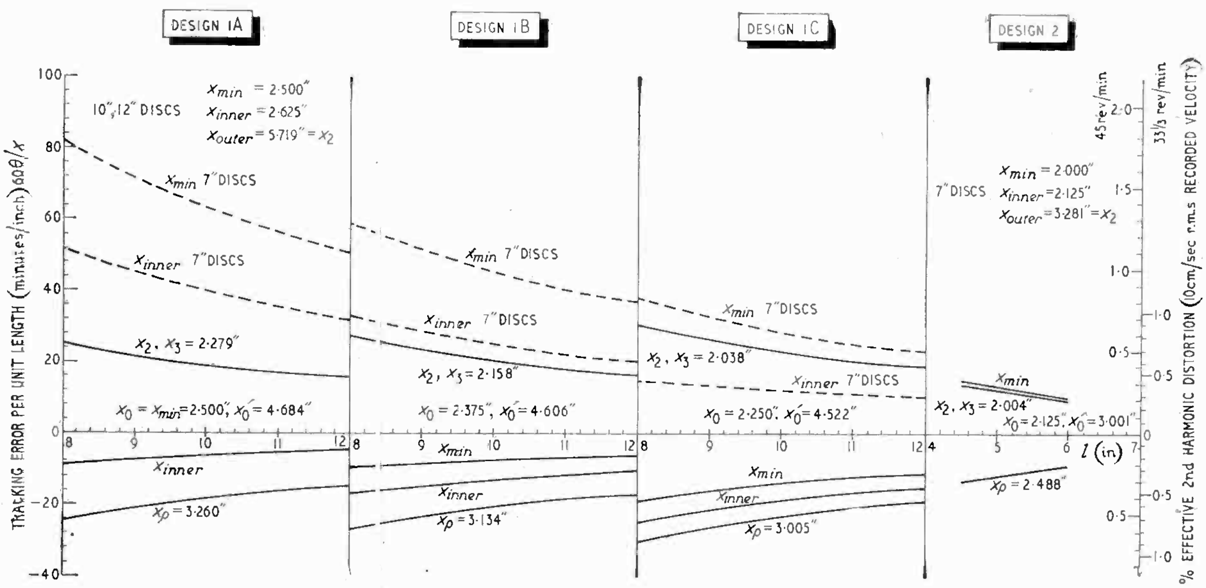
*By maximum distortion, we mean the maximum distortion of a given modulation, and in our calculations of distortion, we consider an effective recorded velocity of 10 cm/sec, a typical maximum value. Values as high as 20 cm/sec corresponding to a peak recorded velocity of 28 cm/sec occasionally occur but only for brief periods, e.g. a clash of cymbals. The average recorded velocity is usually greater for standard 7in discs than for extended play (7in) and long-playing records. However, standard 7in discs are usually restricted to popular music in which harmonic distortions are less objectionable.

†One design may be best for one record and another best for a second record simply because the most heavily modulated passages, at which the largest distortion is most likely to occur, are at different values of x. However, the overall best design is clearly the one for which the maximum distortion of a given modulation is least.



▲ *Fig. 6. Design values. The values of distortion quoted correspond to a 10 cm/s r.m.s. recorded velocity. Of the three designs 1A, 1B and 1C, 1B is recommended. The slightly greater harmonic distortion for 7in discs is counteracted by a reduction in distortion from other causes, as a result of the faster turntable speed. For an 8in pickup arm mounted as suggested, the distance between the edge of a 12in disc and the centre of the arm pivot is $1\frac{1}{4}$ in. A shorter distance corresponding to a shorter arm is impractical if adequate compensation is to be made for side-thrust.*

Fig. 7. Variation of 2nd harmonic distortion with x. The values of distortion are typical maximum values, as distinct from occasional peak values, due to exceptionally heavy modulation. ▼



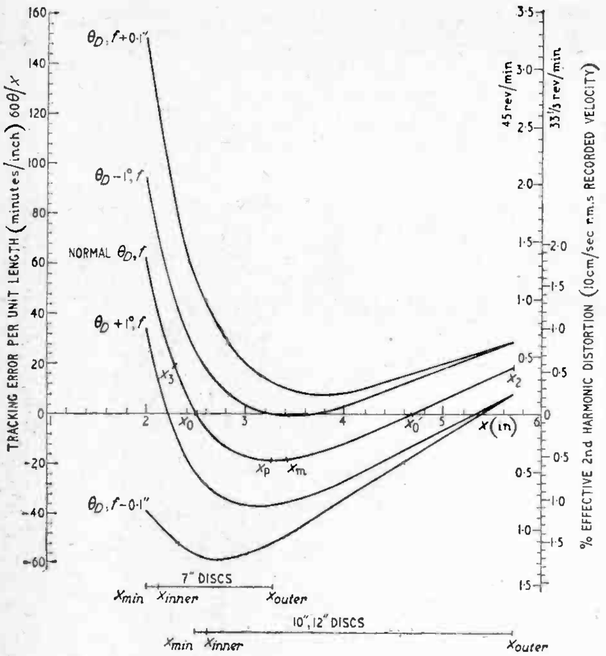
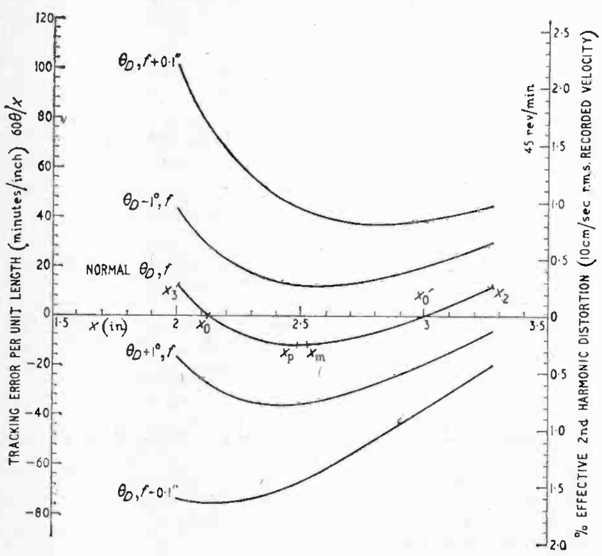


Fig. 8. Variation of 2nd harmonic distortion with changes in θ_D and f from the values given for design 1A in Fig. 6 (l = 10in). For other values of l, multiply harmonic distortion by 10/l (approximate). The same variations are applicable to designs 1B and 1C. It is seen that if f is too small (bottom line), $\phi/x(=[\theta-\theta_D]/x)$ is negative over most of the range of x. The tracking error may therefore be reduced by reducing θ_D as suggested in Fig. 6.

Fig. 9. Variation of 2nd harmonic distortion with changes in θ_D and f from the values given for design 2in Fig. 6 (l = 5in). Design 2 is for 7 in discs only. For other values of l, multiply harmonic distortion by 5/l (approximate).



from all causes) occurs at x_{inner} and in extreme cases at x_{min}. Hence,

$$\left.\begin{array}{l}\frac{1}{sx_{inner}} = 0.0105 \\ \frac{1}{sx_{min}} = 0.0111\end{array}\right\} \text{7in records, 45 rev/min}$$

$$\left.\begin{array}{l}\frac{1}{sx_{inner}} = 0.0114 \\ \frac{1}{sx_{min}} = 0.0120\end{array}\right\} \text{10 and 12in records, } 33\tfrac{1}{3} \text{ rev/min}$$

The maximum value for $1/sx$ is therefore slightly less for 7in records at 45 rev/min than for long-playing records.

Effect of errors in mounting

Figs. 8 and 9 give the tracking error per unit length (ϕ/x) for typical values of l, 10in using design 1A and 5in using design 2. Also plotted are the tracking errors for a pickup arm mounted imperfectly so that the values of θ_D and f are not as recommended. From Fig. 8 it is evident that an error in f of ± 0.1in or an error in θ_D of $\pm 2°$ will more than double the maximum distortion due to tracking error for long-playing records. The tracking error at a given value of x varies fairly linearly with changes in θ_D and f so that the error corresponding to θ_D, $f + 0.05$in for example, is given by the value lying mid-way between the lines (θ_D, f) and (θ_D, $f + 0.1$in.) The changes in tracking error due to variations in θ_D and f are additive so that the error per unit length corresponding to $\theta_D - 0.5°$, $f - 0.05$in is given by a line lying mid-way between the lines $\theta_D - 1°$, f and θ_D, $f - 0.1$in. These changes also apply to designs 1B and 1C (and intermediate designs). Fig. 7 should be consulted as this gives the maximum distortion of a signal of 10 cm/sec recorded velocity, for a pickup arm mounted as suggested, and the values of x at which it occurs. It is fairly clear from Fig. 8 that too large an overhang, f, or too small an offset angle, θ_D, will have a considerable effect on the distortion at the inner grooves of 7in discs. An increase in f of 0.1in will increase the maximum harmonic distortion by almost 2% at a radius of 2in.

For a record player restricted to 7in discs, the maximum distortion need not exceed 0.3% which is negligible. An error in f of 0.03in or an error in θ_D of 0.5° will more than double the maximum distortion as shown in Fig. 9.

When constructing and mounting a pickup arm, it is therefore clear that unless the values for the offset angle and overhang are very closely adhered to, the distortion introduced is liable to be as great as the maximum value of distortion given in the design.

