FIELD-EFFECT TRANSISTORS AT V.H.F.

JANUARY 1966
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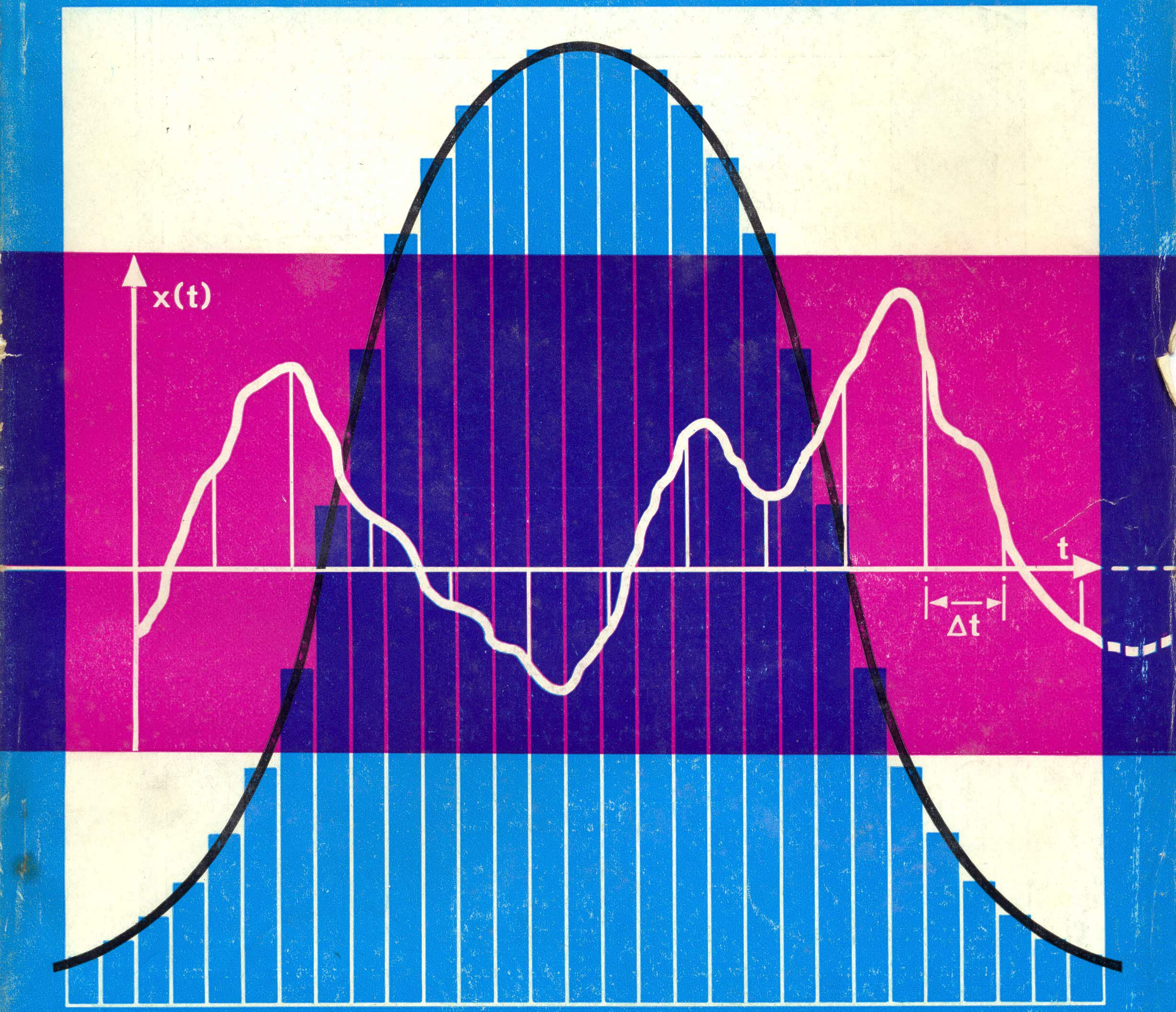

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Degrees and Diplomas

DURING the past few weeks two incidents have focused attention on the subject of technical qualifications. First, the granting of a Royal Charter to the Council of Engineering Institutions, which empowers the Council to award the qualification "Chartered Engineer" (C.Eng.) to suitably qualified persons, and second, the issuing of a statement by the Council for National Academic Awards on its approval of courses leading to the award of the Council's degrees of B.Sc. and B.A.

First, the C.Eng. It will be recalled that there are 13 constituent institutions of the C.E.I. (including the I.E.E. and I.E.R.E.) and under the rules of the C.E.I., a candidate for the diploma, C.Eng., must be a corporate member of one of these institutions and pass an examination set by the Council or have an exempting qualification. It has further been decided by a majority vote of the representatives of the institutions on the Council that they will at some future date discontinue their own examinations and adopt that of the C.E.I. This has drawn strong criticism from some quarters (we published points from the I.E.R.E. criticism in last September's issue) because this would mean that engineering training would be too broadly based with but little, if any, specialization in the discipline of the particular institution. Moreover the proposed common syllabus is heavily weighted in the direction of mechanical engineering.

Another question arising from the granting of the Charter to the C.E.I. is why should anybody want to use the honorific C.Eng. when the use of the initials of their particular diploma already denotes that they are, in fact, "chartered engineers"? Will we see the day when the identification of an engineer's particular discipline disappears from his diploma and he becomes simply a C.Eng.?

Apposite to the subject under review is the statement of the Council for National Academic Awards regarding courses leading to the award of the Council's first degrees. The Council was established by Royal Charter in September 1964 with power to award "degrees and other academic distinctions . . . to students who satisfactorily complete approved courses of higher education in establishments for further education which do not have the power to award their own degrees." Colleges are able to confer a C.N.A.A. degree instead of an "external" university degree.

It will be recalled that when its predecessor the National Council for Technological Awards was set up in 1955 it introduced the Diploma in Technology. This has now been superseded by the new Council's degrees of B.Sc. and B.A. The list of nearly 100 recognized degree courses (the majority "sandwich") at 30 colleges follows fairly closely those approved for the Dip.Tech., in fact the hundreds of students at present taking one of the original diploma courses may, if they wish, opt for one of the new degrees. Incidentally, the Council will grant holders of a Dip.Tech. one of the new degrees if they wish. One can imagine that in time the Dip.Tech. will have a scarcity value!

It is disappointing to note that in the first list of 100 courses leading to the award of the Council's B.Sc., only two are specifically in electronics (Northern Polytechnic and Staffordshire College of Technology) although possibly some of the electrical engineering courses include an optional electronics bias.

It will be apparent from what has been said that the whole field of technological education and resulting qualifications is in a state of flux and we feel sorry for those caught up in these machinations. We would reiterate the warning of the I.E.R.E. (in its statement on the C.E.I. common examination) of the danger of "foundering on the uncharted rocks of educational policy, many of which are not yet discernible."

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The Field-effect Transistor at V.H.F.

TUNER CIRCUIT FOR 100Mc/s OPERATION, PRECEDED BY ANALYSES OF THE M.O.S. F.E.T. AS AN R.F. AMPLIFIER AND AS A LINEAR MIXER

By U. L. ROHDE

ALTHOUGH field-effect transistors capable of working at v.h.f. have been commercially available for almost a year, they have been used very little in r.f. circuits so far. This article arises from experimental work in using two of these devices—the Texas Instruments 2N3822 and 2N3823 planar m.o.s. transistors—in a tuner design for the 100 Mc/s broadcasting band. To assist the circuit designer who wishes to follow up these techniques, the article starts off with analyses of the operation of the f.e.t. as an r.f. amplifier and as a mixer.

The field-effect transistor (Fig. 1) is, in fact, a bilateral device—meaning that the drain and source electrodes are interchangeable. The principle of operation was explained in G. H. Olsen's article " Field-effect Devices " in the June, 1965, issue of *Wireless World*, and the appendix to the present article adds a little more information on the physics of the device. From this appendix it will be noticed that the transconductance of the f.e.t. is shown to be a constant. For mixing and linear amplification this is the most important advantage of the f.e.t. over thermionic valves and transistors, with their non-linear transconductances.

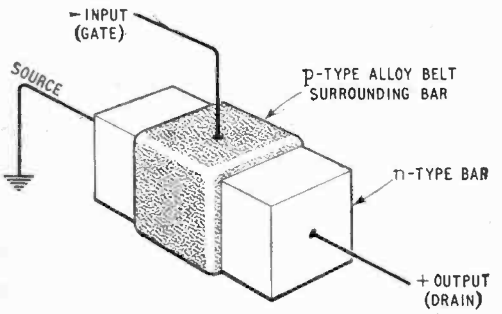


Fig. 1. Basic structure and electrodes of the field-effect transistor.

From the physical structure of the device an electrical equivalent circuit as shown in Fig. 2 may be derived, and this is suitable for the 2N3822 and 2N3823 types that we are concerned with. Since the drain resistance is a function of current, we note that the voltage gain A, which is given by $g_m \times r_d$, is therefore highest when the drain current is at a minimum.

From the π equivalent circuit Fig. 3 we can easily calculate the Y network parameters up to 1,000 Mc/s, which agree with experimental measurements to an accuracy of about 2%.

Table I gives the Y parameters of the 2N3822 and 2N3823, which are slightly different in spot noise figure and figure of merit. Since the figure of merit for transistors is defined as:

$$f_{max} = \sqrt{f_T / 8\pi r_{bb'} C_{cb}} \quad \ldots \quad (1)$$

TABLE I

	2N3822 (100 Mc/s)		2N3823 (500 Mc/s)	
Y_{11}	$(0.3 + j\,3)$	mmhos	$(2 + j\,10)$	mmhos
Y_{12}	$-(0.2 + j\,0.6)$	mmhos	$-(0.5 + j\,4.5)$	mmhos
Y_{21}	$(3.4 - j\,3)$	mmhos	$(4.7 - j\,5)$	mmhos
Y_{22}	$(10.3 + j\,1)$	mmhos	$(10.3 + j\,5.3)$	mmhos

the equivalent definition with m.o.s. field-effect devices is:

$$f_{max} = \frac{|Y_{21}|}{2\pi C_{gs}} \quad \ldots \quad (2)$$

The transistor with the higher figure of merit, the 2N3823, has a higher spot noise figure, as Fig. 4 indicates.

To show the capabilities of m.o.s. field-effect transistors, some evaluations with three-terminal networks will now be made.

Analysis of the mode of operation of a grounded source amplifier by linear network theory

From Kirchhoff's equations we have:

$$I_1 = Y_{11}V_1 + Y_{12}V_2 \quad \ldots \quad (3)$$

$$I_2 = Y_{21}V_1 + Y_{22}V_2 \quad \ldots \quad (4)$$

which leads to the input admittance Y_{aa} of the three-terminal network shown in Fig. 5:

$$Y_{aa} = Y_G + Y_{11} - \frac{Y_{12}Y_{21}}{Y_{22} + Y_L} \quad \ldots \quad (5)$$

Considering stability, Y_{aa} may become zero, but must not become negative. If Y_{11} and the generator admittance Y_G are Y_1, and Y_{22} and the load admittance Y_L are Y_2, and $Y_{aa} = 0$, we can write

$$Y_1 Y_2 = Y_{12} Y_{21} \quad \ldots \quad (6)$$

From these four complex parameters, we know Y_{12} and Y_{21} and Re(Y_2). To obtain the critical values for oscillation:

max b_1 = max Im(Y_1), max g_2 = max Re(Y_2), and max b_2 = max Im(Y_2)

U. L. Rohde, studied radio engineering at the Technical High School in Munich, and since 1963 has been at the Technical High School in Darmstadt, where he is taking his final degree. He is working in the field of transistor applications in low-noise, high-power amplifiers at u.h.f. and has published a book on this subject which appeared last March in Germany. His father is owner of the Rohde & Schwarz company.

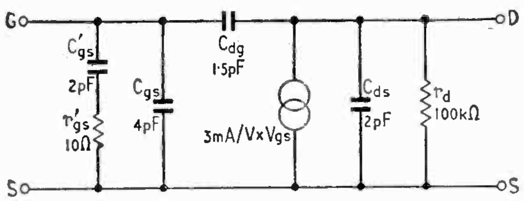


Fig. 2. Equivalent circuit for the 2N3822 and 2N3823 m.o.s. field-effect transistors.

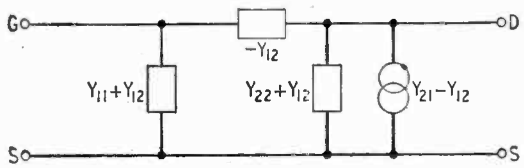


Fig. 3. The π equivalent circuit in Y network parameters.

(where g represents the conductance part of an admittance and b the susceptance part)
equation (6) is separated into real (Re) and imaginary (Im) parts:

$$g_1 g_2 - b_1 b_2 = g_{12} g_{21} - b_{12} b_{21} = \text{Re}\ (Y_{12} Y_{21}) \quad . \quad . \quad (7)$$

$$g_1 b_2 + g_2 b_1 = g_{12} b_{21} + g_{21} b_{12} = \text{Im}\ (Y_{12} Y_{21}) \quad . \quad . \quad (8)$$

and b_1 from equation (7) is put into equation (8). We then get:

$$g_2 = \frac{\text{Re}\ Y_{12} Y_{21}}{2g_1} \pm \sqrt{\frac{\text{Re}^2 Y_{12} Y_{21}}{4g_1^2} + \frac{\text{Im}\, Y_{12} Y_{21} b_2}{g_1} - b_2^2} \quad (9)$$

Oscillation will be avoided when $g_2 >$ max g_2, with max g_2 as the greatest possible value which g_2 as a function of b_2 may have. From $dg_2/db_2 = 0$ and eqn. 9 we get:

$$\max g_2 = \frac{1}{2g_1}\left(\text{Re}\ (Y_{12} Y_{21}) \pm |Y_{12} Y_{21}|\right) \quad . \quad . \quad . \quad (10)$$

with

$$\max b_2 = \frac{\text{Im}(Y_{12} Y_{21})}{2g_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

We obtain for max $b_1 = \dfrac{\text{Im}\ (Y_{12} Y_{21})}{2 \max g_2}$ . . . . . (12)

We have thus found that an active network will start oscillation if, and only if, for a given g_1 the critical values max g_2, max b_2 and max g_1 are present at the same time.

We will now evaluate the stability conditions of a m.o.s. field-effect transistor with a generator admittance $Y_G = g_g = 0{\cdot}3$ mmhos and a load admittance $Y_L = (0{\cdot}24 + j\ 1)$ mmhos. First, we find $Y_1 = (0{\cdot}6 + j\ 3)$ mmhos and determine the critical value max Y_2, and compare this with the given Y_2, which is $Y_{22} + Y_L = (0{\cdot}54 + j\ 2)$ mmhos. We obtain:

$$\text{Re}\ Y_{12} Y_{21} = g_{12} g_{21} - b_{12} b_{21} = -2{\cdot}66\ (\text{mmhos})^2$$

$$\text{Im}\ Y_{12} Y_{21} = g_{12} b_{21} + g_{21} b_{12} = -1{\cdot}4\ (\text{mmhos})^2$$

$$|Y_{12} Y_{21}| = \sqrt{7 + 1{\cdot}96} = 3\ (\text{mmhos})^2$$

$$\max g_2 = \frac{1}{2g_1}\left(\text{Re}\, Y_{12} Y_{21} \pm |Y_{12} Y_{21}|\right) = 0{\cdot}28 \text{ mmhos}$$

$$\max b_2 = \frac{\text{Im}\ Y_{12} Y_{21}}{2g_1} = -1{\cdot}6 \text{ mmhos (inductive)}$$

$$\max b_1 = \frac{\text{Im}\ Y_{12} Y_{21}}{2 \max g_2} = -0{\cdot}23 \text{ mmhos (inductive)}$$

Since max b_1 will never become inductive because of the three-ganged variable capacitor in the input circuit, max b_2 may become capacitive. This circuit will therefore be stable under the given circumstances.

If we study the noise figure of a non-neutralized source base stage with a m.o.s. field-effect transistor as an input stage, we will find that, in comparison with neutralized m.o.s. f.e.ts., the use of non-neutralized m.o.s. f.e.t.s has the following advantages. Owing to the feedback over Y_{12}, by selection of a suitable output admittance such an admittance can be transformed at the input so that power matching with a simultaneous noise minimum can be obtained at the input. As a result of the much lower increase of noise figure from the noise minimum, with the same noise factor at the band edges a considerably wider transmission bandwidth is obtained.