Mounting procedure

In view of the considerable effect of errors in mounting pickup arms, two alternative methods of mounting are suggested for which an alignment protractor is required.

For a given design, the values of x at which the tracking error is zero are fixed and independent of the arm length.

(*a*) *Optimum mounting* (*design* 1B)

The distance of the pickup arm pivot from the turntable centre should be fairly accurately measured and the pickup mounted in such a manner that about 1/20in movement towards and away from the turntable centre is possible. Small slots should replace the normal mounting holes. Similarly, the offset angle which is initially adjusted as closely as possible to the design value should be

(*Continued on page 317*)

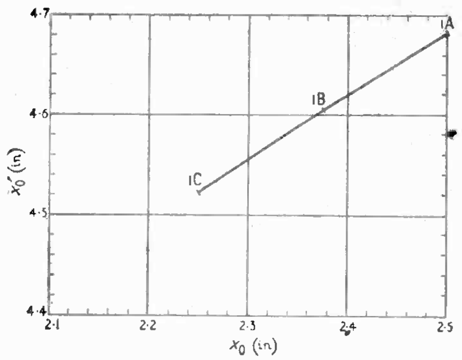


Fig. 10. Values of x at which tracking error is zero. As an aid to mounting for a design between 1A and 1C, values of x are given at which the tracking error is zero. A point one-third of the distance between 1A and 1B in Fig. 6, for example, corresponds to a point one-third of the distance between 1A and 1B in this Fig. Tracking error is zero at x_0 and x'_0.

variable by about 1°. If the head is mounted to the arm with two nuts and bolts, then one of the holes need only be made fractionally wider. Unless the fit is very close, such a movement may already be possible. Clearly it is best to check the mounting as given below before widening any holes. Values of x are given to three decimal places for the benefit of precision engineers. Using an alignment protractor and a metal rule, the average constructor should be able to measure x to 1/50in without undue difficulty.

(*i*) Set x to 2.375in and adjust the overhang by moving the pickup arm pivot towards or away from the turntable centre, until the tracking error is zero.

(*ii*) Set x to 4.606in (4.6in) and observe whether the tracking error is positive or negative. If it is uncertain which is which, set x to $5\frac{1}{2}$in and the indicated tracking error is positive.

(*iii*) If the tracking error at x = 4.606in is positive, then both the offset and overhang are too small: the offset angle should be increased slightly. Similarly, if the tracking error is negative, then both the offset and overhang are too large: the offset angle should be decreased slightly.

The steps (*i*) to (*iii*) are then repeated until the tracking errors at both values of x are negligible (less than $\frac{1}{4}$°).

(*b*) *Alternative mounting* (*design between* 1A *and* 1C)

Although 1B is considered by the writer to be the best design, any design between 1A and 1C may be considered as good and will be optimum insofar as no other method of mounting can result in lower distortion (as a result of lateral tracking error) from *both* long-playing and 45 rev/min records. As seen from Fig. 7, design 1A favours long-playing records and design 1C favours 45 rev/min 7in discs.

It may not be considered possible, or it may be felt undesirable, to alter the offset angle, particularly if different pickups are used in the same arm. In this case, provided that the offset angle for a given value of l is within the range of values in Fig. 6, the following method should be used.

(*i*) Set x to 2.375in (x_o for design 1B), and adjust the overhang until the tracking error is zero.

(*ii*) Set x to 4.606in (x_o' for design 1B), and observe whether the tracking error is positive or negative.

(*iii*) If positive, then both the offset and overhang are too small for this design: move towards 1C which requires a smaller offset angle and overhang. If negative, move towards 1A.

(*iv*) To move towards 1C, x is set to a smaller value of x_o and f is reduced until $\phi = 0$. From Fig. 10, the value of x_o' corresponding to the new x_o is obtained. x is then set to the new x_o' (smaller than before) and the tracking error observed. To move towards 1A, a larger value for x_o is chosen and ϕ set to zero as before. The new x_o' is given from Fig. 10 and the tracking error observed.

(*v*) Return to stage (*iii*) and repeat until the tracking error at x_o' is negligible (less than $\frac{1}{4}$°).

If θ_D for a commercial pickup arm is greater than the 1A value, it has most likely been designed for minimum tracking error. The mounting can be improved by using a value of f slightly smaller than the manufacturer's suggested value so as to reduce the large positive tracking error at the inner grooves. An alignment protractor should be used and ϕ/x at $x = 2\frac{1}{8}$in reduced until equal in magnitude to the largest negative value of ϕ/x which will occur between $2\frac{1}{2}$in and 4in.* If θ_D is less than the 1C value, allowance has probably not been made for the faster turntable speed of 7in discs in which case, provided that θ_D is less than $\frac{1}{2}$° from the 1C value, Fig. 10 may be used with the line slightly extended. Otherwise ϕ/x at $x = 2\frac{1}{8}$in (ϕ/2.125) should be adjusted until equal to the value at $5\frac{7}{10}$in (ϕ/5.7). Both should then be greater than the maximum value occurring between $2\frac{1}{2}$in and 4in.†

Therefore, if a commercial pickup arm is to be mounted and the recommended methods given earlier are not used, ϕ/x at $x = 2\frac{1}{8}$in should be adjusted (by varying f) to equal the other maximum value between $2\frac{1}{8}$in and $5\frac{7}{10}$in. This will occur between $2\frac{1}{2}$in and 4in if θ_D is too large and at $5\frac{7}{10}$in if θ_D is too small.

Shape of pickup arm

Fig. 11a gives the shape of a conventional pickup arm. In order to reduce friction, the most suitable method of mounting is a single pivot (unipivot). A line joining the pivot and stylus tip should be horizontal otherwise the pickup cannot move vertically upwards when tracking a warped record. The centre of gravity of the assembly must lie below this line for stability and directly beneath it with the pickup untilted.

A means of lateral adjustment is usually provided and, in general, this consists of a device clamped to the arm at the pivot, being movable in the direction AA′ so as to apply a moment to the arm to remove any tilt. If a larger tracking mass is required, the counterbalance, or part of it, is moved towards the pivot. This decreases the anti-clockwise moment due to this counterbalance as seen from B, and a pickup which was previously correctly adjusted will tilt slightly in a clockwise direction causing a stylus tip to press on the inner wall of a record groove.

A suggested shape for a pickup arm is given in Fig. 11b. With the centre of gravity always lying along the length of the arm, lateral adjustment is no longer necessary when altering the tracking mass. Also, the pickup arm is slightly shorter for a given value of l, and will therefore be lighter.

A further advantage is that the lateral adjustment at

*Remember that the largest negative value of ϕ occurs at x_m and the largest negative value of ϕ/x at x_p, where x_m is just over $\frac{1}{8}$in greater than x_p. The difference in ϕ/x is very small (as seen from Fig. 8) in which case we may disregard x_p and divide the largest negative tracking error by the value of x at which it occurs (x_m).

†Note that if the largest value of ϕ/x between $2\frac{1}{2}$in and 4in is equal to the values of ϕ/x at $2\frac{1}{8}$in and $5\frac{7}{10}$in, the design will be optimum and lie about $\frac{1}{4}$ of the way between designs 1B and 1C (as seen from Fig. 7 with $x_3 = 2\frac{1}{8}$in).

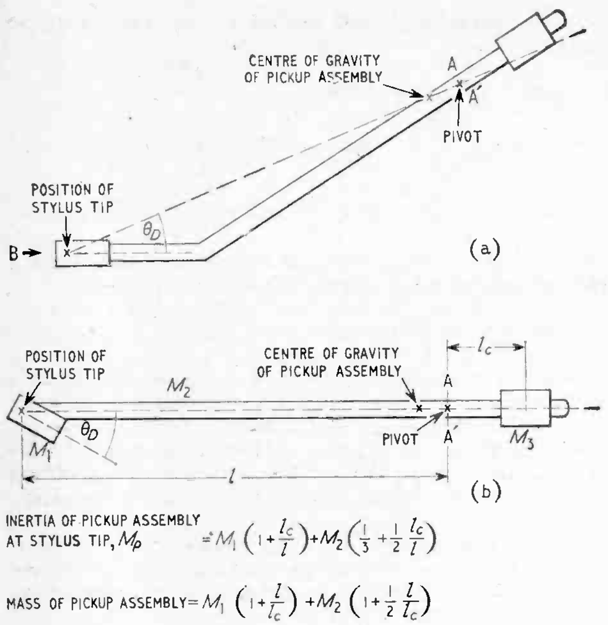


Fig. 11. (a) Shape of conventional pickup arm. (b) Preferred shape of pickup arm.

AA′, which is necessary to compensate for the offset of the pickup (unless the stylus tip is central), is much less than that for a conventional arm.

Compensation should be made for side-thrust, the clockwise moment which a moving record applies to a stylus. A practical explanation of this effect and how to reduce it has been given by J. Crabbe in one of a series of articles on pickups.[2]

Inertia of pickup assembly

A pickup arm should be constructed so that its inertia or effective mass at the stylus tip is as small as possible.† The inertia of the pickup assembly at the stylus tip is given by the moment of inertia of the pickup arm and counterbalance about the axis of rotation (the arm pivot) divided by the square of the effective arm length i.e.

$$M_p l^2 = M_1 l^2 + M_3 l_c^2 + \tfrac{1}{3} M_2 l^2$$

as given in Fig. 11b where M_p, M_1, M_2, and M_3 denote the inertia of the pickup assembly and masses of the pickup (including the mounting shell), arm, and counterbalance, respectively. The mass of the arm is considered to be evenly distributed along the length and, for simplicity, M_3 is assumed to be concentrated at its centre of gravity, and M_1 concentrated at the stylus tip. Taking moments about the pivot with the pickup balanced,

$$M_1 l + \tfrac{1}{2} M_2 l = M_3 l_c$$

Hence, the mass of the counterbalance is given by

$$M_3 = (M_1 + \tfrac{1}{2} M_2) l / l_c$$

and the inertia is as follows

$$M_p = M_1(1 + l_c/l) + M_2(\tfrac{1}{3} + \tfrac{1}{2} l_c/l)$$

M_1 is reduced as much as possible by manufacturers, and constructors should ensure that the pickup arm is as light as possible. The inertia of the assembly may be further reduced by using a heavier counterbalance nearer the pivot to reduce l_c. However, the mass of the pickup assembly is given by

$$M_1 + M_2 + M_3 = M_1\left(1 + \frac{l}{l_c}\right) + M_2\left(1 + \frac{1}{2}\frac{l}{l_c}\right)$$

and M_3 should not be too great otherwise unnecessary friction and wear are liable to occur in the pivot bearings.

Tracking mass for optimum reproduction with minimum record wear

The tracking mass, M_t, must be sufficient for the stylus to remain permanently in contact with the groove walls. At low frequencies we require the compliance of the stylus suspension, in particular the lateral compliance, C_l, to be as large as possible to enable the stylus to cope with modulations of large amplitude. At high frequencies we require the effective tip mass, M_{etm} (the inertia of the stylus and elastic support at the stylus tip) to be as small as possible so that the force on the stylus resulting from the considerable accelerations is much less than that due to the tracking mass. Also, we require the inertia of the pickup assembly, M_p, to be as small as possible so that forces on the stylus caused by tracking warped records are reduced to a minimum.*

To enable the stylus to follow the most difficult modulations, it is suggested that the following should be satisfied

$$M_t \geqslant M'_t$$

where

$$M'_t = \frac{5}{10^6 C_l} + 1000 M_{etm} + \frac{M_p}{40} \quad .. \quad .. \quad 10$$

M is given in gm and C in cm/dyne, e.g. if the compliance is 15.10^{-6}cm/dyne the effective tip mass $\frac{1}{3}$ mg, and the inertia of the pickup assembly $13\frac{1}{3}$ gm, the minimum tracking mass is 1 gm.

If the tracking mass is smaller than M'_t, then for heavily modulated grooves the contact between the stylus and the groove walls is liable to be intermittent, damaging the walls in addition to increasing the noise content of the resulting signal.

Usually the vertical compliance, C_v, need not be considered, for although the value may be as low as half the lateral compliance, the vertical groove modulation only results from the difference (in amplitude and phase) between the two stereophonic signals: such a modulation seldom exceeds half the lateral modulation especially at low frequencies where the phase differences are normally very small. However, if for a stereophonic pickup $C_v < \frac{1}{2}C_l$, $2C_v$ should replace C_l in equation 10. Even a monophonic pickup requires a vertical compliance to track the modulation resulting from the pinch effect. The second harmonic vertical modulation due to a spherical stylus tracking a laterally cut groove is likely to reach 20%. In this case we require $C_v > 1/5C_l$ for a monophonic pickup, otherwise $5C_v$ should replace C_l in equation 10.

Unfortunately, the maximum lateral displacement of the stylus occurs at the same instant as a maximum vertical displacement due to the pinch effect. As a result, it appears preferable for $5/10^6C_l$ in equation 10 to be replaced by

$$\frac{5}{10^6 C_l}\left(1 + \frac{C_p^2}{25 C_v^2}\right)^{\frac{1}{2}}.$$

However, the difference is usually very small except for

[2] J. Crabbe, *Hi-Fi News*, April 1963, p. 797-800.
† See equation 10 and Appendix III.

* Normally, a faster groove speed is an advantage: this is one of the rare instances where the converse is true.

monophonic pickups from a designer who has disregarded vertical compliance.

Equation 10 is obtained from the following

$$M'_t g = \frac{z}{C_l} + M_{etm} a_s + M_p a_a \quad .. \quad 11$$

where z, a_s, and a_a denote the maximum displacement of the stylus, the maximum acceleration of the stylus tip, and the maximum acceleration of the arm, respectively. Representative values[3] are $z = 0.005$ cm, $a_s = 1000g$ $a_a = 0.025g$, where $g = 980$ cm/sec^2.

Clearly, the downward force due to the stylus mass should be greater than the sum of these three forces which try to prevent the stylus remaining in perfect contact with the groove walls. The forces resulting from resistive damping are by comparison very small for modern arms and have not been included: this is permissible as we have considered the worst possible case, although it is most unlikely that all these forces will be maximum at the same time. Equation 11 is based on three equations given by Professor F. V. Hunt[3] who divided the downward force into three equal parts, requiring each to equal or exceed the three individual forces on the right of equation 11 (with the force due to arm damping added to $M_p a_a$). This constraint, although useful for determining suitable design targets, is unnecessary. Note that side-thrust can amount to as much as 20% of the downward pressure so that the maximum lateral deflection due to side-thrust, z_l is given by $z_l = 1/5\ M_t g\ C_l$. Hence, if the lateral compliance of the stylus suspension is very large in relation to the effective tip mass, compensation for side-thrust is especially important to avoid large stylus deflections.

An important point to consider is that a stylus cannot track frequencies above the stylus-groove resonant frequency, f_{rg} where

$$f_{rg} = \frac{1}{2\pi\sqrt{M_{etm} C_g}}$$

C_g, the compliance of the groove material, is given by

$$C_g = \frac{0.00406}{r^{1/3} M^{1/3}}$$

where r is the radius of the stylus tip (in): a value of $3.76.\ 10^{10}$ dynes/cm^2 has been used for the plane-stress elastic modulus of the vinylite record material. It is necessary for the stylus to be able to track the highest frequencies which occur on a record otherwise the record will be permanently damaged. With an upper audio limit of 15 kc/s, f_{rg} must not be less than 30 kc/s, the second harmonic of a lateral signal of 15 kc/s; 30 kc/s occurs as a vertical pinch effect modulation. Hence, $M_{etm} \leqslant 0.00693 r^{1/3} M^{1/3}$. To track at 3 gm with stylii of 0.001in, 0.0007in and 0.0005in, the effective tip mass must not exceed 1.00, 0.89 and 0.79 mg, respectively: tracking at 1 gm, these values become 0.69, 0.62 and 0.55 mg.

The stylus-groove resonance is usually sufficiently excited to introduce audio noise by intermodulation. Scanning loss, the high frequency loss due to the finite size of the stylus in relation to the groove modulations, will prevent this excitation if f_{rg} is sufficiently large. The condition which must be satisfied is $M_{etm} \leqslant 0.197 r M_t$ Hence, to track at 3 gm or 1 gm with stylii of 0.001in, 0.0007in, and 0.0005in, the effective tip mass for a 'low noise' signal must not exceed 0.59, 0.41, 0.30 mg, and 0.20, 0.14, and 0.10 mg, respectively.

[3]F. V. Hunt, *J.A.E.S.*, October 1962, p. 274-289.

To summarise, M_t should satisfy the following conditions:—

$$M_t \geqslant \frac{5}{10^6 C_l} + 1000\ M_{etm} + \frac{Mp}{40}$$

$$M_t \geqslant \frac{k}{10^6 C_v} + 1000\ M_{etm} + \frac{Mp}{40}$$

$$M_t \geqslant \frac{3.10^6\ M^3{}_{etm}}{r}$$

where $k = 2.5$ for a stereophonic pickup and 1 for a monophonic pickup. Also, for a low noise signal,

$$M_t \geqslant \frac{5.1\ M_{etm}}{r}$$

If the above conditions allow, M_t should be set to a value within the range 1-3 gm if $r = 0.0005$in or 1-4 gm if $r \geqslant 0.0007$ in. With M_t less than 1 gm, dust in record grooves becomes a tracking problem: if greater than the upper limit, record wear will occur as a result of the groove deformations no longer being within the elastic limit or the record material.

Much useful advice on pickups is given in a recent book by J. Walton[4] who stresses the importance of a low effective tip mass, the most important consideration when choosing a pickup.

To conclude, there is no practical advantage in a properly mounted pickup arm being longer than 9in or 10in. A 12in arm as well as being heavier usually has a larger inertia at the stylus tip: it also requires more space for mounting. The importance of mounting accurately is usually underestimated. The distortion from a pickup with a 12in arm and an error in mounting of $\pm 1/20$in is greater than the distortion from a correctly mounted 9in pickup. In view of this, an alignment protractor should be considered as essential when mounting a pickup.