As an example for application, a non-neutralized source base stage with the 2N3822 field-effect device will be calculated. We first find the necessary feedback admittance which is given by the fact that, for noise minimum and power gain matching at the input simultaneously, Y_{aa} is found to be:

$$Y_{aa} = (1 + j0) \text{ mmhos}$$

This value was determined experimentally for the 2N3822 at 100 Mc/s.
Since

$$Y_{aa} = Y_1 - \frac{Y_{12} Y_{21}}{Y_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

the necessary feedback admittance Y_F is:

$$g_f + j\, b_f = -\frac{Y_{12} Y_{21}}{Y_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (14)$$

For the real and imaginary parts we find:

$$g_f = \frac{-\text{Re}\ Y_{12} Y_{21} g_2 - \text{Im}\ Y_{12} Y_{21} b_2}{g_2^2 + b_2^2} \quad . \quad . \quad . \quad (15)$$

$$jb_f = \frac{-\text{Re}\ Y_{12} Y_{21} b_2 + \text{Im}\ Y_{12} Y_{21} g_2}{g_2^2 + b_2^2} \quad . \quad . \quad . \quad (16)$$

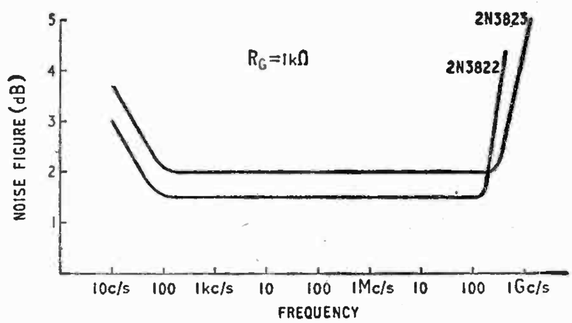


Fig. 4. Noise figure vs. frequency for the two f.e.ts.

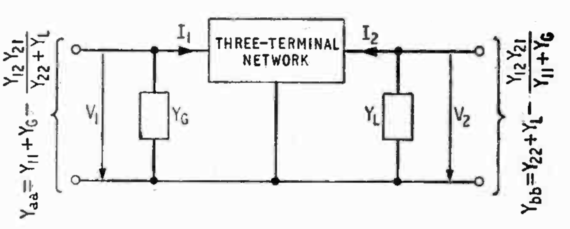


Fig. 5. Network for analysis of grounded-source f.e.t. amplifier.

These equations may be solved for g_2 and b_2 and we then get:

$$g_2 = \frac{1}{g_f}\left[\frac{H\ \mathrm{Im}\ Y_{12}Y_{21} - \mathrm{Re}\ Y_{12}Y_{21}}{1+H^2}\right] \quad \ldots \quad (17)$$

with

$$H = \frac{b_f\ \mathrm{Re}\ Y_{12}Y_{21} - g_f\ \mathrm{Im}\ Y_{12}Y_{21}}{b_f\ \mathrm{Im}\ Y_{12}Y_{21} + g_f\ \mathrm{Re}\ Y_{12}Y_{21}} \quad \ldots \quad (18)$$

and

$$b_2 = -\frac{\mathrm{Im} Y_{12}Y_{21}}{2g_f} \pm \sqrt{\frac{\mathrm{Im}^2 Y_{12}Y_{21}}{4 g_f^2} - \frac{\mathrm{Re} Y_{12}Y_{21} g_2}{g_f} - g_2^2} \quad (19)$$

If we calculate these values for the 2N3822, we obtain

$H = -1{\cdot}65$
$g_2 = 0{\cdot}24$ mmhos
$b_2 = 1$ mmho

as the interested reader will quickly find. The power gain obtainable under these circumstances was found to be 20 dB.

We will next consider an exact method for calculating values for the m.o.s. field-effect transistor as a linear mixer.

Analysis of the m.o.s. f.e.t. as a quadratic mixer

Mixing in linear networks occurs with time-dependent functions. In contrast to non-linear networks, we may assume a step response function in time dependent networks, and we can determine from the behaviour with unmodulated signals the behaviour with modulated signals, e.g., two signals at the input. For additive mixing, as it is used here, we may use an equivalent circuit described by the two-port equation:

$$i_D = S(\omega_o t)v_G + G_i(\omega_o t)v_D \quad \ldots \quad (20)$$

The first sum will be determined later. The second is easily analysed, since the average value of the time-dependent internal admittance

$$g_i = \frac{1}{2\pi}\int_{-\pi}^{+\pi} g_{io}(\omega_o t)\,d(\omega_o t) \quad \ldots \quad (21)$$

produces a current on the i.f.

For the oscillator voltage, we assume an even step response:

$$v_{Go} = -V_G + V_G \cos\omega_o t \quad \ldots \quad (22)$$

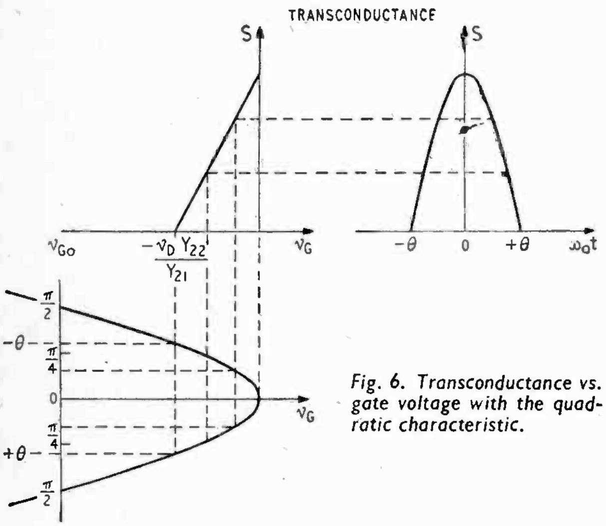


Fig. 6. Transconductance vs. gate voltage with the quadratic characteristic.

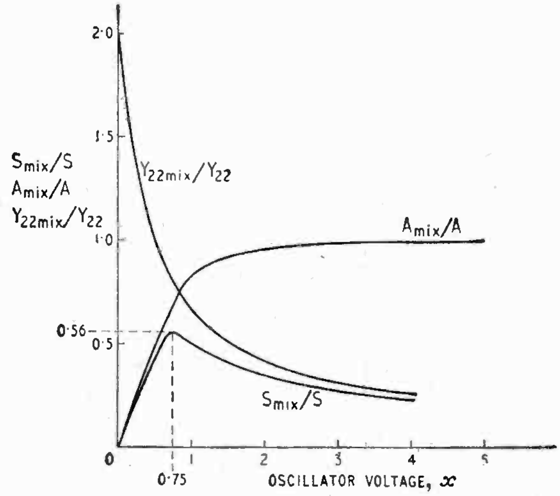


Fig. 7. Mixing transconductance, voltage amplification and internal admittance for the f.e.t. mixer.

The field-effect transistor draws current if the control voltage

$$\left.\begin{aligned} v_G &= v_{Go} + v_D Y_{22}/Y_{21} \\ &= Y_{22}v_D/Y_{21} - V_G + V_G \cos\omega_o t \end{aligned}\right\} \quad \ldots \quad (23)$$

is greater than zero. For simplicity we use a standardized oscillator voltage

$$x = \frac{V_G Y_{21}}{Y_{22} v_D} \quad \ldots \quad (24)$$

and an angle of current flow θ. We then have:

$$x = \frac{1}{1-\cos\theta} \quad \ldots \quad (25)$$

The characteristic of a m.o.s. field-effect transistor is described by

$$i_d = K(v_g + Y_{22}v_D/Y_{21})^2 \quad \ldots \quad (26)$$

Fig. 6 shows the graphical derivation of the time-dependent transconductance from the time-dependent gate voltage with the quadratic characteristic. From this we may assume the transconductance to be exactly

$$S(\omega_o t) = 2S(1 - x + x\cos\omega_o t) \quad \ldots \quad (27)$$

This is a part of a sine wave. For the first two Fourier coefficients of the time-dependent transconductance we get the integral

$$S = \frac{1}{2\pi}\int_{-\pi}^{+\pi} S(\omega_o t)e^{-j\lambda\omega_o t}\,d(\omega_o t) \quad \ldots \quad (28)$$

and its solution

$$S_o = \frac{2}{\pi} S \frac{\sin\theta - \theta\cos\theta}{1-\cos\theta} \quad \ldots \quad (29)$$

$$S_1 = \frac{1}{\pi} S \frac{\theta - \sin\theta\cos\theta}{1-\cos\theta} \quad \ldots \quad (30)$$

Fig. 7 is a graph showing mixing transconductance, voltage amplification and internal admittance for the m.o.s. field-effect transistor mixer. A practical value for Y_{22}/Y_{21} is 15. Since we see from Fig. 7 that the optimum value for x is 0·75, we get a mixing transconductance $g_m = 0{\cdot}56 \times g_{mo} = 2{\cdot}5$ mmhos. Since the value for x is also

$$x = 0{\cdot}75 = \frac{V_G Y_{21}}{Y_{22} v_D} \quad \ldots \quad (31)$$

we obtain $V_G = 1{\cdot}8$ V

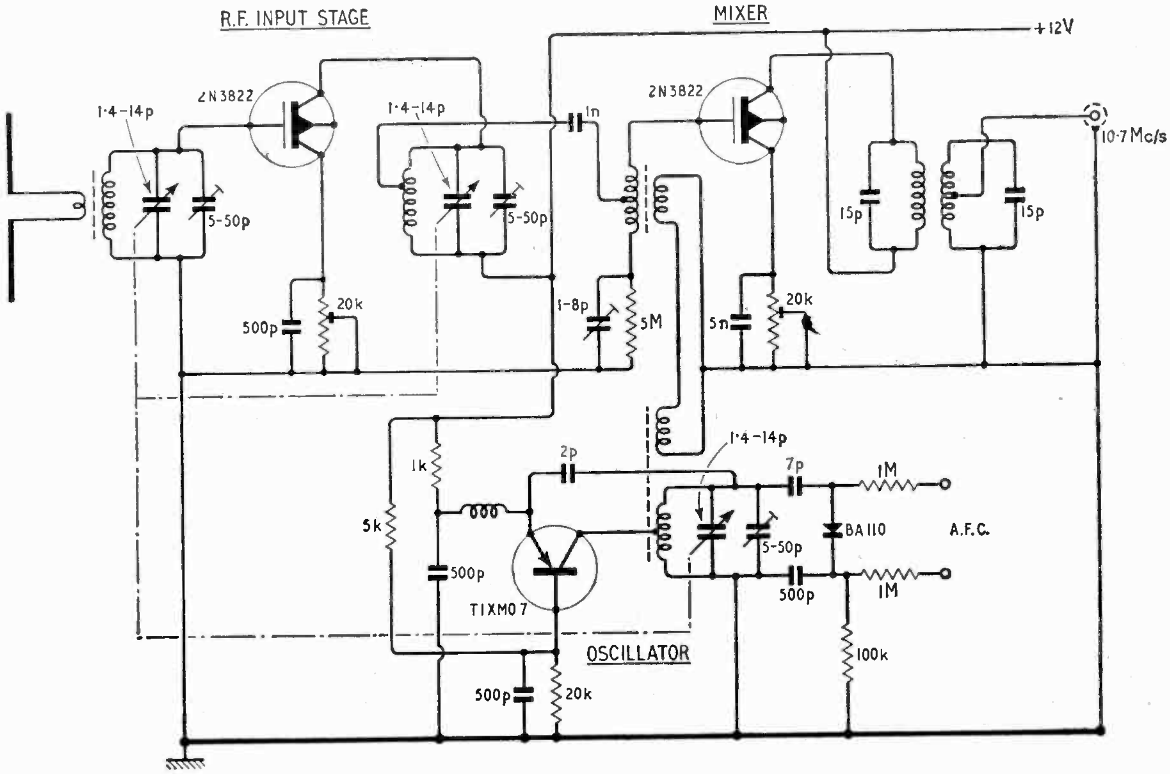


Fig. 8. Circuit of practical tuner for 88-104 Mc/s. The characteristics are given in Table II below.

and the static operating condition is:

$V_G = 1{\cdot}8\text{V}, \qquad V_D = 12\text{ V}$

Practical tuner for the 100-Mc/s band

The tuner shown in Fig. 9 uses a non-neutralized input stage, as already calculated, with a suitable Y_L. The mixer is optimized and uses a bridge arrangement for the oscillator frequency and the signal frequency. The oscillator is made very stable by tapping the tuned circuit, and may be fine-tuned by an a.f.c. voltage obtained from a discriminator. All component values are given on the circuit, and because of the similarity with thermionic valve arrangements, no further explanation is necessary. As can be seen from Table II, the performance of this tuner is superior to that of all valve and transistor tuners so far encountered.

Compared with conventional mixers, with respect to intermodulation and interference from oscillator harmonics the m.o.s. field-effect transistor mixer is superior. Only the second harmonics and the frequencies representing the sum and difference components of the incoming signals are generated. No intermodulation by-products of the form $(1+n)\omega_1 - n\omega_2$ or $(1+n)\omega_2 - n\omega_1$ are present, as they are in conventional mixers. The gate voltage excursion, however, has to be limited to a range over which the transconductance rises linearly with gate voltage. The maximum permissible voltage swing at the gate is

$$\max V_G = \sqrt{I_{Dmax} I_{Dtest}\left(\frac{2}{g_{m\ mix}}\right)} \qquad \ldots \quad \ldots \quad (32)$$

It has been established that the mixer transconductance

TABLE II

Frequency Range	: 88—104 Mc/s
Power gain	: 33 dB
Noise figure	: 2·8 dB
Image reduction	: 65 dB
Stability	: 5 kc/s per °C
Intermodulation	: 1% for $V_{ADI} \leq 1.2$V
Gain control	: 30 dB at first stage
Distortion	: No odd harmonics and even harmonics greater than $2\omega_{sig}$ $2\omega_{osc}$.

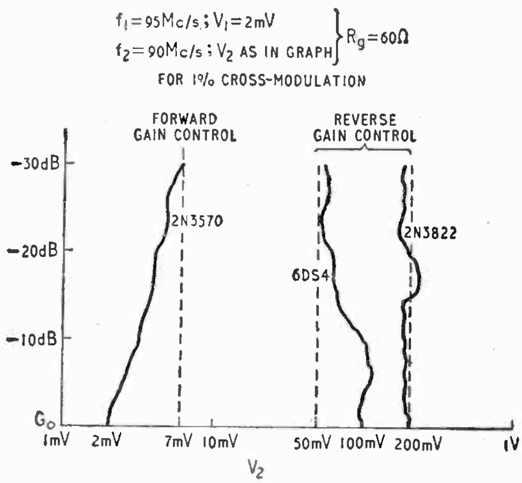


Fig. 9. Comparison of cross-modulation characteristics of a transistor (2N3570), a varistor (6DS4) and the 2N3822 f.e.t.

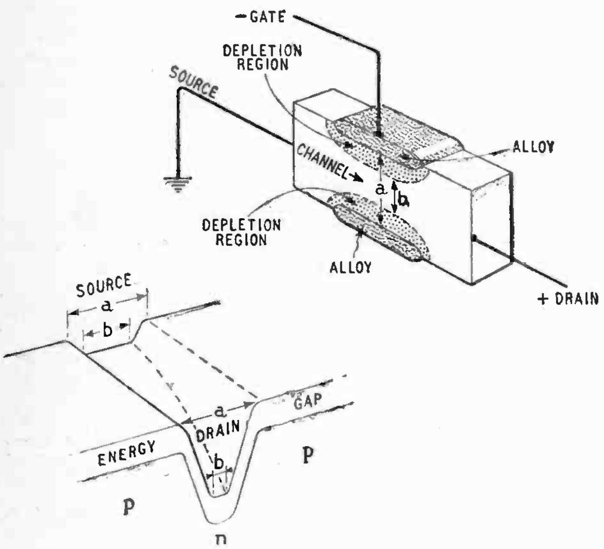
s proportional to the voltage of the oscillator. This effect can be used for automatic gain control. By reducing the local oscillator output the mixer gain can be reduced to zero. When V_{osc} is small, V_{sig} may occupy the entire range of the permissible gate voltage. This is desirable, since maximum gain reduction is needed if the signal amplitude is very large.

Finally, Fig. 9 shows a comparison of the cross-modulation characteristics of a transistor, a nuvistor and a m.o.s. field-effect transistor, as a function of gain control for 1% cross-modulation at two frequencies. One signal is 1 mV, while the other is as shown on the graph with no preselection. In a practical experiment, 1% cross-modulation occurred with two signals, one of 2 mV and the other of 200 mV applied directly to the gate electrode. This is better than with any triode valves at present known.

Acknowledgment.—The author would like to thank Texas Instruments and his teachers at the Technical High School at Darmstadt for their valuable help in the preparation of this article.

APPENDIX

In studying the principle of operation of the field-effect transistor, one has to consider the phenomenon of the variation of depletion layer thickness with reverse bias in the n-type bar of silicon. From Poisson's equation we have, letting y be the



direction perpendicular to the plane of the junction (see diagram):

$$\nabla^2 E = \frac{-qN_D(y)}{\epsilon}$$

where ϵ is the dielectric constant in suitable units, E is the voltage producing the electric field, and qN_D is the charge density in the n region. Integrating twice with respect to y and solving leads to:

$$E = \frac{qN_D a^2}{8}\left[1 - \frac{b}{a}\right]^2 = V_p\left(1 - \frac{b}{a}\right)^2$$

where V_p is the pinch-off voltage.

Under the specific condition of a voltage V at the gate electrode, the source being grounded, the differential resistance of the channel is $dr = dx/b^2$ and the Ohm's law $I_D dx = dV$. From a combination of these expressions we finally obtain

$$I_D = I_{DSS}\left(\frac{V_G}{V_0} - 1\right)^2$$

Differentiation of I_D/V_G gives the transconductance:
$g_{mo} = dI_D/dV_G \equiv 2I_{DSS}/V_0 = $ constant.

FURTHER READING

1. Rohde U.L. "Transistoren bei höchsten Frequenzen," Verlag für Radio-Foto-Kinotechnik GmbH. Berlin-Borsigwalde 1965.

2. Thommen W., Strutt M.J.O. "Kleinsignal-und Rauschersatzschaltbild von GE-UHF-Transistoren bei kleinen Stromdichten," AEU 4 (1965) pp. 169-177.

3. Telefunken-Fachbuch "Der Transistor." Ulm/Donau II. 1962.

4. Richter J. "Eine Anordnung zur Messung von HF-Transistoren im Frequenzbereich 30 bis 3000 MHz mit Hilfe des Zg-Diagraphen ZDU und ZDD," *Rohde & Schwarz Mitteilung.*, 15, pp. 11-14.

5. Rohde U.L. "Eine Entwicklung von rauscharmen UHF-Verstärkern mit Nuvistoren und Transistoren," *Internat. Elektr. Rundschau*, 2 (1964), pp. 74-78.

6. Wallmann H., Macnee A.B., Gadsden C.P., *Proc. I.R.E.*, 36 (1948), pp. 700-708.

7. Sittner R. "Das Rauschen und die Stabilität einer nicht neutralisierten Triode als HF-Eingangsstufe," *Die Telefunken-Röhre*, 33a (1960), pp. 147-206.

8. Luettgenau G.G., Barnes S.H. "Designing with low-noise MOS-FET'S: a little different but no harder," *Electronics*, 23 (1964), 14th December, pp. 53-58.

Data Transmission Service Using P.C.M.?

THE possibility of providing a cheap, high-speed data transmission service through the country's telephone network is being examined at Standard Telecommunication Laboratories. The idea is that if pulse code modulation were adopted universally for the telephone service the system would automatically provide an excellent medium for sending information that already existed in digital form. In p.c.m. telephony (which is already on field trial by the Post Office—see February, 1965, issue, p. 87) speech waveforms are transmitted by amplitude samples represented by 7-bit characters at a sampling rate of 8 kc/s, giving a transmission rate of 56,000 bits/second per voice channel.

G. C. Hartley and D. L. Thomas of S.T.L., in a paper presented at an I.E.E. colloquium on data and telegraph transmission, pointed out that data could be transmitted very economically at this rate, and that for users who did not require such a high speed, the 56,000 bits/second channels could be sub-divided by time division multiplex to provide 2,000 bits/second channels. The paper, which was a tentative economic analysis, gave a comparison of costs between the various types and speeds of information transmission (including analogue speech and p.c.m. speech) and drew the conclusion that the prospect exists of opening up an extensive 56,000 bits/second data service at the same order of cost as the current 600 bits/second service.

1.—WHY STATISTICS?

By D. A. BELL, M.A., B.Sc., Ph.D., M.I.E.E., F.Inst.P.

THE history of the electronic engineering profession is largely a struggle to learn more mathematical techniques. It is true that in the early days the use of $j\omega$ algebra appeared to give relief from the use of differential equations, but then the problem of "transients" forced us to realise that $j\omega$ algebra gave only the steady-state solution. "Operational calculus" was the answer to this one, and since Heaviside had been scorned by some of the pure mathematicians, surely his work should be intelligible to engineers? But by the time mathematicians had organized proofs of Heaviside's results, his approach was no longer fashionable and the new operational calculus rests on Laplace transforms and contour integration with its poles and zeros. On top of all this, is statistics the last straw?

No new mathematical concepts

First, let the reader be reassured that the sort of statistics which is commonly used in radio and electronic engineering does not involve any new mathematical concepts: powers of numbers, exponentials, integrals and the occasional Fourier transform are nothing remarkable. The difficult mathematics arises in the solution of new problems; and by now we can usually find an existing solution which is applicable to our particular problem, so that we can use formulae or tabulated values, which already exist.

Then, what has statistics to do with radio and electronics? Statistics is the technique of describing a population in terms of its collective characteristics instead of reciting a description of each individual in the population. It originated as a branch of state-craft and perhaps the first recorded application of statistics in this sense was Moses "numbering of the people" and the subsequent allocation of certain family and age groups to special tasks (*Numbers*, Chapters one to four). The purpose of the statistical description is to save labour—"the sum of the sons of Gershon . . . from thirty years old and upward until fifty years old" is a lot shorter than a list of the names of all the individuals concerned—and if one man is as good as another within certain limits, nothing of practical value is lost by ignoring the names of individuals. The term "population" has been carried over to other statistical work, and is used equally to refer to a collection of inanimate objects which is being subjected to statistical analysis.

Statistics is sometimes regarded as a means of concealing our ignorance of the individuals, and if we neither know nor care about individual identities this is fair enough. An example in electronics is the specification of resistors to 5% tolerance. Out of a batch of resistors which are 1 kΩ ±5% we neither know nor care the exact resistance value of any individual, nor even whether there is any single resistor which is very nearly 1,000 ohms or whether there are approximately equal numbers above and below that value. Statistics, however, provides means of specifying the two latter characteristics also, without resorting to listing all the individual values. Statistics has been used to answer some questions of this sort in the field known as "quality control" which is the generally used abbreviation for "statistical quality control." If a 10% sample taken from a large batch of resistors is measured, under what conditions and how reliably can one predict the spread of values in the whole batch?

The sampling application is related to the theory of random errors which at one time was a slightly disreputable branch of statistics. However, experimentalists and statisticians are now fairly well reconciled, and from elementary statistics one can at least understand the difference between "probable error" and "standard deviation" and the conditions of applicability of rules of thumb such as the rule of $\sqrt{N}$ for the fluctuation in large numbers or the expectation that in a random distribution one in a thousand will exceed the mean by three standard deviations.

Extracting periodicities from noise

An important application of statistics is to extracting trends and periodicities from data in which they are obscured by random noise. In the simplest case when the quantity which it is desired to determine is a constant, it is only necessary to average over a long enough time in order to make the effects of the noise negligible compared with the constant; but where there is a cyclically varying signal in noise, the technique generally known to engineers as auto-correlation (or the closely related function known to statisticians as auto-covariance) is now generally used in preference to Fourier analysis. It should be remarked that for a given quantity of information, i.e. number of frequency components and confidence limits on their amplitudes, the two methods will

Dr. D. A. Bell is professor of electronic engineering in the University of Hull which he joined at the beginning of the present academic year. He graduated in physics at Magdalen College, Oxford, and then spent 15 years in industry staff of the University of Birmingham. He returned to industry in 1961 as director of the research laboratory of A.M.F. then spent a year as visiting professor of telecommunications at McGill University before going to Hull.

require similar numbers of initial observations; but in terms of current techniques, and in particular the use of general-purpose digital computers in preference to special-purpose hardware, the auto-correlation method is usually more convenient. Early technical examples of periodicities were the annual variation of soil temperature, ocean waves and earthquakes. (The last is still topical, because the possibility of distinguishing the waves generated by a remote underground nuclear explosion from other ground vibration is of great political importance.) A more recent and directly radio application is to be found in the analysis of ionospheric variations which in the F region in particular appear to be almost as complex as the weather. In seeking mechanisms it is important to extract in addition to the sunspot cycle any periodicities which are daily, annual or related to the lunar cycle (atmospheric tides). In addition to identifying a periodicity, the statistical analysis should also establish confidence limits on its amplitude.

Communication system design

The statistical design of communication systems, based largely on the work of Shannon, Feinstein and Wiener, is a special case of seeking conditions in which the statistical confidence level approaches 100% (i.e., the risk of error is made negligible). Shannon's theorem for the limiting channel capacity in the presence of Gaussian white noise is easily derived, but the performance of finite coding systems is a more difficult statistical problem: infinite systems are often easier to handle than finite systems because many mathematical functions have simplified asymptotic forms when the variable tends to infinity. A related problem is that of "detection," i.e., deciding whether a signal is present, and this is an application of statistical decision theory. An example is the radar problem of deciding whether there is a signal (echo) present in noise. The waveform of the signal, if any, is known since it is determined by the transmitted pulse; and detection can then be based on the statistical principle of "maximum likelihood."

"White noise" is a familiar concept, but the only precise definition of it is a statistical one. In terms of frequency spectrum alone, white noise would be indistinguishable from a single narrow pulse, since both have a spectrum which is flat over all frequencies; and regarding white noise as the result of a large number of narrow pulses requires its properties to be deduced by a statistical analysis to take account of the random times of occurrence of these pulses. The use of white noise as a test signal, so as to apply all frequencies more or less simultaneously instead of one-by-one with a sweep oscillator, was applied to loudspeakers many years ago; and more recently band-limited white noise has been proposed for the testing of control systems ("Control system performance tester," by J. Good and G. Morgan, *Measurement and Control*, Oct., 1964, p. 373) giving a direct meter reading of r.m.s. error for random input signals within a specified bandwidth. This assumes, however, that no other signal is present and that the test signal is large compared with internal noise.

It is often desired to analyse process-control systems under working conditions when neither of these conditions is satisfied, and there are two methods of statistical analysis which have been used in such cases. In one method a random signal is applied to the system and its response observed. Since the permissible amplitude of the test signal is comparable with internally generated noise, the results require statistical analysis. In the other method the internally generated noise is used as the test signal, and a comparison of the fluctuations at different points in the loop gives an indication of the transfer characteristics of the elements between the points. In either method a further statistical analysis is needed to determine the confidence limits on the results or conversely the amount of averaging of readings which is necessary to attain a desired confidence level. (Two conferences on random signal testing, at the I.E.E. in London and at Southampton University, were reported in the August, 1965, issue of *Wireless World*, p. 384.)

Particles and molecules

So far statistics has been considered as a technique for minimizing the uncertainty arising from the imperfect observation of perfectly definite events or parameters. But modern physics will not assert the certainty of any single event on the scale of fundamental particles: it merely defines probabilities, and from these we use statistics to infer the magnitude and consistency of phenomena involving large numbers of particles. This most extreme aspect is relevant to solid-state devices, and is particularly obtrusive in the tunnel diode, the functioning of which can only be described in terms of replacing an absolute barrier by one which electrons have a certain *probability* of crossing.

In ordinary electrical conduction in metals or by electron beams we have a situation comparable with that in the kinetic theory of gases, which was the origin of "statistical mechanics." Mechanics is a branch of applied mathematics which can predict the future motion of a body if enough is known about the masses, velocities, positions and collision properties of all bodies in the system. (Note that at this stage we are thinking of bodies too massive to involve the uncertainties associated with fundamental particles.) But an explicit solution becomes impracticable if the number of bodies in the system is large; an example of a very large number of bodies is a gas regarded as a collection of "billiard ball" molecules—there are more than 10^{19} of them in every cubic centimetre of air at sea-level—so workers such as Maxwell and Boltzmann deduced statistical laws which describe the collective behaviour of such assemblies. These are the laws of statistical mechanics, which are based on the conservation of mass, energy and momentum and on certain postulates about the relative probabilities of comparable events.

Probability weighting systems

It is the modification of the latter—the postulates about probability—which allows statistical mechanics to be extended to systems of particles which must individually be described by quantum mechanics. The shot noise which was so well known in thermionic valves, and is also a factor in solid-state devices which involve barriers, can be treated by classical statistical mechanics; but the electrical conductivity of metals, and Johnson noise, require quantum statistical mechanics because the behaviour of conduction electrons in a metal can only be described in terms of quantum mechanics. In case anyone unfamiliar with quantum theory might object that this is inconsistent, since there is only one kind of electron, it should be emphasized that the individual electrons obey exactly the same laws in the two cases: the difference in collective behaviour arises from differences in the probability weighting of the sets of possible events in the two cases. In fact the choice of the system of probability weighting defines a *kind of statistics* and one speaks of Maxwell-Boltzmann statistics, Fermi-Dirac statistics, etc. (There is also a general law that the results of quantum mechanics approach asymptotically the results of classical mechanics when the system combines sufficiently high energy with sufficiently low particle densities.)

A more vital field for the application of statistical analysis is the reliability of complex electronic apparatus. The development of missiles and spacecraft gave a great impetus to reliability studies, because in these there is little possibility of rectifying defects; and the comparative reliability of the physiological mechanisms of animals has provided a tantalizing contrast with the vagaries of electronic apparatus. Air traffic control is becoming too complex and rapid a process to be handled by human brains, and the problem is to design a computer reliable enough to be entrusted with the safety of hundreds of people. This problem has not yet been solved, but the smaller problem of controlling the landing of a single aircraft has been solved with sufficient reliability for the automatic-landing equipment of the Trident to be approved for passenger service. High-speed railways of the future may also depend on electronic signalling. If you are an air passenger, you do not work out the accident risk: at most you have an actuary do it for you if you take out flight insurance. But if you are an electronic engineer of the future you may have to calculate the risk of your electronic equipment failing and bringing disaster to an aircraft or high-speed train; so your statistical technique had better be sound!

I.T.U. CONFERENCE

CENTENARY YEAR PLENIPOTENTIARY MEETING

ALL but eight of the 128 member nations of the International Telecommunication Union were represented at the Plenipotentiary Conference held in Montreux, Switzerland, from September 15th to November 12th. During the past six years the membership has increased by 40 and most of the new member nations have received independence during that time. An indication of the change in the "balance of power" came within hours of the opening when a proposal by the United Arab Republic to exclude South Africa because of its "present policy of racial discrimination" from participating in the work of the Conference was carried.

Our reviewer of the I.T.U. book, "From Semaphore to Satellite," in last October's issue, said, "One of the avowed aims of the Union is to harmonize the action of the nations in working towards the better use of telecommunication channels. To have achieved that aim in a world of increasingly prickly nationalism . . . is a matter for legitimate congratulation." With the change in the "balance of power" the Union's task is obviously going to be more difficult.

A proposal to increase the size of the I.T.U. Council from 25 to 29 was accepted, after much debate, thereby giving three more seats to the African Group (D) and one more to the Asian-Australian Group (E). In the subsequent ballots the following member nations (votes received in brackets) were elected to serve on the new Council:—

Group A (Americas). Argentina (90), U.S.A. (88), Canada (87), Mexico (85), Venezuela (59), Brazil (57).

Group B (Western Europe). France (108), Italy (105), Switzerland (105), Federal German Republic (93), United Kingdom (88), Ireland (78).

Group C (Eastern Europe/Northern Asia). U.S.S.R. (94), Yugoslavia (90), Poland (79).

Group D (Africa). Morocco (87), Dahomey (74), Nigeria (74), Algeria (71), Ethiopia (70), Malagasy (65), Uganda (64).

Group E (Asia/Australasia). Japan (102), Australia (90), India (71), Pakistan (65), Lebanon (63), Saudi Arabia (55), China (52).