APPENDIX I

According to E. R. Madsen[5], intermodulation in a lateral cutting appears as modulation of the even harmonics, and in a vertical cutting as modulation of the odd harmonics. The percentage distortion, E_{im}, due to an incorrect vertical tracking error is given by

$$\epsilon_{im} = 100 \left[\sqrt{\frac{\cos\ (\alpha - \phi)}{\cos\ (\alpha + \phi)}} - \sqrt{\frac{\cos\ (\alpha + \phi)}{\cos\ (\alpha - \phi)}} \right]$$

$$\text{where } \tan\ \alpha = \frac{\sqrt{2}\ V_{rms}}{u} = 5{\cdot}32\ \frac{V_{rms}}{xs}$$

Therefore, when as in our case $\phi < 5°$, this expression for distortion may be reduced to

$$\epsilon_{im} = 200 \sin\ \phi \tan\ \alpha \approx 200 \left(\frac{\pi}{180}\ \phi\right) \tan\ \alpha = 18{\cdot}6\ \frac{V_{rms}\phi}{xs}$$

Note that the distortion is proportional to ϕ/x. Distortion due to lateral tracking error is similarly proportional to ϕ/x.

If an elliptical stylus is used, lateral tracking error will cause the stylus to sink slightly further into an unmodulated groove. It can be shown[6] that

$$p = \frac{2a\left(1 - \frac{b^2}{a^2}\right)\sin\ \phi}{\left(1 + \frac{b^2}{a^2}\tan^2\phi\right)^{\frac{1}{2}}} \approx 2a\left(1 - \frac{b^2}{a^2}\right)\sin\ \phi \approx \frac{\pi\left(a - \frac{b^2}{a}\right)}{90} \cdot \phi$$

where a and b denote the major and minor radii, respectively,

[4]J. Walton, "Pickups—The key to Hi-Fi" (Pitman).
[5]E. R. Madsen *Audio*, November 1962, p. 21-24.
[6]Private communication to C. Dineen, July 1965.

of the horizontal cross-section through the points of contact with the groove walls, and p the distance in the direction of record motion between these points of contact. The distortion, peculiar to elliptical styli, due to the points of contact not being perpendicular to the groove walls, depends on the time difference, t, i.e. the time taken for the groove to move a distance p.

$$t = \frac{p}{2\pi x} \cdot \frac{60}{s} = \frac{1}{3}\left(a - \frac{b^2}{a}\right) \cdot \frac{\phi}{xs}$$

where a, b, and p are in inches and t in seconds. The distortion depends on ϕ/x and may be reduced by reducing this quantity.

When tracking with styli of both circular and elliptical cross section, it is therefore evident that the maximum distortion due to tracking error is least when ϕ/x is a minimum, as in the given designs.

APPENDIX II

An examination of pickup arm manufacturers' recommended values of offset angle and overhang reveals considerable discrepancies. Some manufacturers have clearly determined these values on a trial and error basis: others have minimised the angular tracking error forgetting (or not knowing) that the distortion resulting from tracking error is inversely proportional to the distance from the turntable centre. The most suitable values appear to have been obtained from a graph by Bauer[7] who (using our notation) derived the following formulae.

$$\phi = \frac{57{\cdot}3\, x_3\left(1 + \frac{x_3}{x_2}\right)}{l\left[\frac{1}{4}\left(1 + \frac{x_3}{x_2}\right)^2 + \frac{x_3}{x_2}\right]}$$

$$f = \frac{x_3^{\,2}}{l\left[\frac{1}{4}\left(1 + \frac{x_3}{x_2}\right)^2 + \frac{x_3}{x_2}\right]}$$

Bauer set x_2 and x_3 to the radii of the inner and outer grooves, and therefore x is maximum at the extreme limits of the stylus movement. Bauer's values are $x_2 = 5.75$in, $x_3 = 1.75$in.

Although suitable at the time, x_3 is too small for a modern record player. The tracking error which changes from positive to negative and back to position between x_2 and x_3 is still negative when $x = 2$in. Replacing these constants with the values used in the present design 1C ($x_2 = 5.719$in, $x_3 = 2.038$in) reduces the maximum distortion due to lateral tracking error of a given modulation by 16% for an 8in pickup and 18% for a 10in pickup. However, unlike the present designs, the maximum negative of x is less than the values x_2 and x_3. If our design 1C is used, the improvements become 29% and 27%, respectively. Bauer made two approximations: in an expression for $\sin\theta$, $2l-f$ is replaced by $2l$, and $\sin\theta$ itself is replaced by $\pi\theta/180$. These approximations have not been used in the present analysis which, as a result, is more extensive. The reduction in distortion is fairly small and it may not be considered worthwhile to modify an existing pickup arm. However, if a new arm is being designed, values of offset angle and overhang have to be chosen, and as no extra work is involved in using the values given here in preference to Bauer's, it would be foolish to disregard these improved values on the grounds that the reduction in distortion is very small. It is a step in the right direction although two or three such steps may have to be made before the improvement is audible.

APPENDIX III

The movement of a stylus relative to a pickup produces the required electrical signals. If the stylus moves very slowly from side to side (or up and down), the pickup will follow these movements and result in a negligible signal. Maximum signal is obtained at the transition frequency f_{ar}, the frequency of 'arm resonance' given by:—

$$f_{ar} = \frac{1}{2\pi\sqrt{M_p C}}$$

where M_p is the inertia of the pickup assembly and C the compliance (or inverse stiffness) of the stylus suspension.

We require the lateral arm resonant frequency to be greater than 1 c/s so that the effect of the stylus moving towards and away from the turntable centre as a result of eccentric record-mounting holes is negligible. Similarly, for stereophonic pickups we require the vertical arm resonant frequency to be greater than about 10 c/s so that signals are not obtained from ripples and warps. Although sub-audio, these signals are liable to overload the amplifier. Both resonant frequencies should be less than 20 c/s to permit a flat frequency response down to 30 c/s.

The optimum vertical resonant frequency is about 15 c/s. A stereophonic pickup with a vertical compliance of 5.10^{-6} cm/dyne restricts the inertia of the pickup assembly to the range 13 to 51 gm corresponding to resonant frequencies of 20 and 10 c/s respectively (an easy requirement). However, many modern pickups have a compliance of 10.10^{-6} cm/dyne corresponding to an inertia of 6 to 25 gm and some pickups require an even smaller inertia. Since the pickup is liable to weigh about 10 gm, it is evident that the effective mass of a present-day arm (and counterbalance) as seen at the stylus tip should be as small as possible; this is also suggested by equation 10.

The lateral compliance is usually equal or up to twice as large as the vertical compliance so that the lateral resonance occurs at the same or a slightly lower frequency than the vertical resonance. Since the lower limit for lateral resonance is 1 c/s, it is clear that if the frequency of vertical resonance is suitably fixed, the lateral resonant frequency requirement is automatically satisfied. In these circumstances, only a small amount of damping is necessary. Any additional damping required should be associated with the arm pivot and not the stylus suspension and preferably of a viscous type.

If a pickup which has been lowered until the stylus just touches a record is released, it will sink slightly lower at the same time compressing the stylus suspension. The compliance is a measure of the 'springiness' of this suspension and denotes the distance relative to a stationary pickup that the stylus will move as a result of a given force acting on it. A larger compliance implies that the stylus can move more easily relative to the pickup, and therefore the force on the stylus tip due to a groove modulation is smaller. Hence the minimum tracking mass is smaller. The stylus is driven by the groove laterally and upwards and relies on the vertical compliance of the stylus suspension and gravity for downward movement; vertical compliance above the vertical arm resonant frequency and gravity below this frequency. The downward force resulting from the tracking mass becomes the force on the effective tip mass due to the vertical compliance of the stylus suspension acting as a spring. Therefore, the smaller the effective tip mass, the smaller the force required by the stylus to follow a high frequency modulation requiring a large acceleration. Hence the minimum tracking mass is smaller.

Correction:—We regret the error which occurred on p.216 of the May issue. The 20th line from the bottom of the second column should start with $\sin\theta_p \approx$ and not $\sin\theta_p n$. In the caption to Fig. 4 $x_2 < x < x_0$ was used, but the caption should have conveyed "as x varies from x_2 to x_0 . . . . ." On the left hand side of the first equation on p.217 (second column), θ_D should have read θ_0. But since θ_0, which corresponds to x_0, is equal to θ_D the design value, θ_0 may be taken as θ_D.

[7] B. B. Bauer *Electronics*, March 1945, p. 110-115, and quoted by "Sound Recording and Reproduction", J. W. Godfrey and S. W. Amos (Iliffe) and "Disc Recording and Reproduction", P. J. Guy (Focal).

The Root-locus Technique

1—INTRODUCTION

By W. TUSTING

The root-locus technique is a largely graphical method which enables the stability conditions of a feedback amplifier or closed-loop control system to be determined rather easily. Its great merit is that it enables an approximate solution to be found quickly and easily. This series of articles explains how to use the technique and in this first article the preliminary concepts are discussed.

THE designer of any feedback system is faced with the problem of predicting whether or not a proposed system will be stable. If, as often happens, it turns out that it will not be stable, he has the further problem of finding out what to do about it. The system with which he is concerned may be an electronic amplifier or it may be an automatic control mechanism, which may not embody electronics at all, but the basic problems and the methods of solving them are the same.

The deliberate controlled use of negative feedback in electronics started something like 40 years ago when it was used to improve the performance of valve amplifiers in telecommunications. It is still very widely used in electronic amplifiers and in this field it is still called by that name. It is just as widely used in automatic control, in closed-loop control systems, and here the mechanical applications of the principle go right back to the 17th century. In both cases the purpose is the same: to make the output of a system or device follow the input as closely as possible.