The Council is the Union's governing body and normally meets annually in Geneva. Among decisions reached at its inaugural meeting, held on November 11th, was an agreement that the African L.F./M.F. Broadcasting Conference (which met in Geneva during October 1964 but was abandoned for constitutional reasons) should reconvene in that city on September 19th, 1966, for three weeks.

By 64 votes to 39 the Conference agreed to retain the International Frequency Registration Board in its present independent form but to reduce the membership of the Board to five—one from each Group. A proposal by the United Kingdom to replace the Board by a Frequency Registration Department, although supported by the U.S.A., Federal German Republic and other western nations was rejected. The United Kingdom argued that as the processes of frequency registration were now well established and simpler a less expensive organization would be adequate. Isolated cases that required further examination could be considered by the Administrative Council. The I.F.R.B. is the permanent organ of the I.T.U. responsible for the recording of radio frequency assignments made by individual countries and advising them on the avoidance of harmful interference between radio stations. In the words of the I.T.U. Convention, its members serve "not as representatives of their respective countries, or of a region, but as custodians of an international public trust."

The new members of the Board are F. Dellamula (Argentina), R. Petit (France), I. Petrov (U.S.S.R.), A. Berrada (Morocco) and T. Nishizaki (Japan).

In a series of resolutions, the Conference called for methods of improving technical co-operation, the improvement of Union facilities for providing information and advice to new or developing countries, and the application of telecommunication science and technology in the interests of such countries. One resolution, concerning telecommunications and the peaceful uses of outer space, stated that it was highly desirable that all countries should have equal opportunity to use space radiocommunication facilities. The Conference also stated its opinion that centres for the study of space communications should be established as soon as possible in the different regions of the world.

A proposal by the U.S.S.R., which received a good deal of support, to change the word "International" in the title of the Union to "World" was rejected after a spirited discussion.

Mr. Gerald Gross, secretary-general of the Union for several years, has retired. The new secretary-general is Dr. M. B. Sarwate, deputy to Mr. Gross since 1959. He was elected in the fourth ballot. Dr. Sarwate, who is 55, is a bachelor of science of the University of Bombay and received his doctorate of philosophy in radio engineering at the University of Liverpool. After serving in the signals radio branch of the Indian Air Force during the war he held various government appointments in the field of telecommunications.

How Will Integrated Circuits Affect Us?

A DISCUSSION BETWEEN FIVE EXPERTS FROM DIFFERENT FIELDS OF ELECTRONICS

Participants (left to right): Dr. B. H. Venning (University of Southampton); Mr. G. C. Padwick (SGS-Fairchild Ltd.); Dr. S. S. Forte (The Marconi Company Ltd.,); Mr. W. A. Flack (Radio and Allied Industries Ltd.); and Mr. A. T. Lawton (E.M.I. Electronics Ltd.) **Interlocutor:** T. E. Ivall (*Wireless World*).

Ivall: It seems likely that integrated circuits will have a considerable impact on the present structure of the electronics industry. It has been suggested, for example, that all device manufacture may eventually be done by only three or four companies. Could we discuss the effect of this re-organization on the work of the various engineers concerned?

Padwick: What I see happening is that many present-day circuit designers will move in one of two directions—either into device design or into systems design. Similarly, many logic designers will also move into the fields of device design or systems design. By the end of this decade I think we shall probably see just two categories: the device designer, covering the whole field from basic materials through to an understanding of circuits, and the systems designer, who will be taking complex functional blocks and joining them together to make systems.

Forte: The electronic equipment industry seems at the moment to be in a state of being pushed from buying "building bricks" into buying entire "walls." The one fear in the industry which is very marked is that it will finish up by buying the whole "house." This means that eventually we shall have an equipment industry which consists of no more than purchasing agents. Another fear in the U.K. at the moment is that a lot of these "walls" and "bricks" have to be bought from across the water, and even if they are being made under licence in Britain, it means that we are putting more and more of our design know-how into somebody else's hands. There may be fields where design is a relatively simple process for which you can buy standard functions, or conglomerations of functions, but there are still a lot of areas where you can't dispense with individual design, and while I agree with Mr. Padwick that basically we will lose the circuit designer as such, I think that if equipment manufacturing firms effectively have nothing but systems designers they will find themselves in a very peculiar position quite soon.

Padwick: Can I take you up on that? First of all, the integrated circuit as we know it today is accepted because it is economic to use it. A lot of people in equipment manufacture today certainly resent the idea of being supplied with these "walls," but the time will come when economically it is worth their while to accept them. They will be able to make their equipment cheaper, and therefore sell it more competitively, and so make more profit. There is no question of forcing. This will come through economics.

Forte: But economic pressure *is* forcing. It's forcing by dint of giving people almost no alternative because the thing is so cheap. The problem is, of course, that if everybody buys the same "walls" you are not going to get very different equipments.

Lawton: I cannot see the state of affairs spoken of by Mr. Padwick occurring within five years. He was obviously talking about digital systems, but remember that in present-day practice 90 per cent of all circuitry used in the electronics industry is analogue. You will not invade that side of the business as fast. I would suggest ten rather than five years.

Flack: May I come in at this point? I represent the down-to-earth entertainment field—a branch of the industry which is worth something over £150 million a year retail—and that can't be ignored. From the previous remarks I gather we have nothing to fear from integrated circuitry. It's only the computer manufacturer who will be getting rid of his design staff and buying all his "bricks" and "walls." Would you say that was correct?

Padwick: No. First of all nobody has anything to fear from integrated circuits. We all have a terrific amount to look forward to. Secondly, nobody is going to lose jobs. What I am saying is that people are going to be diverted more into device design or into system design.

Flack: Perhaps I shouldn't have used the word fear. I was thinking rather of the possibility of our having to face a considerable change-over in production or assembly techniques.

Lawton: On this question of people using similar systems, will it be as a result of technical excellence or because of other expediences? Dr. Forte is obviously worried by the possible domination of the British electronics industry by American-financed companies. If, in fact, the best system emerged from a purely British manufacturer, what would be the reaction of the American companies?

Padwick: Our experience of the American industry is that it is based very much on economics. Where equipment is available from Britain which is superior and economically advantageous, it is sold in the United States. But I think we were trying to discuss what was going to happen to the consumer industries.

Flack: Yes, my impression was that your eyes were solely on the computer field, and while I appreciate the reason why integrated circuits have gone into that first, we can't ignore the consumer side.

Padwick: Nobody is ignoring it. When integrated circuits were first conceived the attractive thing to do was to try and make two or three different circuits which could be sold in tens or hundreds of thousands, and the obvious field for this was digital computers. But we have now moved on from there. There are already integrated circuits used in consumer goods—for instance in hearing aids—and we have heard about them in audio amplifiers and other parts of radio equipment. The consumer industry will certainly accept integrated circuits, when they are economically justifiable.

Flack: How soon will that be?

Padwick: It has already happened with hearing aids.

Flack: But that is a special case, where price is no object.

Padwick: A special case, yes, but it is not true to say price is no object. In other things I think we shall begin to see developments within the next year or two.

Forte: Isn't the problem in the consumer industry basically the problem with most linear systems—that there are a variety of functions which you can't (or haven't been prepared to so far) standardize. For instance, you don't normally find a standard i.f. strip in every radio receiver, do you?

Flack: That is correct.

Forte: If you are going to accept integrated circuits into consumer products, you will have to standardize much more. The other problem, of course, is that in the sort of circuits you use there will always be a large proportion of functions which are not amenable to microelectronics —tuned circuits, mechanical switches and so on—and it may well be that the amount of circuitry which *is* amenable is going to be still quite small. So you will not get the impact in the consumer field that we do in the computer field.

Flack: But this business of standardization can only be achieved by economic arguments. If you can prove that by standardizing you can save 6d or 1s in the construction, you will get standardization. All equipment manufacturers have differing production techniques, and many of their designs are conditioned by those techniques. *We* happen to have a technique which is different from any other manufacturer, and we take advantage of it.

Forte: This question of cost obviously comes into it. You will never get a cheap integrated circuit for a particular application unless there is a large market.

Venning: Isn't the domestic market surely the one portion of the analogue field where you can expect standardization?

Forte: It hasn't occurred so far!

Venning: No, but won't we be forced into it, economically?

Flack: I say again that economy will bring standardization. Each manufacturer believes that he has the most efficient and the most economical method of assembly.

Padwick: In terms of present day discrete components?

Flack: Yes, but obviously we all have different costings; we don't produce everything the same way. Who is to judge which is the best system, which is the most economical?

Padwick: Two or three months ago a half-watt output stage for an audio amplifier was announced in a single-chip form. This is surely an indication that these things are possible.

Forte: Yes, here is one particular circuit, but you can't really see an equipment manufacturer like Mr. Flack's company changing his entire production to accommodate one thing only.

Flack: No, but if changing over to this half-watt output stage would show an economy over using either a pair of transistors or one large one plus all the components, I can assure you that everyone would be using it.

APPLICATIONS PROBLEMS

Ivall: The electronics industry seems to me a rather inward-looking one. It's full of enthusiasts, all concerned with their own bits of technology, who don't concern themselves very much about the applications of their work to the outside world. Do you think this new field of integrated electronics will make any difference here? It has been suggested that, as a result of standardization and so on, it will allow more time for the electronics engineer to think about these wider things?

Forte: One of the things we find is the resistance of circuit designers to other people telling them their job. When we started work in integrated circuits, you could buy them off-the-shelf from manufacturers **a, b, c,** If the little black box didn't do exactly what you wanted, it was just hard luck. What was inside it and how it performed in detail was not supposed to be any concern of yours. So the circuit designers in the company felt that they didn't have a proper grasp of the thing. They'd been able to specify their tolerances, their linearities and so on for a very long time, and they just didn't like the feeling that here was somebody else doing it for them. This is why, in fact, as an equipment manufacturer basically, we have started our "component" manufacturing facility, because "components" are no longer components, but sub-systems. Having now started to sell these things, we have put ourselves in the position of the manufacturer of the black box, but the last thing we want to do is to tell people: here is a black box; use it and lump it. That's why we have set up an applications facility. We work very closely with the designer to enable him to specify exactly what he wants. This doesn't mean to say we could make every single little thing every designer wanted, because this would be completely uneconomic. And obviously we try to guide the designer into doing the things we feel are better from the economic point of view.

Lawton: This applications backing has got to be much more clearly defined, because, as Forte has said, you're dealing with sub-systems, not components. Our own experience has been that with components it is the customer who finds the shortcomings of the product, not the manufacturer. And now it is the customer who is finding the shortcomings of the integrated circuits, more than the manufacturer—simply because the customer has a far wider range of applications than possibly the original device designer dreamed of. Consequently the organizational structure between consumer and producer has got to be much closer than it has been in the past.

Padwick: Yes, people do use integrated circuits in ways in which the manufacturers perhaps hadn't thought of doing. And they have difficulties. But these are eliminated through close co-operation between the equipment designer and the integrated circuit manufacturer's design and application engineers.

Forte: This, of course, raises another thorny point. People have applications which they don't always want to reveal to their competitors. So the applications service has to be a very commercially secure one.

Lawton: Another problem you have to avoid is the pitfall of designing to unspecified parameters, which is very easy with this sort of system.

Ivall: What about the ultimate user—the man who knows nothing about electronics at all?

Padwick: Because of the improvement in reliability the ultimate user has to know and care less about what is inside the equipment than he had to previously. This has improved his morale no end.

Lawton: Yes, I agree with Mr. Padwick in that respect, but he also has to make a much more careful initial choice of his manufacturer.

Padwick: There's a difference between American industry and British industry in this respect. There are a lot of companies in America who are prepared to assess an integrated circuit fairly quickly and go ahead and use it. In Britain there are far too many equipment manufacturers who'll spend months and even years assessing and comparing integrated circuits.

Forte: I think there's a very good reason for the American equipment companies pushing ahead—they've got everything on their doorstep.

Padwick: Let me quote a specific example in our company. When the new complementary transistor micrologic family was first produced our digital systems research group got some elements straight off the production line and assembled them into a fairly big data processing system. They did very little detailed design, and, of course, they had some problems, but the thing worked, after a very short debugging effort. But this could just as well have been a *digital* computer company.

Lawton: The equipment designers committed themselves to your system of integrated circuits.

Padwick: Yes.

Lawton: But what would happen if, say, another equipment maker committed himself to a system and decided that this was ideal, and then the manufacturer ceased manufacture? This is the whole problem. If a component manufacturer goes bust, there's usually a second source of supply.

Padwick: Let's be realistic. There are, as was said at the beginning, only relatively few device manufacturers. If you buy your integrated circuits from one of the well-established manufacturers, they're going to continue in production.

G. C. PADWICK

". . . nobody has anything to fear from integrated circuits. We all have a terrific amount to look forward to."

Forte: It has been pointed out already that American industry is highly economic-conscious. Now if economics dictate that the profitable thing is to buy a certain type of logic and everybody starts buying that type of logic, and if there are one or two British companies who (because they've designed their system painfully and slowly as is their wont) have adopted an earlier type of logic, and then you or any other American company decides that it is not worthwhile pursuing this whole line of production for one or two small British manufacturers—what happens then?

Padwick: Theoretically this can happen. In practice it hasn't. Any established line of integrated circuits is available from a second source now.

Lawton: I think you're over-generalizing. Some of these second sources are doubtful in the extreme.

Padwick: They may be doubtful right now. But all these second sources are sincere about it. They *are* supplying.

TRAINING FOR A NEW TECHNOLOGY

Ivall: Would anyone like to talk about the effect of this new technology on the training of electronics engineers?

Venning: It's really up to the companies in the electronics industry to undertake a lot of this training—especially if they want to give people confidence in the use of integrated circuits. Have any of the large firms taken it upon themselves to bring in designers from other companies and train them?

Forte: One of the functions of our applications laboratory is just that. An example of this, but within the company, was an airborne receiver we made some time ago. It was done in co-operation with our Aeronautical Division, by having one of their engineers working in our lab. But we are also doing the same sort of thing with other companies.

Venning: Strictly speaking this retraining is the function of the organizations concerned with training—the appropriate faculties of the universities, the CATs and the technical colleges—but very few of these establishments have, in fact, got the know-how necessary for organizing courses aimed at retraining mature engineers, so we would have to rely on help from the manufacturers who *have* got this know-how—and the applications.

Padwick: How are you proposing that they should be retrained?

Venning: It is a matter of trying to recast their thoughts, to get them used to the systems approach instead of the individual component approach.

Lawton: I suppose it is an exaggeration to say that the future engineer won't really need to know Ohms Law! But certainly we are experiencing this change, that people are becoming more interested in systems. It's not until a system is almost completed that the elementary calculations come into it.

Venning: This depends. The analogue integrated circuits which one can foresee getting will in fact nearly all have to have components built around them, in order to refine their capabilities. The kind of thing I mean is feedback systems, for example, where you'll just have the one block in the middle and somebody's then got to synthesize the whole of the design around it. This will certainly need more of Ohms Law than we've had in the past. The new design approach will not now be concentrating on getting the right current going through the right transistor and keeping the power dissipation within limits. (By the time the chap's done that he's so fatigued that he can't bother to do his advanced circuit design to make certain the system is stable and so on.) No, in future you're going to have to have your block all prepared, with defined currents and power and so on, and you will then be able to put the whole of your design effort into getting the right stability criterions.

Forte: Are we going to get a generation of engineers, then, who will not know the first thing about a basic amplifier circuit?

Venning: No, I don't think so. Particularly for analogue applications, you cannot satisfy everything with standard blocks. And if you're going to build up a conception of circuit design you must make people familiar with the basic circuit elements.

Lawton: It will be a question of placing different emphasis on different parts of the same course.

Venning: This means that we've got to reject some things from the present courses and we'll have to pay more attention to the way we teach these things, to get more useful material into the given three years. I think, too, we shall have to accept the idea of more post-graduate and in-service training.

Padwick: Electronics moves so rapidly that we can talk today about training engineers to use transistors and integrated circuits, but in five years time, by the standard evolution of the industry, something else is going to break—or possibly before that. The engineers we're training today at university level must be prepared in their thinking and basic knowledge to take up whatever else happens.

S. S. FORTE

" Are we going to get a generation of engineers who will not know the first thing about a basic amplifier circuit?"

Lawton: Many of our trainees complain that even now their electronic lectures are top-heavy with thermionic valve techniques.