There exists an enormous amount of literature on negative feedback and a great deal of it is concerned with the problem of achieving stability. This is a good indication that the problem is a difficult one. There are, too, a considerable number of different ways of tackling the problem.

Whether one does so consciously or not, the prediction of stability involves expressing the gain of the proposed system in the form of an equation. This is usually quite easy. It is then necessary to find out whether the equation satisfies certain stability criteria. This is the difficult part in all but the simplest cases and the difficulties are entirely mathematical ones. All the different methods that exist are basically different mathematical ways of solving the problem.

The root-locus method is comparatively recent and its use is largely confined to the control field, although it is equally applicable to any other feedback problem. Its use is explained in many books on control but most explanations suffer from being either too terse or too complex for the beginner. Often the " explanations " are comprehensible only when one has gained some familiarity with the method.

The purpose of these articles is to explain how to use the method and as far as possible this will be done in a succession of steps which form a kind of drill. As with most of the other available methods, the root-locus technique is limited to linear circuits.

Feedback amplifier.—Fig. 1 shows the block diagram of a feedback amplifier. It comprises an amplifier of voltage gain A and a feedback path of voltage gain β. Usually $A \gg 1$ and $\beta \ll 1$, but there are cases where $\beta = 1$ and then A is rarely very large. The product $A\beta$ is quite often of the order 10–30. It is commonly called the open-loop gain.

From Fig. 1 $A = V_0/V_i$. The amplification of the feedback amplifier as a whole is $A_f = V_0/V'_i$. Now

$$V'_i = V_i + \beta V_0 = V_i(1 + A\beta)$$

consequently

$$A_f = A/(1 + A\beta)$$

and $A_f =$ is the closed-loop gain.

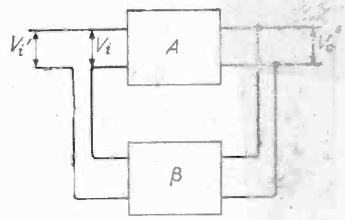


Fig. 1. Block diagram of feedback amplifier.

Temperature control.—Now consider a control problem. Suppose that we have a room which we desire to keep at a temperature θ_r and we have in it a heater delivering heat power P. The outdoor temperature is θ_0 and the room loses heat through the thermal resistance R of its walls. In the steady state the heat lost equals the heat supplied and so

$$P = \frac{\theta_r - \theta_0}{R}$$

If we measure P in watts and temperature in °F, thermal resistance is in °F/watt.

The control problem is so to vary P that θ_r stays constant, or nearly so, despite changes of θ_0. The first step is to derive a control signal proportional to θ_r. We use a set of elements, which we need not now specify, which produces a d.c. output signal of voltage $V_r = k_1\theta_r$, where k_1 is a constant. We compare this with a reference voltage $V_s = k_2\theta_s$, where θ_s is called the set value of the room temperature. For example, if we want the room temperature θ_r to be 70 °F we turn a control on the apparatus so that its calibrated scale reads 70 °F; we set the apparatus to produce this temperature. It may not in fact do so, which is why we must distinguish between θ_r and θ_s. A block schematic of the control system is shown in Fig. 2.

By comparing V_r and V_s we form an error signal

$$\epsilon = V_s - V_r = k_2\theta_s - k_1\theta_r$$

Under some given mean conditions, say, $\theta_r = 70$ °F,

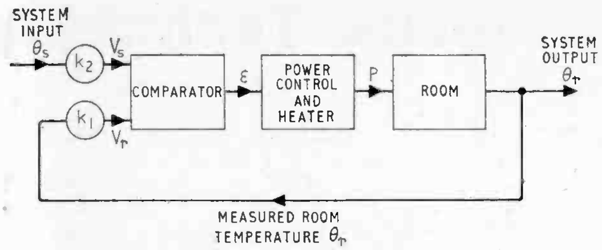


Fig. 2. Block diagram of temperature control system, for comparison with feedback amplifier in Fig. 1.

$\theta_0 = 40$ °F, a certain power P_0 is supplied. Under these conditions, $\theta_s = 70$ °F and $\epsilon = 0$, and if $k_1 = k_2 = k$, $P_0 = (70-40)/R = 30/R$. To cope with other conditions we arrange for the error signal to control the power supplied to the room so that

$$P = P_0 + K\epsilon$$

Combining these equations

$$\frac{\theta_r - \theta_0}{R} = P_0 + Kk\,(\theta_s - \theta_r) = \frac{30}{R} + Kk\,(\theta_s - \theta_r)$$

or $\quad \theta_r - \theta_0 = 3\theta + KkR\,(\theta_s - \theta_r)$

and so $\theta_r = \dfrac{30 + \theta_0 + kKR\;\theta_s}{1 + KkR}$

or $\quad \theta_r - \theta_s = \dfrac{30 + \theta_0 - \theta_s}{1 + KkR}$

Quite clearly whatever the values of θ_0 and θ_s, the difference between θ_r and θ_s can be made as small as we like by making KkR large enough. Of course, this presupposes the availability of unlimited power for heating the room, but that is inherent in the assumption of a linear system. Even with limited power, conditions will be the same but for a limited range of θ_0 and θ_s.

The point of importance is the similarity of the equation with that for the closed-loop gain of an amplifier. The term $1 + KkR$ of the one is analogous to the $1 + A\beta$ of the other.

Symbols.—Instead of the $A\beta$ symbolism usual for amplifiers a GH symbolism is common in control theory. Thus $1 + A\beta$ of the one is the same as $1 + GH$ of the other, with $G = A$, $H = \beta$. We shall here adopt the GH symbolism because it is the one most used in expositions of the root-locus technique. Its use here thus facilitates comparisons with the literature.

To use the root-locus technique it is necessary to write the expression for the open-loop gain GH in terms of the Laplace transform or Heaviside operator. It does not matter which is used, for the result will be exactly the same. Some people use the symbol s for the Laplace operator and p for the Heaviside and this is helpful as an indication of which system is being used. Here we shall use p.

No knowledge at all of these operational systems is needed for the root-locus method. All that is necessary is that the equations should be written in terms of p. All this means is that the " reactance " of an inductance is written as pL instead of $j\omega L$ and of a capacitance as $1/pC$ instead of $1/j\omega C$. Indeed, any steady-state equation written in terms of $j\omega$ can be translated into the proper forms merely by making the substitution $\omega = p/j$.

Also an equation written as a differential equation can be put into p form just as easily, since $p = d/dt$, $p^2 = d^2/dt^2$, $p^n = d^n/dt^n$ and $1/p = \int_0^t \ldots dt$.

When the equation for GH has been obtained it will be found that it is always in the form of a constant multiplied by the ratio of two polynomials in p. It is necessary that both numerator and denominator be factored into the products of simple factors. In some cases this factorization may be difficult, but in most cases the equations turn out automatically in factors and there is no difficulty at all.

An ordinary valve amplifier stage has a coupling resistance R with shunt capacitance C. With a valve of mutual conductance g_m, the stage gain is $A = g_m R/(1 + j\omega CR)$, as is well known.

Writing $G_0 = g_m R$, $T = CR$ and $\omega = p/j$ we have

$$A = G = \frac{G_0}{1 + pT}$$

For the root-locus technique it is necessary that the coefficient of p should be unity. We thus divide numerator and denominator by T and so get

$$G = G_0 K \frac{1}{p + 1/T}$$

with $K = 1/T$. This is the proper form for the root-locus technique and all equations must be brought into it.

For a three-stage RC amplifier having different time constants in each stage we should clearly have

$$1 = GH = 1 + G_0 H_0 K \frac{1}{(p + 1/T_1)\;(p + 1/T_2)\;(p + 1/T_3)}$$

where $K = 1/T_1 T_2 T_3$.

The critical condition for stability is $0 = 1 + GH$. The system is stable if $|GH| < 1$ even if it is negative but is unstable if $|GH| > 1$ and is negative. To determine the critical condition it is necessary in some way to solve the equation $0 = 1 + GH$. This means finding its roots. For stability it is necessary that all the roots should have negative real parts. The critical condition occurs when the real parts of one pair of complex conjugate roots become zero; that is, when there is a pair of imaginary roots.

This may sound rather complicated. In fact, the only difficulty is the mathematical one of finding the roots of an equation. In the case of the above expression for a three-stage RC amplifier a general algebraic solution is easy. For more complicated expressions the difficulties grow rapidly. The root-locus technique enables solutions to be obtained by a graphical method.

There are three terms in constant use, the meanings of which must be clearly understood. These terms are root, pole and zero. Bearing in mind that in general GH stands for a fraction which may have terms in p in both its numerator and denominator, a *root* is a value of p which makes $1 + GH = 0$, a *pole* is a value of p which makes the denominator of GH equal to zero, and a *zero* is a value of p which makes the numerator of GH equal to zero. Poles and zeros are thus respectively the roots of the denominator and numerator of GH, but in the root-locus technique the word " root " is in the main reserved for the special values of p which make $1 + GH$ equal to zero.

As an example, suppose

$$GH = G_0 H_0 \frac{p + 2}{(p+3)\;(p+4)} \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

then there is one zero, $p = -2$, and there are two poles, $p = -3$ and $p = -4$. The roots of $1 + GH = 0$ can easily be found algebraically in this instance. Multiplying out we get

$$p^2 + p\,(7 + G_0 H_0) + 12 + 2G_0 H_0 = 0$$

whence

$$p=\frac{-(7+G_0H_0)\ \pm\ \sqrt{[1+6G_0H_0+G_0{}^2H_0{}^2]}}{2}$$

so that there are two roots which in this instance are always real.