Venning: But things have certainly improved within the last few years. Many of the colleges are putting a lot of effort into materials technology, for example. The difficulty is, I think, that for many years you are going to get physicists who will know a lot about the materials side and relatively little about circuit design. And you will still have the legacy of a lot of the older type of electrical engineering light-current courses which will not give sufficient emphasis to the sort of physics which you need for materials technology in integrated circuits.

Ivall: You're speaking now in terms of training the device designer rather than the systems designer?

Venning: The function of a university ought to be to turn out the two types of people—or people who may go either way. The person who is going towards the device side probably will have had the sort of interest to embark on a physics course or physics plus electronics. He might come to us to get the type of electronics degree in which we combine electronics and physics, as opposed to electronics and electrical engineering. The systems designer will probably be the man who's embarked on the electronic engineering type of course. But both of these have got to come together in the middle. The systems designer has got to buy his elements, he has to be able to understand the jargon of the device manufacturers, so he's got to have a good knowledge of what the various processes are and their different characteristics. And the device engineer, now that he's concerned with integrated devices, has got to know something about circuits.

RELIABILITY OF INTEGRATED CIRCUITS

Flack: Mr. Lawton, I seem to remember that at the I.E.E. meeting in May, the major part of your lecture was devoted not to the benefits offered by integrated circuits but to all the troubles that you had experienced with them. Anyone coming in at that time would have had considerable doubts as to their reliability.

B. H. VENNING

". . . . the small man is the one who stands to lose most if he gets a bad batch and uses it without realizing it."

Lawton: In some of the examples I described they would be quite justified in having those doubts. I have learnt since I am not the only equipment maker who has done such assessments and found that there are good and bad manufacturers. Despite some of the propaganda we have heard from integrated-circuit manufacturers, there are good and bad boys in this industry just as there are good and bad boys in the components industry. The trouble is that it is often very difficult to detect just who the bad boys are. One of the dangers of microelectronics is that the reliability that can be achieved by these systems is very high indeed, but because of this, the complexities of failure and the mechanisms of failure can be somewhat masked. For example, early technical reports seem to suggest that the Atlas-Agena failure which wrecked the recent Gemini programme was, in fact, due to the failure of an integrated circuit. But the peculiarities of failure are special in many respects to the realms of integrated electronics.

Padwick: We must get this question of failure and reliability in perspective. Of course integrated circuits will sometimes fail. But people must understand that the interest in the reliability of integrated circuits is *because* they are so very reliable, compared with conventional components. I don't want anyone to go away with the idea that reliability is a problem in integrated circuits.

Lawton: But I don't want people to get the opinion that seems to prevail at present that it is a *fait accompli:* it is not.

Forte: It seems to be a basic property of integrated circuits, that, provided you have a tight degree of control in your manufacturing processes, you will get a reliable product.

Lawton: That is the whole point. You are making a product which is amenable to the regulations of quality control as much as any other product—more so, because the consequences of failure are even more disastrous.

Forte: No, but it is much more amenable because you're making your complete piece of electronic equipment, your sub-system, under one control. You haven't got resistors made in one place, capacitors in another place, printed-circuit boards somewhere else, and all put together in a fourth place. You have under one roof one continuing quality control process—not a thousand different ones.

Lawton: And, of course, you're working with fewer materials. Look at the number of materials used in the ordinary components industry—a fantastic mixture of organic and inorganic products. In a plain resistor, you'll find something like 18 interfaces in the construction of the complete component.

Flack: The fact that everything is under one roof and you have good control may give you the impression that you're controlling everything, but I can't really see that this is the sole reason for high reliability. Many years ago there were equipment manufacturers who decided to produce every one of the components that went into their products. And everyone, without exception, made a flop of it. It was far too complex for them.

Forte: Because you had a large variety of different materials and processes.

Flack: But it still comes back to quality control.

Forte: In addition there is the fact that nobody, as yet, has found a characteristic failure mechanism in integrated circuits.

Lawton: In the semiconductor chip?

Forte: In the actual silicon. All the failures which have been proved so far have resulted from lack of control on the production line. The conclusion is very simple—that provided you have enough samples to check and you feed back enough information to the quality control, you can eliminate all the failures.

Flack: But surely, doesn't that apply to all methods of manufacturing electronics?

Forte: This is a diversified quality control.

Flack: That may be, but it's a question of quantities. With large-value capacitors, for example, the very volume of the production demands that you have separate factories to manufacture these items. You couldn't manufacture them, for instance, as part of your integrated circuitry.

Venning: Don't you think there's a need for some organization to guide the smaller manufacturer in the testing of integrated circuits? The big firms obviously have their own test facilities, but the small man whom you're trying to encourage to use these devices is the one who stands to lose most if he gets a bad batch and uses it without realizing it.

Padwick: There are plenty of examples of relatively small equipment makers who've bought integrated circuits on the reputation of the device manufacturer, and have gone ahead, designed and made, and have had no significant problems—everything worked.

Forte: The real problem is at the ultimate customer. He doesn't want guarantees of quantitative failure rates. He wants guarantees backed by money. But it is a very difficult thing to give a financial guarantee of the reliability of an equipment if you only have the word of some other manufacturer for the components.

Lawton: Mr. Padwick is probably quoting the happy experience that customers have had with his company. It would be interesting to hear the views of other customers on their experiences with other companies.

Flack: In the long run, of course, the bad manufacturer—the one who produces faulty integrated circuits—will go to the wall.

Lawton: The trouble is, he may take a lot of the little men in equipment manufacture with him.

Flack: I believe you have said, Mr. Lawton, that the main weakness in all current integrated circuitry is the interconnections with the outside world. What degree of reliability would you consider necessary here? I've been connected with a project in a Government establishment where they were assessing the reliability of soldered joints. They have well over half a million soldered joints which are being treated in the usual manner over a wide range of temperatures. The current tests are approaching something like 10^9 joint-hours without any failures. Now I believe that represents a very high degree of reliability.

Padwick: It's certainly possible to make very good and reliable soldered joints.

Lawton: And welding is a method of interconnection which can be done very badly.

Forte: Yes, welding has been publicized as the cure to all our problems, but I think this is a great fallacy. If as much time and effort were spent on quality control of soldering we'd get some very good joints—we do, in fact.

Lawton: This does emphasize the importance of control. With the small dimensions of some of these soldered joints, problems which weren't really problems before—because the joints were saturated by a mass of tin and lead—are tending to come to the fore. For example, gold-tin alloying can cause trouble.

HOW DESIGN WORK WILL BE DIFFERENT

Padwick: One way in which design work with integrated circuits is going to be different is in giving a much faster turn-round between the conception of the system and its being manufactured. This is because the integrated circuit simplifies every stage of design and production. So now the designer is going to see his equipment actually made before he has forgotten about having designed it.

Lawton: But because design with integrated circuits has this high efficiency, it should not be tacked on to existing facilities—which is a common mistake a lot of people are making.

Forte: What exactly do you mean by that?

Lawton: Well, how did your microelectronics group start? It started as an addition to the semiconductor group, but it rapidly emerged as an area in its own right. Many manufacturers are tending to tack it on to an existing design area, and this is wrong.

Venning: It's now possible to make considerable use of computing methods in design if your engineers have been trained in them—if they've already used digital computers to do a lot of their laborious arithmetic. If we train them early enough they'll automatically think of this—partly for reliability, but certainly for design optimization, which can now be tied in with your quick turn-round.

Lawton: Yes, but optimization of design to a more refined degree within the time period allocated. This has always been a problem—getting your design sorted out to a degree which satisfies the designer but in a time period which satisfies the manager of the project.

Ivall: Do you think redundancy techniques are likely to be used more in systems, now that it's possible to make thousands of circuits very cheaply?

Padwick: The reason redundancy is used in systems is because the reliability of the hardware isn't high enough. Integrated circuits give us at least an order, probably two orders, of improvement in system reliability. So, although the more complex functions permitted by integrated circuits give the possibility of making redundant systems economically, the necessity for redundancy is actually less.

Forte: I think you might use redundancy for a different reason here. As the device manufacturer makes more and more complex circuits, he will inevitably have problems of yield. Perhaps you could build redundancy into your systems to help. The reason would, therefore, be purely one of economics.

A. T. LAWTON

". . . design with integrated circuits should not be tacked on to existing facilities—which is a common mistake a lot of people are making."

Lawton: We may also find that these complex circuits will give us the space to have redundancy in connections, because the more complex the function you put inside a package the greater the onus you place on the equipment manufacturer to make reliable connections with it. Already the standard package has a reliability of over 0.01% per thousand hours in an average environment. This means that if it has ten leads, you've got to guarantee that each lead joint has a reliability of 0.001% per thousand hours if it is just to keep pace with the circuit. So as the circuit becomes more and more complex, this inter-connection reliability has got to outstrip the circuit reliability by the same factor.

Forte: We're now coming to the real problem in microelectronics—the packaging and connection problem.

Flack: It is certainly a step in the right direction that you're making these packages larger than they used to be. I would say that a 0.1-in grid spacing is probably quite satisfactory, but if you want to improve things even further then we should go up slightly larger, purely for the sake of the terminations.

Padwick: I don't know whether the package we've designed for the computer field is suitable for consumer applications, or whether we're going to have to think about packaging particularly for consumer equipment. Nobody's really tried to do this yet.

Forte: People are talking about fabricating a complete computer on a semiconductor slice, so that you don't have to dice up the slice or make interconnections.

Lawton: I don't think this will be a practical possibility for some time to come. But more cunning methods of interconnection of the slice are likely to emerge.

Venning: This question of yield brings us back to tolerancing in circuit calculations again, which has been largely ignored in the past or only catered for in worst-case design. You're very much concerned now with circuit design bringing in tolerancing just to get the yield up. It really brings the economics back to the circuit calculations.

Lawton: It also means that tolerancing once again is done in one area, and is not a multiplicity of people's ideas on tolerancing. Therefore, if it is a rigorous analysis it is a good analysis.

Venning: Let's not forget the systems designer in all this. What about the man who works completely on his own, for example—the small manufacturer who gets the devices off-the-shelf?

Padwick: There's a very big future for him. He's the man who can work very quickly. Most of his tolerancing problems are taken away from him. He's got thoroughly worst-case designed components that he can join together quickly—and out of the door goes his product.

W. A. FLACK

"It is certainly a step in the right direction that you're making these packages larger than they used to be."

Lawton: That is looking at the theoretical aspect of design. What you do not emphasize is that he is then saddled with problems of how to put his equipment together—and this is where specialist knowledge is required. You may shake your head, but this is true. The little man cannot purchase this specialist knowledge economically, but the big company can, because it carries it as an in-house facility.

Flack: This is very similar to when transistors first came in. They coincided with the advent of printed circuitry, and an enormous number of small manufacturers set up to produce transistor radio receivers. They did very well for about 18 months. Some lasted a bit longer.

Lawton: There's one way in which the man who wants to work alone may survive. If he is an expert and has original ideas, he can well work as a retained consultant. But on his own completely—I don't think so.

Padwick: Many of the problems of the small equipment maker are solved for him already by the sensible use of outside services—of printed-circuit boards in particular.

Lawton: But if he's buying all these outside services, how does he make any profit? Apart from that, you're still making a very big assumption—that all the things he wants are existing and available.

Padwick: If he has a sensible approach to design, he'll use integrated circuits only where they'll do economically what he needs to do. He'll even use valves if he has to.

Venning: I think the small man would find a market, because there are always the one-off, two-off jobs, the instrumentation problems, for example, which the big firms just will not look at.

Forte: But he won't be able to afford it, because his costs in getting boards designed and buying in circuits for the one-off, two-off jobs are going to be prohibitive.

. . . AND FOR THE AMATEUR

Ivall: It has been suggested that integrated circuits will eventually be available on the surplus market for the amateur constructor to buy. Do you think this will be so?

Flack: I think it will be a long time before *Wireless World* can have designs for the amateur using integrated circuits.

Padwick: I don't agree on that. I seem to remember that around 1956-57 when transistors were first available they cost two or three pounds each, didn't they? Well, integrated circuits are getting to that sort of price already.

Lawton: Yes, but then you were dealing with a component. Now you're dealing with a sub-system. How many amateurs want to use the kind of sub-system that you're going to sell cheaply? But if you started producing audio amplifiers for about ten shillings each you'd probably sell a great many of them in this market.

Padwick: But the amateur is interested in making all sorts of gadgets to do different things.

Lawton: Yes, but how many of them are based on logic? Very few surely.

Flack: But there must be a surplus market sooner or later because we've already agreed that the small manufacturers are going to go bankrupt!

Lawton: It's quite possible there'll be a degree of re-education amongst amateurs because I feel sure that a large percentage of them do think in analogue terms rather than digital terms. You may get your surplus circuits absorbed as time goes on, but it won't be immediately.

Padwick: I wish we had a surplus. . . . But I see Mr. Ivall is about to switch off the tape recorder. . . . Before we close may I just say I am convinced that, for amateur and professional alike, integrated circuits are going to make electronics a lot more exciting and a lot more interesting in the future. [*And with general agreement on this sentiment the meeting ended.*]

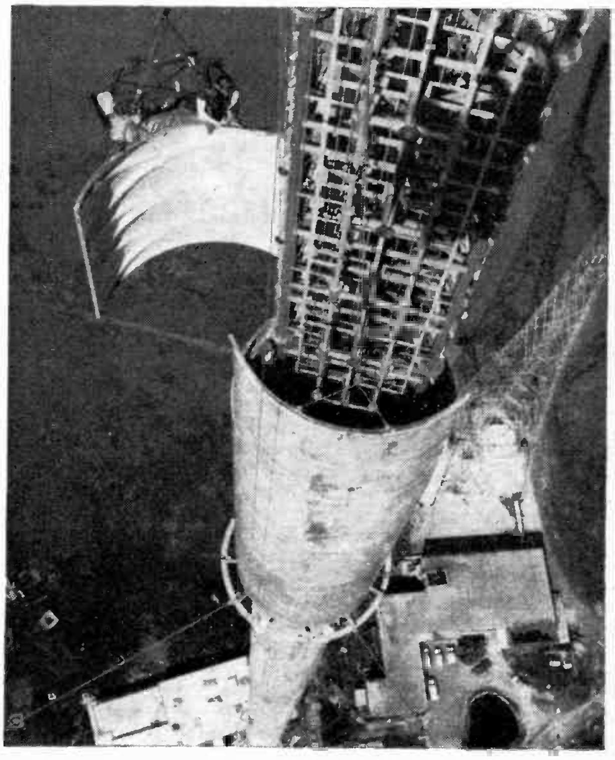
WORLD OF WIRELESS

A Single TV Standard for the U.K.?

A TECHNIQUE called "pulsed sound" is being examined by the B.B.C. as a possible means of compressing the bandwidth of 625-line television transmissions. By this means the present 8 Mc/s channel width might be reduced to 6 Mc/s or even 5 Mc/s. The technique was described briefly by G. D. Monteath of the B.B.C. during a discussion meeting at the I.E.E. devoted to the problem of achieving a single television standard—that is, a 625-line standard—for the U.K. The significance of being able to compress the transmission bandwidth, by this or any other method, is that it would enable a greater number of 625-line channels to be accommodated in the v.h.f. television bands than would otherwise be possible. Four 6 Mc/s channels could be squeezed into Band I and up to eight into Band III, provided the bands were stretched a little and some degradation of picture quality was accepted. The v.h.f. bands may have to be utilized because it is not yet certain whether complete national coverage can be obtained on u.h.f. (see p. 38).

In the pulsed sound system (originally proposed by Pye under the name Videosonic), the existing sound carrier is eliminated and the audio information is transmitted by pulse-position modulation of special sampling pulses added to the television waveform. Each sampling pulse consists of one cycle of 1.2-Mc/s a.c. and is positioned on the back porch of the line sync pulse. Since the sync-pulse, and hence the sampling-pulse, frequency is approximately 15 kc/s, the upper limit of the a.f. response is about 7.5 kc/s. Possible difficulties were envisaged by people taking part in the discussion—for example, interference on flyback or with a colour sub-carrier.

Two other possibilities for achieving a single standard were considered: duplication of programmes on v.h.f. and u.h.f.; and channel sharing by the use of precision offset—a refinement of the offset method already used for channel sharing by two geographically separated transmitters but involving relative positioning of the field-frequency sidebands as well as the line-frequency sidebands.



Approximately 1,000 ft. above the ground, workmen of the British Insulated Callender Construction Company are shown lifting a 12 ft. diameter glass-fibre segment to cover the aerials in the top section of the new I.T.A. mast at Winter Hill, Lancashire. The date at which the mast is to be put into service is as yet unknown.

B.B.C./I.T.A. Joint Colour Service?

A JOINT B.B.C./I.T.A. national colour television service on the present BBC-2 channel, showing appropriate and good quality programmes contributed by both organizations, is proposed by F. E. Jones, Managing Director of Mullard Ltd. Addressing a member of the Government, Roy Jenkins, Minister of Aviation, at the opening of the redesigned Mullard Electronics Centre in London, Dr. Jones said: "We feel that the Whitehall red light has already been shining too long on the matter of colour television" and asked Mr. Jenkins to persuade the Prime Minister to "take the brake off this particular sector of industry . . . for even the present delay has been very costly to the industry and the economy of this country." Mr. Jenkins opened the Centre without making any reply on colour television.

European Colour Indecision

THE Television Advisory Committee has recommended the PAL system for the U.K., but the Postmaster General has not yet made his decision known. It had been hoped that this recommendation would have facilitated the reaching of an international agreement during the recent 3-day meeting of the European Broadcasting Union in Rome. Six countries were represented and the three systems—PAL, SECAM and N.T.S.C.—were discussed by 32 experts. However, no decision was reached and it appears that the expected introduction of colour in this country in 1967 will not materialize. Further discussion will take place in Rome, probably during next March.

1966 London Radio Show

PLANS are well advanced for an international television and radio show to be held at Earls Court from August 22nd to 26th. Organized by Industrial and Trade Fairs Ltd., the exhibition will be open to trade visitors only. Invitations to exhibit have been extended to home and overseas manufacturers of television and radio receivers, audio equipment, radiograms, records, record players, tape recorders, musical instruments, transmission and studio equipment, and allied products and services. The decision to stage the exhibition, in spite of last year's abortive attempt, is based on the result of a country-wide poll of dealers' opinions conducted with the co-operation of the Radio and Television Retailers' Association.

Services Equipment Criticized

"IT is clear . . . that . . . for many years British troops have been compelled to use unsuitable and out-of-date wireless sets. What is not so clear is why this situation was allowed to develop." Thus the Commons Estimates Committee, in its report on electrical and electronic equipment for the Services, summarizes its findings on the use of manpack sets in the Army. The h.f. "62" set, which came into service in 1944/5 is still in use, its replacement, the A13, having been delayed several years before being ready for service. Incidentally, the 62 set, which weighs 59 lb, was designed for mules and vehicles. The Committee's report occupies 50 pages, but the evidence published with it runs to over 275 pages.

Among the Committee's 21 recommendations is one calling for a review of the security classification of equipment and a regular reclassification "with rapidly evolving techniques, a piece of electronic equipment may be highly secret one year, and almost obsolete the next." It is pointed out that Departments refusal to disclose classified information is not "because disclosure would prejudice national security, but because it might cause departmental inconvenience."

Two Scientists Honoured.—In 1927, the "Davisson-Germer Experiment" was demonstrated showing that electrons had the wave-like property forecast three years earlier by Louis deBroglie in France. Subsequent observation of the property formed an experimental basis for "wave mechanics," the theory that has successfully explained many of the properties of matter. These two American scientists have been honoured in the title of a biennial award, the "Davisson-Germer Prize," which has been created by the American Physical Society and Bell Telephone Laboratories "for outstanding contributions in the fields of electron and optic physics." Dr. C. J. Davisson shared the 1937 Nobel Prize in Physics with Sir George Thomson for work on diffraction and wave properties of electrons. He died in 1958 aged 76. Dr. L. H. Germer perfected an electron diffraction spectrometer used to analyse the structures of a variety of materials, and he studied and described the crystalline structures revealed in photographs of surface diffraction patterns. In 1961, Dr. Germer retired from Bell Laboratories and is now Visiting Professor at Cornell University.

Rugby Transmitter to be Modernized.—During the first six months of 1966, the time signal service provided by the Rugby v.l.f. transmitter GBR on 16 kc/s will be withdrawn to enable the transmitters to be modernized for frequency-shift keying. The service will be transferred to the Criggion v.l.f. transmitter GBZ on 19.6 kc/s. In addition to the existing i.c.w. morse code transmissions on 16 kc/s, it is intended to transmit 50 baud (element length of 20 ms) by frequency-shift keying using frequencies of 15.95 kc/s and 16 kc/s. The present accuracy ($\pm$ 5 parts in 10^9) of the 16 kc/s carrier will be maintained and the modifications will prevent a phase shift in the carrier when the aerial is retuned to change from either morse or f.s.k.

Apprentices at the Chelmsford & Basildon works of Marconi now total 838—an increase of nearly 100 on a year ago. This total includes 411 craft, 212 technicians and 143 student and 72 graduate apprentices. At the annual prizegiving on November 26th, Mr. Neil Sutherland, chairman of the company, said that an amount equivalent to over 5% of the company's payroll has, for years, been spent on education and training. Of the 538 apprentices who took examinations during the year 79% passed. A new apprentice award scheme introduced this year includes a "directors award" of £50 for the best overall record throughout the year (won by G. Evans who is 20), £25 to the top apprentice in each of nine groups and £10 for the runners up.

British Standard on Fixed Capacitors Revised.—"Fixed capacitors for direct current using impregnated paper or paper/plastics film dielectric" BS2131 has been revised. The standard, available from the B.S.I. Sales Branch, 2 Park Street, London, W.1, at 15s, gives uniform requirements for assessing the electrical and mechanical properties and the effects of climate on this type of capacitor. Test methods are described and capacitors are classified according to their ability to withstand tests specified in BS2011 which describes climatic and durability testing of electronic components.

I.E.R.E. in Canada.—The Canadian Division of the Institution of Electronic and Radio Engineers has established new headquarters at 504 Royal Trust Building, 116 Albert Street, Ottawa 4, Ontario (Tel.: 234-5513).

The Exploration of the Universe is the title of the Christmas lectures for young people (aged 10-17) being given at the Royal Institution, Albemarle Street, London, W.1, at 3.0 on December 28th and 30th, and January 1st, 4th, 6th and 8th (Fee £1). The lecturers will be Sir Bernard Lovell and Professor F. Graham Smith of the Nuffield Radio Astronomy Laboratories, Jodrell Bank, and Professor Martin Ryle and Dr. A. Hewish of the Mullard Radio Astronomy Observatory, Cambridge.

Two R.A.F. Colleges Amalgamate.—The R.A.F. Technical College, Henlow, will be amalgamated by January 3rd with the R.A.F. College, Cranwell. For many weeks, work has been in progress to move the five technical college wings—Basic Studies, Electrical, Mechanical, Weapons, Systems, Cadet—to new study quarters costing over £2 M at Cranwell. The Cranwell-Henlow merger was decided four years ago to combine the high-grade instructional staff and equipment so that cadets of the general duties and technical branches could share the best training facilities available. The move is probably one of the most complicated ever undertaken by the R.A.F. in Gt. Britain and by the time it is completed hundreds of thousands of different items worth millions of pounds will have been moved.

British Experiments in Explorer XXXI.—Two of the experiments in Explorer XXXI, an ion probe and an electron temperature probe, were provided by the Department of Physics, University College, London. Previous U.C.L. probes were included in Ariel I and Explorer XX. The satellite is making various ionospheric measurements in conjunction with **Alouette II,** a Canada-U.S.A. ionospheric-sounding satellite. The two satellites were launched simultaneously on November 29, from a Thor Agena rocket. The orbit is polar with an apogee of 3,000 km and a perigee of about 500 km, carrying the satellite(s) further into the magnetosphere than previous ionospheric satellites. Due to this deeper penetration it has already been determined that the electron temperature is around 5,000 °K and not 3,500 °K as predicted. One tentative suggestion is that the high energy is supplied by the solar wind via the magnetosphere.

The National Electronics Research Council has moved to 50 Bloomsbury Street, London, W.C.1. (Tel: MUSeum 2076/8.)

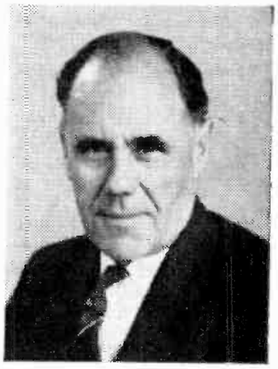
The television test card D for 405 lines has been modified to increase the range of brightness in the frequency gratings—all other characteristics remain unchanged. The modified test card is identified by a white dot on each side of the letter D.

For the Record.—Our attention has been drawn to a mis-statement in our November issue. Although Perdio have specialized in the production of transistor receivers they were not "the first British manufacturers" in this field. Pam, a member of the Pye group, marketed a transistor radio receiver in March, 1956.

"Active Impedance Converters."—We regret the error which occured on p. 604 of the December issue, the reference to "Filternics" (by Thomas Roddam) should read August, 1962 p. 370, and not 1960.

PERSONALITIES

P. H. Spagnoletti, O.B.E., B.A., M.I.E.E., who has been with Standard Telephones & Cables since 1929, when he joined as a development engineer, has been appointed director of business development. In 1945 he became chief engineer of the associated company



P. H. Spagnoletti

Kolster-Brandes and two years later was made general manager. In 1957 he started the components group at Foots-cray, Kent, of which he has been manager. The new manager of the components group is **D. Stevenson,** who has been with S.T.C. since 1955.

G. C. Rowley, A.M.I.E.E., has joined the Industrial Markets Division of Mullard Ltd. as assistant manager of the Computing and Telephone Exchange Market Department where he is concerned with the future component requirements of the computer industry. Mr. Rowley was with Standard Telecommunications Laboratories where he was in charge of their contribution to the D.S.I.R., now Science Research Council, scheme for long-range computer development. Previously he was chief engineer of the Elliott Computing Division and was at one time at the Royal Aircraft Establishment.

G. C. Rowley

Professor P. M. S. Blackett, C.H., emeritus professor of physics London University, senior research fellow, Imperial College of Science, London, and part-time scientific adviser to the Ministry of Technology, has been elected president of the Royal Society. Prof. Blackett, who is 68 and was educated at Osborne and Dartmouth, served with the Royal Navy from 1914 to 1919. He then studied at Cambridge and worked under Lord Rutherford in the Cavendish Laboratory until 1933. Since 1933 he has been successively professor of physics at Birkbeck College, London, the University of Manchester and Imperial College. During the last war he was seconded from Manchester to become a scientific adviser first to the War Office, then to the Air Ministry, and finally to the Admiralty.

Gordon T. Roberts, B.Sc., Ph.D., has joined Hewlett-Packard Ltd. of Bedford, as projects manager and is going to the Company's new plant at South Queensferry, near Edinburgh, which opens

Dr. G. T. Roberts

in March. After graduating in electrical engineering at Bangor, North Wales in 1954, he spent three years at Manchester University on post-graduate studies for which he received his doctorate. He then joined the Electronics Division of Bruce Peebles and Co. Ltd. in Edinburgh and from 1962 until his new appointment, Dr. Roberts, who is 34, was a lecturer in electrical engineering at Edinburgh University.

Dr. H. C. Husband, C.B.E., managing director of Husband & Co. of Sheffield, has received a Royal Medal from the Royal Society for "his distinguished work in many aspects of engineering particularly for his design studies of large structures such as those exemplified in the radio telescopes at Jodrell Bank and Goonhilly Downs."

Professor J. H. Westcott, B.Sc., D.I.C., Ph.D., M.I.E.E., professor of electrical engineering at the Imperial College of Science and Technology since 1961, has been appointed to the chair of control systems at the college. Professor Westcott was at the Telecommunications Research Establishment, Malvern, from 1942 to 1945. He then went to Germany for a year as senior technical assistant on the Control Commission. He has been on the staff of Imperial College since 1950 and was responsible for the setting up of the control systems laboratory. Professor Westcott has been chairman of Feedback Ltd. since 1960.

E. D. R. Shearman, B.Sc., A.C.G.I., A.M.I.E.E., since 1961 senior lecturer in electro-magnetism in the Department of Electronic & Electrical Engineering in the University of Birmingham, is the first incumbent of an additional chair established in the Department on October 1st. There are now four professors in the Department, of which Professor D. G. Tucker is the head, and it has nearly 120 graduate workers and staff in addition to students. Professor Shearman, who is 41, graduated at Imperial College, London, in 1945. For two years he worked on naval communications at the Admiralty and in 1947 went to the Radio Research Station of D.S.I.R. at Slough where he stayed until going to Birmingham in 1961. At Slough he was particularly concerned with radio propagation and the ionosphere and in 1960 spent six months in Canada assisting in the design of the ionosphere topside-sounding satellite, *Alouette*.

Max Settelen, Assoc. I.E.E., formerly manager (aviation) in the Radio Division of Standard Telephones and Cables Ltd. at New Southgate, has been appointed manager (aviation development).

Max Settelen

for the company and will be at the company's new Strand headquarters. Mr. Settelen joined S.T.C.'s associate company in Switzerland in 1945 on leaving the R.A.F., where he had been a technical signals officer. He transferred to S.T.C's Radio Division in 1948. He represents the company on the Electronics Engineering Association, and is on the steering committee of the European Organization for Civil Aviation Electronics. The new manager (aviation) in the Radio Division at New Southgate is **Kenneth W. King,** M.I.E.R.E., who joined the company a year ago from Rank Cintel where he was general manager of the Avionics Division. Previously he was with the Decca Navigator Company and before that A.C. Cossor Ltd. He served in the R.A.F. as a signals officer during the war.

Kenneth W. King

R. F. Champion, A.M.I.E.R.E., until recently group head of the Marine Communications Development Department of A.E.I., recently joined Redifon Ltd. as marine projects manager. Mr. Champion began his career in communications in 1942 as a student apprentice with Siemens Bros. subsequently becoming a development engineer in the Acoustics Department. In 1948 he transferred to the Marine Development Section of Siemens which later became a subsidiary of A.E.I.

R. F. Champion

Air Commodore John H. Hunter-Tod, O.B.E., M.A., who has been a signals specialist since joining the R.A.F. in 1940 after graduating at Cambridge, has been appointed Senior Technical Staff Officer, R.A.F. Germany. After various signals postings he was seconded in 1948 for research on the staff of Dr. Barnes Wallis at Vickers-Armstrong. Two years later he joined the Guided Weapons Department of the Royal Aircraft Establishment at Farnborough. Air Cdre. Hunter-Tod, who is 48, was on the staff of the British Joint Services Mission in Washington from 1957 until 1960 when he entered the Air Ministry where he has been Director of Guided Weapons (Air).

M. H. C. Lewis, who was recently appointed to the board of Radio Rentals (U.K.) Ltd., has been in the relay field since 1932 when he joined Broadcast Relay Services. Prior to joining the relay service he was a sea-going radio operator. In 1941 he was appointed chief engineer of the Relay Exchanges Group and he has been a director of several companies in the group for some time. Mr. Lewis is a founder member of the Society of Relay Engineers and has been an amateur transmitter (G2MM) since 1928.

M. H. C. Lewis

D. H. C. Scholes, who has been with Plessey since 1946, and for the past three years has been executive director and group technical co-ordinator, has become technical director. He was with Marconi's from 1932 to 1940 and during the war served in the Fleet Air Arm in which he became Lieutenant Commander. Mr. Scholes is a member of the research advisory committee of the E.E.A. and of the research committee of the Conference of the Electronics Industry.

W. J. Dalziel, production director of Plessey Group Management Ltd. and a deputy managing director of Automatic Telephone and Electric Company until the Group's re-organization a few months ago, has become director of manufacturing of the Plessey Company. He will now advise the managing director on all the company's manufacturing operations, both at home and overseas.

L. I. Charin, B.Sc., A.M.I.E.E., has joined Mullard Ltd. as a member of its Government Liaison Department. He obtained an honours degree in electrical engineering from London University in 1948 and after working on component design for E.M.I. was chief engineer of the Microwave and Electronic Instruments Division of Elliott Automation.

L. I. Charin

Air Commodore E. V. Stokes, C.B.E., B.Sc., deputy director (radio) at the Air Ministry and Ministry of Defence for the past three years, has been appointed Command Signals Officer, R.A.F. Fighter Command. Air Cdre. Stokes, who is 50, was commissioned in 1939 and became a signals specialist. After war service he was posted to the Air Ministry in 1946, and in 1951 went to the H.Q. Strategic Air Command, U.S.A., on an exchange posting for three years. He was appointed deputy director, guided weapons, at the Air Ministry in 1957 and two years later went to the Far East Air Force H.Q. as command signals officer.