As an example of the root-locus technique consider a three-stage valve amplifier at high frequencies. The relevant equation is

$$GH = G_0H_0\frac{1}{(1+pT_1)\,(1+pT_2)\,(1+pT_3)}$$

To bring it into the proper form we divide numerator and denominator by $T_1T_2T_3$ to get

$$GH=G_0H_0K\frac{1}{(p+1/T_1)\ (p+1/T_2)\ (p+1/T_3)}$$

with $K=1/T_1T_2T_3$.

We must now assign numerical values to the terms in T. Let $T_1=1$ μsec, $T_2=$ 2.5 μsec and $T_3=10$ μsec, then $K=1/25$ and

$$GH=G_0H_0K\frac{1}{(p+1)\,(p+0.4)\,(p+0{\cdot}1)}\ \ldots\ldots\ldots\ (3)$$

and since T is in microseconds, frequencies will be in megacycles per second.

In this particular example there are no zeros and there are three poles viz, -1, -0.4 and -0.1.

Before we continue and deal with the way in which a root-locus diagram is prepared, it is useful to consider the final diagram itself. Fig. 3 shows the root-locus plot for our example.

The diagram is one in what is called the complex p-plane. It is a plot of all the values of p which make $1+GH=0$; some of these values of p are real, and $p=-\rho$ say. Other values of p are complex, and $p=-\rho\pm j\omega$.

The root-locus is a plot of the roots of $1+GH$ as G_0H_0 is varied from zero to infinity.

In Fig. 2 the three poles of our example are plotted and marked by crosses. These points are also roots for $K_0G_0=0$. As K_0G_0 is increased the roots move away from the poles. One moves to the left from $p=-1$ along the real axis and tends to infinity when $K_0G_0\rightarrow\infty$.

Of the two other roots one moves to the left from $p=-0.1$ and the other to the right from $p=-0.4$.

For some particular value of K_0G_0 the two roots meet, in this case at $p=p_b$ -0.235 approximately. For a further increase of K_0G_0, these roots become complex. They move away from the real axis along the curve one upwards and the other downwards.

There is a critical condition for stability when the roots become purely imaginary. This is where the curved part of the locus crosses the $j\omega$ axis, for this is the transition from complex roots with negative real parts (stability) to complex roots with positive real parts (instability).

In our example this occurs at $p=\pm0.735$ megaradians per second. If our amplifier becomes unstable it will thus be at a frequency of $0{\cdot}735/6.28=0{\cdot}117$ Mc/s.

Now what we really do want to know is the value of G_0H_0 at this point; that is, we want to know the critical value of the open-loop gain. We can find this very easily. In our example, we measure the distance between the critical point $p=j0.735$ and each of the poles and then form the product of these distances. This is the value of G_0H_0K. The distances are 0.74, 0.835 and 1.24, so $G_0H_0K=0.775$. Now $K=1/25$ so $G_0H_0=19.4$.

One can find out other things about the amplifier. For example, suppose it is required that the transient response be non-oscillatory. This requires that there shall be no complex roots, so the critical condition is with a pair of equal real roots at $p=-0.235$. The distances to the poles from this point are $0.235-0.1=0.135$, $0.4-0.235=0.165$ and $1-0.235=0.765$. The product is 0.01435 and, dividing by K, we get $G_0H_0=0.358$. In this case the response becomes oscillatory for a very small open-loop gain.

This has been something of a digression, for we have been showing the end before the middle. Our aim has been to show how easy it is to find out important things about the amplifier from the root-locus plot. We shall now show how to produce the plot. Parts of this are easy; other parts can be tedious.

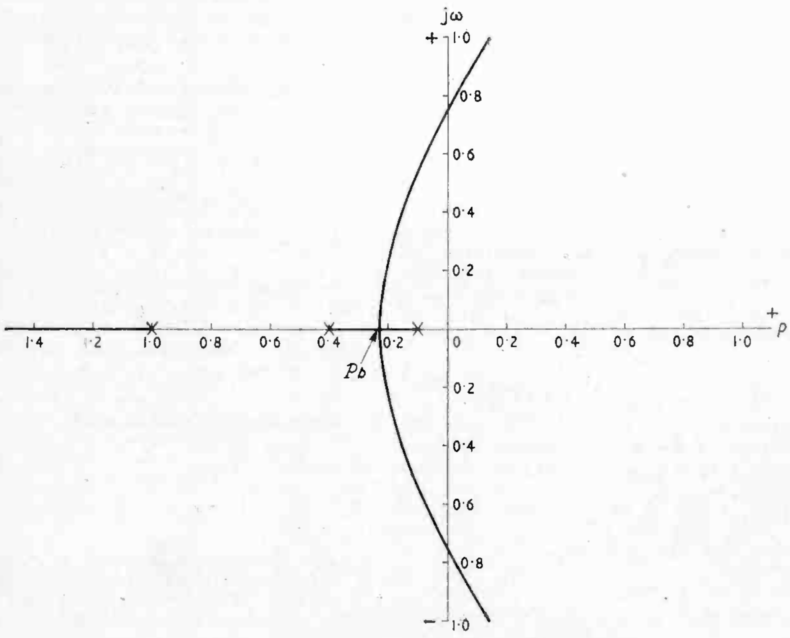


Fig. 3. Root-locus plot for a three-stage RC amplifier.

We shall necessarily have to give the whole procedure and it will seem lengthy and complicated. There is no doubt that in some cases the production of an accurate root-locus plot can be laborious. However, in most practical cases it is unnecessary to do so. If we are mainly interested in finding the critical gain for stability, for example, we need find only one point with any pretensions of accuracy. This is the one at which the locus crosses the $j\omega$ axis.

What we usually do is to draw the curved part of the locus free-hand! There are certain guides which enable us to do this and it enables us to find the crossing point within perhaps 10 or 20%. We can then explore that region and find the right point as accurately as we want. However, in the initial stages of design we usually need to know G_0H_0 only quite roughly, for it will often turn out to be a lot smaller than we want and we shall have to modify the amplifier to obtain the required stable gain.

It is the great merit of the root-locus method that it enables rough values to be determined very easily and quickly.

(To be continued)

NEWS FROM INDUSTRY

TRANSMITTERS WORTH £500,000 FOR ONGAR RADIO STATION

S.T.C. Radio Division is to supply and instal 23 high-frequency transmitters and ancillary equipment for use at the G.P.O. radio station at Ongar, Essex. [With this equipment the station will then be able to handle radio-telephone traffic.] Important features will include remote control of tuning and other functions. There will also be facilities for self-monitoring and automatic fault location and service restoration in the event of a failure.

This new system of automatic control will provide for the pre-selection of all the facilities required to work a number of services which can then be selected by a single switch for each service frequency. Facilities are provided for "dualling" during periods of frequency change.

An operator at a console in the control centre will be able to select any one of five frequencies particular to any service. He will also be able to monitor and test equipment without disturbing traffic.

QUEEN'S AWARD FOR INDUSTRY

IN 1965 the Prime Minister announced that the Duke of Edinburgh had consented to chair a committee which would draw up a scheme for awards to industry, to be made by the Sovereign for outstanding achievement either in increasing exports or in technological innovation. Recipients of the Award will be entitled to display the emblem; both the Award and the title to display the emblem expires after five years. However, an industrial concern in possession of an Award may apply for a fresh Award. The first list of recipients contains 115 names, these include British Insulated Callender's Cables Ltd., Decca Radar Ltd., Derritron Electronic Vibrators Ltd., Elliott-Automation Ltd., English Electric Co. Ltd., Garrard Engineering Ltd., General Electric Co. Ltd., Hilger & Watts Ltd., George Kent Ltd., Morganite Resistors Ltd., Multicore Sales Ltd., Pye of Cambridge Ltd., Redifon Ltd. and Smiths Industries Ltd.

The design of the emblem symbolizes Royal recognition of technological and export achievements. The crown signifies the Royal connection, the arrows symbolize exports to the four corners of the earth and the cog-wheels have been chosen as a symbol common to most industrial processes.

As a result of an order from Iraqi Airways world sales of the **Marconi Doppler Navigator** now total over £15 M. The equipment being supplied is the latest Sixty Series version AD560, a civil Doppler system that is being fitted to the Iraqi Airways fleet of new Trident aircraft.

£25M of a recently announced £102M **Saudi Arabian air defence** contract, the largest order of its kind received in Britain, is for electronic equipment. AEI Electronics, who are providing Type 40 radar control stations, have sub-contracted part (over £5M) of the £25M order to the Marconi Company for data handling, display and communications equipment. The data handling system is based on the Marconi Myriad micro-electronic computer. Among the displays provided will be a large screen presentation of the air situation shown by three-colour synthetic radar projectors.

A new company, **Devices Implants Ltd.**, has been formed to specialize in the development and manufacture of implanted electronic stimulators, that control human body functions. The new company, taking over the manufacture of the St. George's cardiac pacemaker, will be established in a newly acquired factory, with specially equipped research laboratories. Their products will be distributed by P. J. Reynolds Ltd., of Enfield, Middlesex.