Air Commodore C. R. C. Howlett, who has commanded No. 1 Radio School, R.A.F. Locking, since early in 1964, became Director of Air Armament (Research & Development) at the Air Ministry on November 1st. Air Cdre. Howlett, who is 50, is an armament specialist and before going to Locking was Superintendent of Armament at the Aeroplane and Armament Experimental Establishment at Boscombe Down, Wilts.

D. W. Pretious has been appointed chief engineer of Vactric Control Equipment Ltd. He joined the company two years ago and has been a senior project engineer in charge of a group working on the design and development of all Vactric's rotating electrical components. Prior to joining Vactric he was with Plessey-UK Ltd. where he specialized in the design of synchros and motor tachogenerators. Vactric have also appointed **C. B. Elkins** as quality assurance manager, who will be responsible for the approved environmental test house, electrical standards and test equipment, and materials and processes laboratory.

NEWS FROM INDUSTRY

NATIONAL COMPUTING CENTRE

THE Minister of Technology, Mr. Frank Cousins, told the House recently that he has now decided to set up a National Computing Centre. "The Centre," he stated, "should reduce wasteful duplication of programming effort. It will achieve this in two ways; first, by providing computer users with information about programmes already available in its library or elsewhere. Second, by developing and sponsoring the development of programmes designed to serve users having closely similar tasks.

"The Centre will also provide and encourage training in systems analysis, programming principles and computer applications. It will promote research into methods of programming and operating computers and into the influence of these methods on the design of computers.

"All these objectives will be pursued in close co-operation with the computer manufacturers and with users in industry, commerce, administration, science and technology.

"The Centre will be set up as an independent non-profit making Company, limited by guarantee. I know that we can count on a wide measure of support for the Centre. I shall be inviting representatives of manufacturers, users, and of professional and other interested bodies to become members of the Centre and to be represented on the Council which will run it.

"Professor Gordon Black, who is at present Technical Manager (Computing) in the Reactor Group of the Atomic Energy Authority and part-time Professor of Automatic Data Processing in the Faculty of Technology of Manchester University, has accepted my invitation to become the first Director of the Centre. The Atomic Energy Authority have agreed to release him from his present appointment for that purpose and the University have agreed that Professor Black shall retain his professorial appointment.

"The location of the Centre is a matter of importance. I hope to announce shortly that it will be built in Manchester on a site where it would be easily accessible to industry, close to the University with its traditional interest in computing science and close to the Business School.

"I hope that the Centre will be built up during the course of the next year and be fully in operation in 1967."

Answering questions following his statement, Mr. Cousins said "the staff of the Centre will not be Civil Servants. It is likely that we shall require between 40 and 50 on the staff."

In reply to another question asking how many computers will be needed, the Minister said "the staff will be composed of people who know what is needed and who will set out to get the instruments to do it."

£1.5M Russian Order Near Completion.—Vacwell Engineering, of Mitcham, Surrey, will in the next three months complete the order for two transistor production lines and associated equipment they received from Technopromimport, the Russian buying organization. Since the original order for £1M worth of equipment, which was the result of a Moscow visit, Vacwell Engineering have received additional orders for spares and associated equipment worth approximately £500,000. Vacwell Engineering export over 90% of all the equipment they manufacture.

Green Archer mortar locating radar equipment identical to that already in use by the British and Swedish Armies is to be sold to the West German Government. Twenty-five sets of this equipment, worth about £3M, are to be supplied by EMI Electronics Ltd., of Hayes, Middx. Several other countries are evaluating this equipment, which pinpoints enemy mortar firing positions by plotting the bombs in flight. The illustration shows an installation fitted to an armoured fighting vehicle.

£4M Data Handling Contract.—A number of data handling systems for the Royal Air Force are called for in a £4M contract recently awarded to Plessey Radar, in collaboration with Elliott-Automation. Plessey, who will act as prime contractors, are to make the radar display equipment and data handling components, and Elliott-Automation the computers and associated software. The systems will be used by the R.A.F. Air Defence Control Staff

Anglo - American Semiconductor Agreement.—Thorn Electrical Industries Ltd. have signed an agreement with the American General Electric Company primarily concerning the manufacture of semiconductor devices. Under this agreement, Thorn-AEI, the Group's manufacturing unit, will receive "know-how" from G.E. to enable them to extend their range of semiconductors. The new devices will include a number of silicon planar types and will be marketed under the Mazda and Brimar trade names, carrying non-American type numbers. Royalties will be paid on all of these devices. Thorn will also be manufacturing semiconductor devices for General Electric. These will be G.E. branded devices for sale in the United States. Thorn are also to make a quantity of semiconductor production equipment for General Electric. Jermyn Industries, of Vestry Estate, Vestry Road, Sevenoaks, Kent, who at present distribute G.E. semiconductor devices, will continue to do so.

Atlas Data Link.—The University of London Atlas Computing Service is the first commercial computer service to operate on-line data links over the G.P.O. public telephone network. The Shell company and a number of London colleges are now linked with Atlas which handles a wide variety of industrial, commercial and scientific material. The A.C.S. is associated with the University Institute of Computer Science and is run by a University-owned company. The data links were installed by G.E.C. Electronics Ltd.

A "life-time" guarantee on all Zener diodes has been announced by the International Rectifier Company (Great Britain) Ltd. This announcement follows a similar statement by the parent company two months earlier in the United States. International Rectifier began manufacturing Zener diodes in 1956 and four years later production started in the United Kingdom. Today over 500 different types of Zener diode are being produced covering the range 3.3 to 200 V, 250 mW to 50 W. All of these diodes will carry the guarantee, which in effect lasts for the life of the equipment in which they are fitted.

Dansette Buy Perdio.—Dansette Products Ltd., a company formed recently to take over the assets of Perdio Electronics Ltd. The price has not been disclosed. The company will continue to manufacture radio and television receivers, and will be operated in association with Dansette. Both companies will have the same directors, headed by Mr. Louis Margolin.

A-MP Lose Appeal.—Two actions have been brought by A-MP against Hellermann concerning the alleged infringement of a patent relating to hand crimping tools. In February last year, the High Court found in favour of Hellermann and a subsequent appeal—heard in November—against the judgment was dismissed with costs. A-MP's application to appeal to the House of Lords was refused. The action was started in the late fifties.

Ferranti to sell Parametric Amplifiers to the Americans.—Following the success of Ferranti's parametric amplifiers in the United Kingdom and in Europe, the company have decided to attack the American market. A sales engineer from the company's electronics department is being sent to the offices of Ferranti Electric Inc., Plainview, New York.

Educational Television System.—The Marconi Company have received an order for an educational television system for the new first-year science building at Edinburgh University. Closed circuit television techniques will be used to interconnect, via a comprehensive control room, nine fully-automatic cameras and 51 receivers. The distribution network will link the various lecture theatres and viewing rooms throughout the building, which is now under construction. The distribution network, will be installed by Rediffusion Ltd., who will also provide the receivers.

Long-term Instrument Leasing.—Dynamco Instruments Ltd., previously known as Digital Instruments Ltd., announce a scheme under which it is possible to hire their a.c. and d.c. measuring instruments. Details of the scheme, which has a minimum leasing period of five years, are available from the company's offices in Salisbury Grove, Mytchett, Aldershot, Hants.

Decca Radar Ltd. received their 20,000th order for marine radar on 4th November last. In 1965, the number of orders for marine radar exceeded 3,500. Some 90% of the company's marine output is exported.

Green Electronic & Communication Ltd. have closed their office and showroom in Hornsey Road, London, N.7. All correspondence should now be sent to their works at 79-91 Braemar Road, London, N.15. (Tel.: STAmford Hill 1387.)

***Redifon Ltd.** have received an order for £135,000 worth of communications equipment from the Federal German Ministry of Interior. The order is for Type GB 345, s.s.b. "man-packs" (one illustrated) and associated converters which enable them to be operated from vehicle supplies. Frequency selection is achieved in this equipment by means of a synthesizer, which offers a selection of 9,999 channels, in 1 kc/s steps from 2 to 12 Mc/s. This equipment will be used by the Bundesgremzschutz, the Federal German Frontier Force.*

SELLING TO CANADA

IN recent months the Government has been making great efforts to encourage British manufacturers to sell in the Canadian market. Since pre-war years the trade gap between the two countries has been widening in Canada's favour and the last available figures (1964) show that it is now $634M. In 1938 it was $218M.

In an attempt to close the gap Britain is to support—at a cost exceeding £1M—two trade fairs and a British Week (lasting ten days) to be held during the 1967 Centenary of Confederation celebrations.

Both fairs take place in May 1967 and are actually fairs within fairs. The first, called the British Industrial Fair, is to be held within the National Industrial Production Show in Toronto from 1st to 5th. Through financial assistance from the Board of Trade, the cost of buying space (70,000 sq ft available) at this fair has been approximately halved—to $3 (£1) per sq ft. The other fair, within the British Columbia Industrial Trade Fair, will comprise a British Pavilion—with 15,000 sq ft of exhibition space costing $2 per sq ft, again subsidized. It will be held in Vancouver from 17th to 27th May. Consumer goods can not be shown at either of these shows.

The British Week which will deal exclusively with consumer goods will take place in Toronto during October 1967.

A lot of information has been published to assist those wishing to trade with Canada. One such publication "Selling to Canada" is available from the British National Export Council, Committee for Exports to Canada, 21 Tothill Street, London, S.W.1. Another supplier of information is the Board of Trade Export Services Branch (direct or through the Board's regional offices).

Electrical equipment to be sold on the Canadian market must, with some exceptions, bear the approval of the Canadian Standards Association. To obtain approval, the apparatus must be electrically safe, free from fire risk and, in some cases, have no mechanical hazards. Prior approval can be obtained through the British Standards Institution who have made special arrangements for British exporters. The joint B.S.I./C.S.A. Agency, which offers this service, is at Maylands Avenue, Hemel Hempstead, Herts.

British goods enter Canada under the lowest of the three tariff ratings—British Preferential—and in some cases enter duty free. The British Preferential tariff for radio equipment for instance is 20% lower than what is known as the Most Favoured Nation rate of duty. As to sales prospects, quoting from the "Selling to Canada" publication, "Experts who have examined the subject, including Canadian agents of British firms and buyers of Canadian firms, are convinced that, given efficient salesmanship backed up by efficient production, supply and after sales service, there could be significant and profitable increases in the following categories: . . . telecommunications and electronic equipment and components; and scientific instruments, including recording, control and measuring instruments, and equipment for industrial, laboratory and educational use. . . ."

In 1964 Canada's imports totalled $7,490M of which Britain's part was only $580M. Canada's imports are rising yearly and her Economic Council has estimated that her imports are likely to exceed $10,000M by 1970. Can Britain's exports rise proportionally?

Torsional Stability and the Unipivot—1

By J. BICKERSTAFFE

A low inertia, low friction, unipivot arm of good torsional stability and offering improved stability to shock. Constructional notes and diagrams for those wishing to build the arm will be published next month.

IT IS difficult to imagine a more simple suspension for a pickup arm than the simple unipivot where the arm is balanced on the bare minimum of bearings—one. Apart from its simplicity this system has an advantage in that with reasonable care friction can be held to insignificant values without the need of delicate adjustments. One merely sits the arm in position and forgets about excessive friction or rattles due to poor bearing adjustment.

However, a unipivot, as well as allowing freedom of movement in a vertical and horizontal direction, also permits torsional movement and herein lies the snag. It is a saddening sight to see an arm tracking out of torsional balance with its head leaning heavily to one side, rather like a cow with ear-ache. It could also be an alarming experience, especially for a sensitive person, to witness an arm rocking violently from side to side while trying to cope with a warped record. Apart from the psycholgical effects of these antics on the observer there is the small question of their detrimental effects on pickup performance and consequently it would be better all round if the arm could be made torsionally stable and behave in a more seemly fashion.

The cure for the first of these snags is to arrange that the arm is always held in torsional balance but the cure for the second is not quite so obvious. Usually arms using the unipivot are suspended at a point a fair distance above their centroids to provide a large restoring force tending to keep the arm tracking without tilt against torsional pivot friction and varying forces due to the leads. This also tends to reduce torsional motion induced by warps, etc., and a final damper is supplied in the form of grease stuffed around the pivot.

The snags to this scheme are two-fold: (*a*) suspending the arm well above its centre of gravity tends to make it sensitive to player movements caused by jolts and floor vibrations, etc.; (*b*) grease around the pivot increases friction and it can offer substantial resistance to fast movements of the head such as can occur with some record irregularities.

It would seem a better proposition therefore to first find a solution to the torsional motion problem that avoids the necessity for grease damping and would allow the arm to be suspended from a point just above its centre of gravity. If the torsional pivot friction and lead torque were then kept very small so as not to affect torsional balance, torsional stability would be achieved without the disadvantages (*a*) and (*b*).

The mathematicians among us would now launch out into an analysis of the mechanism of torsional motion induced by record irregularities and show how this could affect the effective inertia of the arm and whatnot. Although, some time ago, the author spent several days and nights shrouded in smoke and confusion carrying out such an analysis, it is not intended to reproduce it here in full since it is not necessary to the understanding of the problem.

Instead consider the counterbalanced arm depicted in plan in Fig. 1. P is its point of suspension and S the stylus. If a warp caused the head to rise vertically, this movement would tend to be transferred to all parts of the arm, the amount of movement transferred depending upon the distance of the part in question from P. The movement of A, for instance, would depend upon x and the mass m at this point would offer a reaction of this movement proportional to mx. The moment of this reaction about the SP axis will then be proportional to mxy and would tend to cause a torsional motion in the arm around SP.

In a similar way each portion of the arm lying along SP produces a reaction moment tending to turn the arm one way or the other around SP depending on which side of SP it happens to lie and whether before or behind P. A little thought will make it apparent that with the arm shape shown in Fig. 1, the reaction moment of the

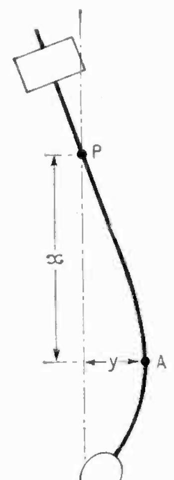


Fig. 1. Arm of conventional shape.

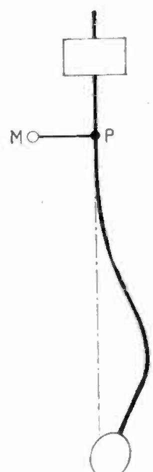


Fig. 2. Shape required to eliminate torsional forces due to counterweight.

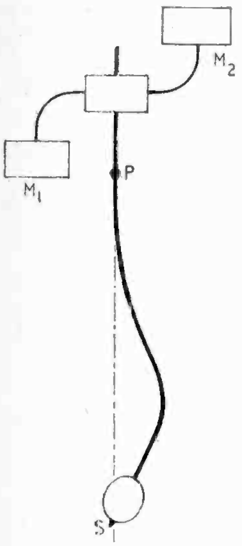


Fig. 3. Shape required to eliminate all torsional forces.

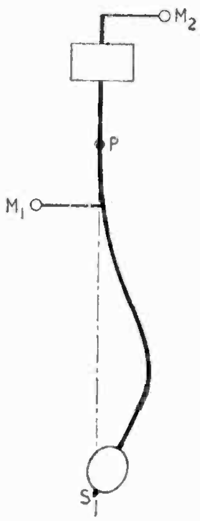


Fig. 4. Same as Fig. 3 but with stabilizers comprising counterweight.

counterweight would tend to produce torsional motion in the same direction as that due to the part of the arm situated in front of P. So a conventionally shaped arm is a potential lively rocker.

The situation could be improved by reshaping the arm as in Fig. 2 to situate the counterweight along SP where it can contribute no reaction moment. Torsional balance could then be secured by a small weight situated at m opposite the pivot. However, the scheme outlined in Fig. 3 is far more effective, for here the two stabilizing masses m_1 and m_2 can be positioned to both provide torsional balance about SP and to cancel the reaction moment of the rest of the arm—thus (theoretically!) leaving no torsional force acting around SP.

A similar scheme which might be considered as a tidier arrangement is shown in Fig. 4 where m_1 and m_2 comprise the counterweight. But here m_1 and m_2 may be arranged to give both torsional balance and zero torsional force at only one particular setting of the counterweight. The spacing of m_1 and m_2 does, of course, increase the total arm inertia referred to stylus but this increase can normally be kept quite small ($<20\%$ total head inertia).