The electronic timing system installed at Coventry's new £1,300,000 international standards swimming baths by **Hadley Telephone & Sound Systems Ltd.**, gives individual times in six lanes to 0.01 sec., with an accuracy of 0.01 sec. This is one of four systems being installed as the bath's communications and signalling network at a total cost of £16,000.

Solbraze Ltd. announce a change of address to Lakedale Road, London, S.E.18. Tel. PLUmstead 3428/9.

Livingston Transistor Agreement.—An agreement has been signed by which Livingston Components Ltd. of North Watford, Herts., will market exclusively in the U.K., the range of field effect, dual, n-p-n and other special types of transistors manufactured by Union Carbide of U.S.A. There will be off-the-shelf delivery of these components.

Zambia's first radio manufacturing plant is being built on the outskirts of Livingstone. The factory is expected to be completed within weeks and will be used to produce transistor radios and radiograms for the Zambian market and for export. The plant, which is costing £250,000, is owned by Supersonic Radio Zambia Ltd., a subsidiary of Standard Telephones and Cables Ltd., of London.

General Technology Corp.—Racal Instruments Ltd. are now able to offer—through their marketing agreement with Tracor Inc.—the range of frequency standards manufactured by the General Technology Corporation, of California. The marketing agreement covers all countries except the U.S.A., Canada and France.

The latest **Soviet industry** five-year plan (1966-70) calls for considerably increased outputs of certain consumer goods. The 1965 production of radio receivers and radiogramophones was 5.2M; by 1970 it is planned to be as high as 8M. Television receivers are to rise from 3.7M to 7.7M in the five years.

Cleveland Electronics Inc. has appointed T. J. Sas and Son Ltd., of Victoria House, Vernon Place, London W.C.1, as U.K. distributors for their Audio Division. The company manufacture hi-fi and p.a. equipment.

A new company, **B. & K. Instruments Ltd.**, has been formed within the B. and K. group to market electronic instruments from manufacturers located chiefly in the U.S.A. B. & K. Laboratories Ltd. will continue marketing the internationally established Bruel and Kjaer instruments from Denmark.

Australian telecommunications exports in 1964-65 amounted to £2.75M, this included £323,000 worth of radio transmitters compared with £417,000 the previous year.

Racal Electronics Ltd. announce that the group profit (before taxation) for the year ended 31st January 1966 amounted to £731,000 compared with £611,000 for the previous year.

The **Instrument Division of Claude Lyons Ltd.** has moved to Valley Works, Ware Road, Hoddesdon, Herts. All enquiries, orders and correspondence in regard to sales and service should be sent to this address.

NEW PRODUCTS

equipment systems components

Digital Voltmeter 301A

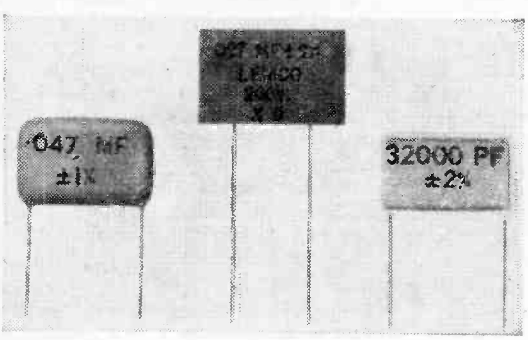
THE Fenlow Digital Voltmeter 310A is a precision instrument using a new strobe locked integration technique. The oscillator which produces pulses to be counted during the signal and reference integration periods, is servo controlled to be 20,000 times the mains frequency by means of an early and late strobe principle often used in radar tracking systems. When the mains frequency deviates the strobe locked integration reduces the effect of series mode signals (without the use of filters) by about 100 times over fixed integration period systems.

The input and integrator amplifiers make use of field effect transistors for chopping, thus reducing the drift and giving very low input currents and high input impedances. The whole of the input system is floating, permitting differential operation even when used for driving a printer. The instrument contains a programme unit facilitating operation from external commands. Voltage ranges are: 0 to 100 mV, 0 to 1 V, 0 to 10 V, 0 to 100 V, and 0 to 1,000 V. Calibration is achieved by means of a Muirhead reference cell with current and voltage zero balance by front panel controls. Data output consists of decimal coded information, sign, range, and overload by means of a 54-way connector to the rear. For any b.c.d. outputs, a decoder unit plugs into the rear of the instrument. When the decoder is used, the levels and signs correspond with the N.P.L. standard interface. Size is $15 \times 5\frac{1}{4} \times 18$ in and weight 30lb. Fenlow Electronics Ltd., Springfield Lane, Weybridge, Surrey.

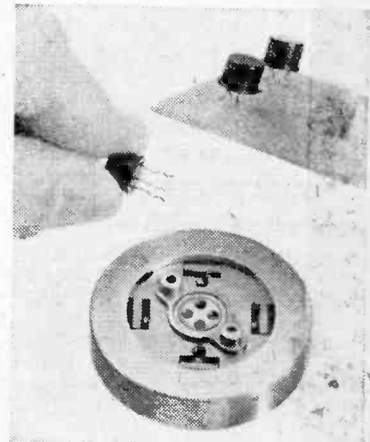
WW 301 for further details

Silver Mica Capacitators

LEMCO have now added to their range of sintered silver mica capacitors by the use of mica blades 25 mm × 15 mm in a sintered construction. Pure silvered ruby mica plates are stacked, compressed, and fired, bonding the plates into a stable, robust block. Available moulded or dipped in synthetic resin or with a wax finish, with capacities from 5,000 pF to 0.05 μF, and operating voltages of 200 and 350 V d.c. London Electrical Manufacturing Co. Ltd., Bridges Place, Parsons Green Lane, London, S.W.6.



WW 302 for further details



Transistor Joggling Die

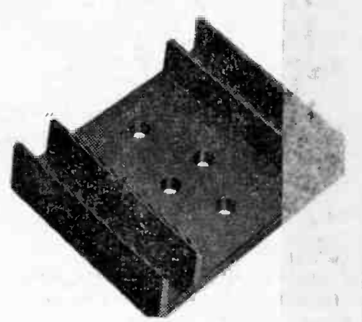
THIS lead cutting and joggling die manufactured by Pico Crimping Tools Co. of the U.S.A. eliminates the need for transistor pads between transistor and printed circuit board, since the die cuts three or four leads to predetermined length, and joggles in a single operation. Transistors are then snapped into standard hole patterns, and remain in place with a $\frac{1}{8}$ to $\frac{5}{32}$ in air gap, regardless of p.c. board position. For use with the manufacturer's 300, 300B or 300BT air power unit. Available from Kingham Electronics Ltd., 17 Briary Wood Lane, Welwyn Heath, Welwyn, Herts.

WW 303 for further details

Heat Sink

A FLAT based heat sink (A1057) is introduced by Jermyn Industries, for power transistors, s.c.r.s and G.E. triacs. Of black anodized aluminium extrusion, standard units are drilled for TO3 cans, or with a single hole which accepts the press-fit version of the G.E. triac. Thermal resistance is better than 8°C/watt. Jermyn Industries, Vestry Estate, Vestry Road, Sevenoaks, Kent.

WW 304 for further details



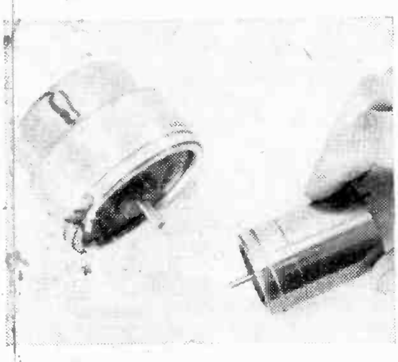
AUTOMATIC PROGRAMMABLE TIMEBASE

THIS unit by Tektronix, known as the 3B5, will, when used with the 3A5 automatic programmable amplifier, provide an automatic oscilloscope display. Programmable functions include time/div, magnifier range, trigger mode with coupling, and trigger slope, by contact closure to ground. By using a 263 programmer, which accepts 6 plug-in type programme cards, the oscilloscope system can be externally pre-set for a given measurement. There is a selection of 11 different programmable functions from plug-in units, and the combination eases the problems involved in many measurements such as production line testing systems check-outs, and also simplifies "away from the oscilloscope" tests, where manual manipulation of the front panel controls would be inconvenient. Further information from Tektronix UK Ltd., Beaverton House, Station Approach, Harpenden, Herts.

WW 305 for further details

Angular-motion Transducers

The Nilson Manufacturing Co., of Florida, U.S.A., have produced a range of angular motion transducers that utilize the principle of phase modulation, and claim that these Variogon transducers overcome the difficulty of phase-shifting accurately in the r.f. range.



This electrostatic phase-shifting transducer has an offset dielectric rotor, providing a variable capacitance between fixed input and output plates. No electrical coupling to the rotor is required. The input plate has four segments which are fed by a quadrature network, the amplitude of the four inputs being equal. These four voltages are capacitively coupled to the output plate through the dielectric rotor, without which the algebraic sum of the resultant output voltage would be zero. Since the rotor is present however, their sum does have some value, the phase of which varies as a linear function of the angular position of the rotor shaft. Variogon transducers are available from the U.K. agents Kynmore Engineering Co. Ltd., 19, Buckingham Street, London, W.C.2.

WW 492 for further details

Portable Gas Torch

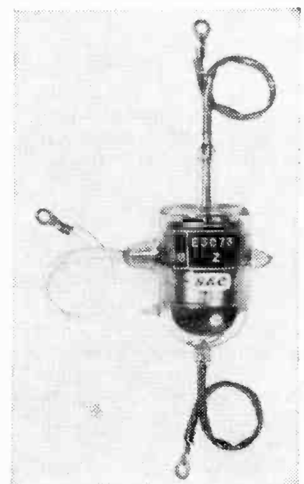
A MINIATURE, portable butane gas torch for soft and hard soldering of small objects is marketed by the Southern Watch and Clock Supplies Ltd., 48 High Street, Orpington, Kent. The Flamidor, as it is called, is 7¼ in long, 1⅝ in diameter and weighs 4½ oz. It is stated that the pencil-sharp flame reaches a temperature of 1,500° C. Complete unit costs 38s 6d and replacement gas containers cost 6s. A slip-on soldering bit is included in the unit.

WW 306 for further details

Triggered Discharge Device

DESIGNED for protection purposes, or for the discharge of capacitor banks the triggered cold cathodes gas discharge device E 3073 is offered for high current, single shot applications such as nuclear research, laser and photographic flash uses, and discharge welders. The working voltage range in 500 to 1200 V, and the peak anode current is 2000 A. Total discharge per operation is 0.5 coulomb. Two valves can be used in series to give 24 kV operation, and in this configuration only one valve needs to be triggered. The E 3073 will operate in any position through an ambient temperature range of −40 to +70°C. The M-O Valve Co. Ltd., Brook Green Works, London, W.6.

WW 307 for further details



4MM MAGNETRON

THE Elliott 4 mm magnetron Type 4MA can maintain stable frequency and efficiency characteristics for operating periods in excess of 200 hours. It is claimed that a useful life of 500 hours can be expected. It has a power rating of 5 kW, a minimum pulse duration of 5 ns, and a rise time of about 1 ns. Typical operating characteristics include peak anode voltage 10 kv, peak anode current 6.4 A, heater current 3.2 A. Overall dimensions are $8\frac{3}{4} \times 7\frac{1}{4} \times 3\frac{1}{4}$ in and it weighs 14 lb. Cooling of the anode and also the cathode bushing is carried out by forced air. Information from Elliott Electronic Tubes Ltd., Elstree Way, Boreham Wood, Herts.

WW 308 for further details

Mercury Relay

A HERMETICALLY sealed mercury relay, the Euroswitch-M utilizes the principle of breaking the arc on mercury-to-mercury contacts, and it is claimed that a life expectancy in excess of 10 million operations is a result. Since operation is by plunger action, external moving parts are eliminated. The stainless steel mercury container will withstand severe shocks resulting from current surges, arcing, etc.

A current of 25 A at 440 V a.c. resistive, can be disconnected at a rate up to 2,000 per hour. Standard coil voltages are available, while operating power required is 4 W on d.c. voltages, and 6 VA on a.c. voltages.

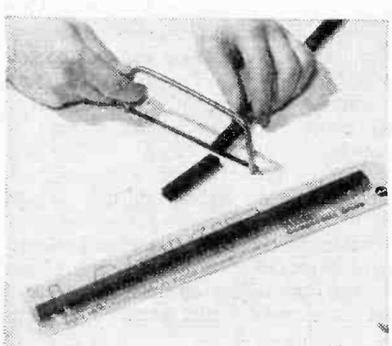
The relay operates to within 25° of vertical. Size 1.5 in diameter × 3.25 in long. Distributed by Techna (Sales) Ltd., 47 Whitehall, London, S.W.1.

WW 309 for further details

EDGE CONNECTOR KITS

THESE Plessey 603 printed circuit edge connectors to be marketed as Labkits, comprise a 78-way strip, four pairs of mounting feet and four polarizing keys. The two basic kits, Nos. 1 and 2 with contact spacing of 0.156 in, and 0.150 in, respectively, are intended for use by prototype and development engineers in industry, universities and technical colleges. The connectors can be cut to size depending on the number of terminations required. Manufactured in glass-loaded polycarbonate, with brass, gold flash or silver contacts, the connectors are rated at 750 V a.c. r.m.s. Operating temperature range is −40° to +85°C, with current rating at 5 A continuous. Available from the Plessey Blue-Arrow Service, Wiring and Connectors Division, Cheney Manor, Swindon, Wilts.

WW 310 for further details



Electronics and Shipping

A REPORT ON THE GLASGOW I.E.E./I.E.R.E. SYMPOSIUM

THE main aims of the recent symposium on Electronics, Measurement and Control in Ships and Shipbuilding which took place in Glasgow during mid-April was to bring to the attention of shipbuilders and shipowners the advantages that electronic techniques would have from the point of view of building and operating ships. However, an impression gained during the lively discussions which followed some of the sessions was that the shipping industry appears to be wary of the "black box," especially as regards data logging. In addition, an overall mutual appreciation of the problems facing engineers from both industries is required. In general, the ship should be treated by both industries as a basic unit to be automated.

Working within the electronics industry, we were perhaps biased but a general example quoted by one speaker who was involved in the installation of data logging equipment was where the ship builder considered the installation as three separate entities—the transducers, the cables and the data logger, instead of a complete installation—and tried to dictate the siting of these three "separate entities." Accordingly where the cables are routed through an electrically noisy environment, error signals are introduced into the system and cause a detrimental effect on performance. In fact, another speaker quoted an example where interference was so bad that it simulated a starting pulse for a generator normally operated by a push-button. As a result of these effects, the ship owner is obviously dissatisfied and this has produced a great deal of scepticism and almost hostility towards the equipment. The logical attitude of one speaker was that a great deal of basic electronic experience gained from other industries is available to the shipping industry, but this has to be studied in a different perspective before it can be applied to an "aboard ship" environment.

Although most of the papers were concerned with shipping there were several of general electronic interest.

In his paper "Modern Marine Radar Systems," C. J. Collingwood (A.E.I.) described current types of marine radar presentation. The form of presentation was a most important factor from the point of view of the navigator and the author felt that collisions of vessels in radar contact were due to ineffective or delayed interpretation by the navigator of radar information.

When considering the relative motion type of p.p.i. display which is available with ship's head or compass stabilization, the author thought that it was adequate for long range navigation and detection of targets at medium and short ranges, but in congested shipping areas where avoiding action was necessary the relative movement of echoes had to be resolved graphically by plotting methods before an avoidance course could be decided. Time required for manual plotting was not always available.

Another form of presentation considered was the true motion or chart-plan presentation on which the progress of the ship is shown against a stationary background, i.e., coastline and fixed navigational marks. With this method the navigator is provided with the means to assess simultaneously the position and movement of the ship relative to stationary objects, and all moving targets tracking on their true courses and at their true speeds. Mention of a computer used in conjunction with chart-plan presentation was also made by the author, and this included the feature of tide correction applied to the ship's course and speed. The author also described a reflection plotter which can be used so that direct plotting can be made on a form of display. Combination of the plot and radar display provide the navigator with past, present and predicted information.

Basically the reflection plotter consists of a half silvered mirror midway between the face of the c.r.t. and a plotting surface which has a surface curvature equal but opposite to that of the c.r.t. The author proved that a point or mark on the plotting surface appears to be on the face of the c.r.t. Thus plotting lines appear as if they were drawn directly on the face of the c.r.t.

From this type of display the author continued with a discussion on photoplot. With this method, radar information is displayed with high brilliance on a $3\frac{1}{2}$ in c.r.t. and photographed on special 16 mm film which is processed in a few seconds, and then projected on the underside of a translucent screen, large enough to allow observation by several viewers at the same time. Pictures can be projected successively at intervals of 15 seconds, three minutes or six minutes. Targets appear black against a white background. As the author pointed out, during the long time intervals, successive radar paints of moving targets become integrated and are then automatically shown on the display as lines of varying length and direction which indicate the track and distance travelled.

The importance of radar as part of a ship's equipment was stressed by the author who pointed out that during the past 15 to 20 years the number of ships in the world has almost doubled and much more sea room is required by tankers and carriers which have increased in size by a factor of five, but, surprisingly, radar aboard ship is not compulsory.

Collision avoidance of aircraft has been discussed in *Wireless World* recently, and it is interesting to note that a paper, by P. G. Tarnowski (A.S.W.E.) "Radar Computer for the Closest Point of Approach" dealt with the collision avoidance of ships. An experimental computer has been developed which can be connected to any radar set of the Merchant Navy. During operation, the bearings of the tracking ship and the other ship are displayed in p.p.i. form. The operator locks a bearing and range marker to the echoes from the possible hazard and this marker then follows the movement of the hazard. The echoes are fed to a computer which processes the received bearing and range information in rectangular co-ordinates and computes the relative course of the hazard. Information in the form of the x and y co-ordinates is stored by the computer and after half a mile decrease in range a second set of x and y co-ordinates is obtained, stored in a second store and subtracted from the first to give the first value of relative track. Alternating voltages corresponding to this information are amplified and fed to a c.r.t. where the relative track is displayed as a line on the screen from which the closest point of approach (C.P.A.) can be read. After a second half-mile decrease in range, the first store is cleared to receive the latest x and y co-ordinates from which relative courses over the second half mile can be obtained. The stores are cleared alternately during the overall track. If the true course of the hazard is required provision has been made for subtraction of the velocity of the tracking ship. In addition, when the tracking ship alters course to avoid collision the computer will predict the result of the altered course.