Similar conditions exist for horizontal movements of the head to cause torsional inertia, and although these are usually less dangerous than vertical movements, it is desirable to reduce reaction moments due to these. This can be done by either placing m_1 below the SP axis or m_2 above it—or both.

The addition of stabilizing as indicated above results, then, in a substantial reduction in the torsional forces induced by record irregularities. In addition, the spacing of these masses a fair distance from SP appreciably increases the arm's torsional moment of inertia—its "resistance" to these forces is thus increased. So an extra advantage has popped in through the back door for good measure.

The torsional moment of inertia, and the distance above its centre of gravity at which the arm is suspended, can be arranged to give a torsional resonance away from any fundamental or harmonic of the turntable speeds likely to be used and so avoid any possible constant excitation of this resonance.

The reduction of torsional forces as outlined leads to the possibility of pivot friction now being put to a useful purpose. If the total reaction moment of the arm is reduced so that it is never likely to exceed the moment of the torsional pivot friction then no torsional motion could occur. In practice it has been found possible to utilize very small frictions in this manner.

The photographs illustrate two arms based on Figs. 3 and 4, built during the past two or three years, both of which proved to have very satisfactory all round performances. Fig. 5 shows the arm based on Fig. 4 undergoing tests and the photograph was taken with a 1 second exposure of the arm tracking a $\frac{1}{4}$ in, $66\frac{2}{3}$ cycles per minute warp and this shows about one complete warp cycle. The front face of the lower counterweight bob was situated opposite the pivot and hence any blurring of this could only be due to torsional motion. In the original, slight blurring of the rest of the counterweight was desirable owing to vertical movement transferred from the head, but no blurring of this face could be detected. This particular arm, though successful, was difficult to construct and set up and later a simpler arm based on Fig. 3 was built. This is shown in Fig. 6 and to date is the author's pet woggle arm. The arm of Fig. 6 is fairly straightforward to construct requiring no intricate machinery, and the parts for four arms have been successfully made using only a grindstone and $\frac{1}{2}$ in capacity bench drill in addition to an assortment of hand tools.

Other features

To minimize inertia and to provide a relatively rigid and simple means of fixing the cartridge, the arm is undercut to half its diameter at the head end and the cartride clamped to the underside with a light-weight metal clip.

The "top hat" over the pivot is a screen around the connecting wires between arm and pivot assembly. To reduce torque these consist of one single strand only from each lead taken from the top of the arm. They are then looped over and plugged into a socket in the top of a pillar supporting the screen.

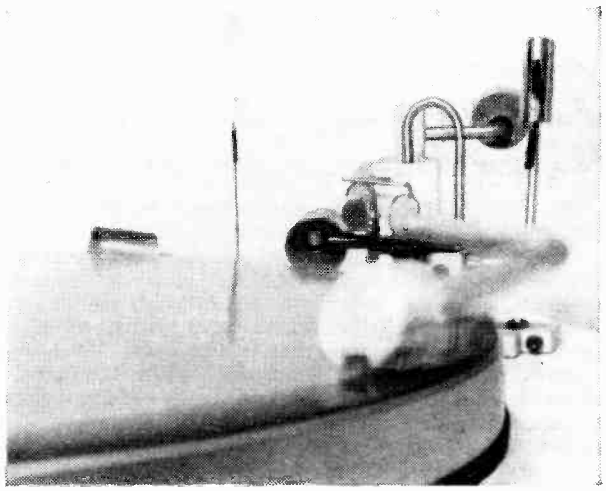
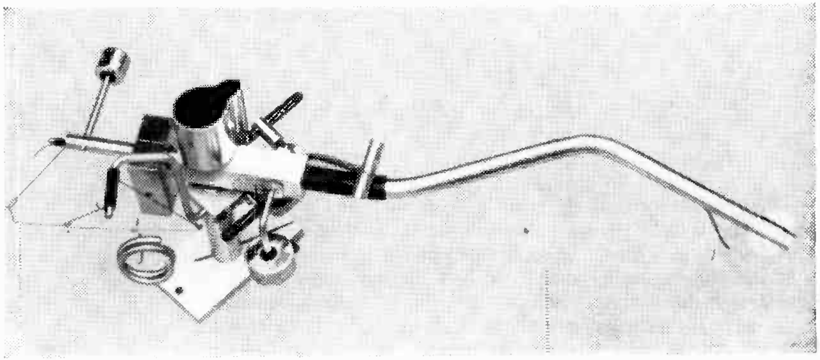


Fig. 5. Arm based on Fig. 4. The photograph was taken with a 1 second exposure and the arm tracking a $\frac{1}{4}$ in $66\frac{2}{3}$ cycle/min warp. Note that blurring of the front counterweight does not occur. (The warp was formed by a rod placed under a blank disc, hence the vertical wire, just left of centre, and thread, which has not reproduced, to prevent the head moving to the disc centre.)

Fig. 6. A simpler arm, based on Fig. 3. The connecting wires between arm and pivot assembly are not shown.



Tracking weight is set by first fixing appropriate weights to the rear of the arm balancing horizontally and then removing them.

Side-force cancellation may be achieved by fitting a bias compensator based on a torsion balance principle. No additional friction is involved to movements of the pickup and the approximate cancelling force is secured when the above weights are transferred from the arm to the compensator. Elliptical stylii, however, appear to require an increase in the cancelling force of up to 50% and hence appropriate weights would need to be added if an elliptical stylus is used.

A simple raising and lowering device is incorporated in which the lift arm lifts about a horizontal axis passing through the pivoting centre of the pickup. This ensured that both the lift arm and pickup move vertically about the same axis thus minimizing any tendency for pickup to " walk " along the lift arm as it is raised or lowered.

The pickup may be retained in its raised rest position clear of the turntable by pulling the lift lever fully forward to trap the arm between lever and knob.

Pivot parts are set in rubber bushes. This, apart from easing construction and permitting easy replacement, helps to reduce tome arm resonances. The main damper in this respect, however, is the rubber mounted counterweight (which for best damping is fitted with its rubber back flush with its front face).

Performance

Some performance figures that can be expected for the finished arm are included in the specification given below.

- Height required above record surface .. $2\frac{1}{8}$ in.
- Clearance required to rear and r.h. side of pivot 3 in.
- Range of cartridge weight—tracking weight catered for .. .. 1-10 gm. (e.g. max. cartridge weight of 12 gm, tracking at 2 gm).
- Distance between stylus and pivot .. .. 9·0 in.
- Distance between pivot and turntable centre 8·3 in.
- Head offset .. .. 3·68 in., set for zero tracking error at a radius of 2·6 in (for minimum distortion between $2\frac{3}{8}$ in and $5\frac{3}{4}$ in).
- Lead capacitance with 4 ft low-capacity coax. (10pF/ft) fitted:—
  - each channel to common earth .. .. 70 pF
  - cross-capacity between channels .. .. 6 pF
- Vertical friction referred to stylus .. 10-30 dynes
- Lateral friction referred to stylus .. 0·5-1 × vertical
- Total variation in lead torque (referred to stylus) between inner and outer grooves .. .. 10 dynes
- Arm inertia referred to stylus (including 1 gm for clip and screws) .. .. 7-9·25 gm.
- Stability to linear player movements in terms of the effective stylus mass (i.e. the "free" mass to which the stylus may be considered attached):—
- Horizontal movements along SP .. .. 1·7 gm.
- Horizontal at right angles to SP tracking weight + ≈0·75 gm.
- Vertical .. .. tracking weight.
- Stability to rocking movements largely depends upon the total inertia and the difference in the motions of stylus and pivot and therefore cannot conveniently be quoted.

APPENDIX

A complete analysis taking into account pivot friction and the restoring force of the arm's centre of gravity towards a point beneath SP, both of which tend to reduce torsional motion, appears extremely complex. Perhaps some interested competent mathematician would care to tackle the job.

An easy way out seems to be to assume zero friction and an induced motion so limited to confine displacements of the centroid from below SP to insignificantly small values, when both could be ignored. Analysis may, briefly, proceed along the following lines.

Vertical movements at the stylus in Fig. A cause the SP axis to move about a horizontal axis through P while the reaction of the various parts of the arm to this movement tends to produce a torsional motion around SP. A portion of the arm at M therefore can be considered as having vertical motions V and T about these two axes. The reaction of the mass, m, of each portion to the vertical component of its total motion can be referred to the stylus and the sum of these reactions gives the total reaction R_s, offered at the stylus to its acceleration, f_s. The effective inertia, $\mathcal{I}_s$, referred to stylus, of the arm about P, can then be found from $\mathcal{I}_s = R_s/f_s$.

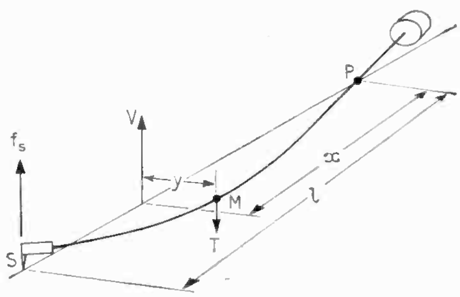


Fig. A

An expression derived by the author for this effective inertia is:

$$\mathcal{I}_s = \mathcal{I}_p \left(1 - \frac{(\Sigma mxy)^2}{2I_p I_t}\right)$$

where $\mathcal{I}_p$ = inertia referred to stylus about P when no torsional motion occurs

I_p = M.I. of arm about P.

I_t = M.I. of arm about SP.

x & y = distances indicated in Figs. A & B.

From this it will be seen that no torsional motion occurs when $mxy = 0$. Also, although $\mathcal{I}_s$ cannot be greater than $\mathcal{I}_p$ it is not the "parallel sum" of two inertias, e.g., $\mathcal{I}_p$ and some inertia due to the torsional mode. This is reasonable since if this were so, a force applied at the stylus would directly cause both a vertical and a torsional motion. This cannot be so since the force acts at a point on the SP axis and consequently cannot directly produce motion around it. The reason for $\mathcal{I}_s \ngtr \mathcal{I}_p$ could be simply explained by the fact that forces at the stylus tend to swing the SP axis around P without (because of some torsional "slip") carrying all the arm mass with it.

The total reaction moment of M_R of the arm around SP is given by:—

$$M_R = \frac{\Sigma mxy}{2l} \cdot f_s$$

For torsional pivot friction to prevent induced motion, its moment about SP must exceed M_R. Assuming that torsional friction is the same as the vertical friction, whose value referred to stylus is F_v, then no torsional motion will occur when:—

$$F_v > \frac{\Sigma mxy}{2l^2} \cdot f_s$$

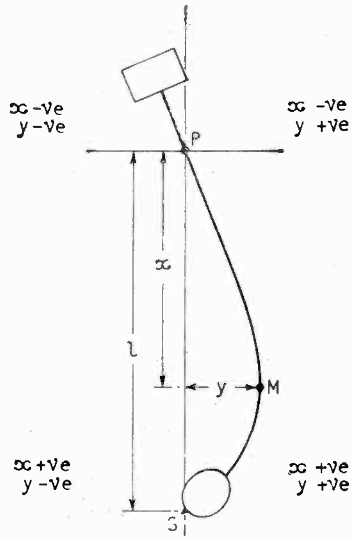


Fig. B

LITERATURE RECEIVED

Selenium surge suppressors for the protection of germanium and silicon rectifiers are described in Engineering Publication 19-13 issued by the rectifier division of the Westinghouse Brake and Signal Company, 82 York Way, King's Cross, London, N.1.
WW 325 for further details

Printed Circuits.—Leaflet PCB 10 gives details of the printed circuit board service offered by S.C.E.E. Ltd., of Reddicap Trading Estate, Sutton Coldfield, Warks. The company has capacity for prototype, small batch and long production runs, and invites readers to send for leaflet.
WW 326 for further details

Aerials and Accessories.—The October 1965 catalogue covering aerials and accessories is now available from Antiference Ltd., of Aylesbury, Bucks. It contains details of their radio and television aerials and the various mountings and accessories.
WW 327 for further details

Loudspeakers and enclosures are described in a publication obtainable from Goodmans Industries Ltd., of Axiom Works, Lancelot Road, Wembley, Middx. Electrical specifications are included in this 23-page brochure.
WW 328 for further details

A publication describing the "**Heat Sinks and Transistor Mounting Pads**" made by Hellermann Electric Ltd. is available from the company's offices in Gatwick Road, Crawley, Sussex. It includes performance curves and data.
WW 329 for further details

Information on the **Bourns range of trimmer potentiometers** is now available through the American company's recently set-up organization in the United Kingdom—Bourns (Trimpot) Ltd., Hodford House, 17-27 High Street, Hounslow, Middlesex. (Tel.: Hudson 0111).
WW 330 for further details

"**Thorn Signal Lamps and Lampholders**" are described in a brochure obtainable from Thorn Special Products Ltd., Great Cambridge Road, Enfield, Middlesex. Electrical and mechanical characteristics are included.
WW 331 for further details

Silicon Rectifiers.—Quarndon Electronics (Semiconductors) Ltd., of Slack Lane, Derby, have available a four-page leaflet containing a summary of the semiconductor devices made by Transistor A.G., of Zurich, Switzerland, for whom they are agents.
WW 332 for further details

"**Reliability of A.E.I. Semiconductors**" is discussed in publication 4450-252 now obtainable from the semiconductor department of the Electronic Apparatus Division of Associated Electrical Industries Ltd., Carholme Road, Lincoln. This publication deals with germanium junction rectifiers and is intended to be read in conjunction with publication 4450-251—where greater detail of the methods of test analysis of results is given.
WW 333 for further details

Modular Racking System.—Details of the Type 7500 modular construction system are available from C. & N. (Electrical) Ltd., The Green, Gosport, Hants. This system, which is suitable for the construction of cases, cabinets and racks for 19in panel mounted assemblies, was previously known in the U.K. as Uniframe.
WW 334 for further details

"**Micronotes**" on the method of determining the quality of varactors and p-i-n microwave switching diodes are available from Microwave Associates Ltd., Cradock Road, Luton, Beds. Reference is made in this little booklet (Vol. 3, No. 3) to earlier issues of "Micronotes" which are also available on request.
WW 335 for further details

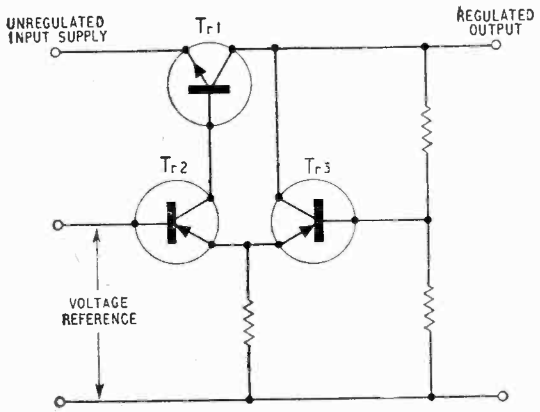
LETTERS TO THE EDITOR

The Editor does not necessarily endorse opinions expressed by his correspondents

Power Supplies

MAY I congratulate Mr. T. D. Towers on his very interesting and informative series on "Electronic Laboratory Instrument Practice." In his final article he discusses power supplies, and in the section on stabilized supplies he points out the self protecting property of the shunt regulator, and states that the series regulator requires additional protection circuitry if it is to tolerate accidental shorting of the output terminals. A suitable, "add on" circuit for protecting a series stabilizer using four transistors is discussed.

Indeed, I agree with the need for protecting the series regulator against overload, but preferably without additional circuitry. To illustrate one of the interesting properties of the "complementary" series regulator a basic circuit is shown in the diagram.



At normal load currents the regulator behaves much the same as a normal series regulator in terms of output resistance and stabilization ratio. Under overload, however, the mechanism is as follows. As the load current increases Tr2 passes a greater proportion and Tr3 a lesser proportion of the total tail current. Eventually Tr3 is cut off and the control loop broken. Tr2 now passes a constant current as does Tr1. Therefore, the output current is limited to a constant value down to zero output voltage.

An additional protective feature is possible if the reference source is a Zener diode fed from the stabilized line. When the output voltage has dropped to the Zener volts, the Zener cuts off with the result that the output voltage and current drop to low values determined by leakage currents. The circuit automatically resets when the load is removed.

In practice there are difficulties in obtaining the constant current region at low load currents, say below 2 A, using the simple configuration shown. Tr1 is usually a compound pair and its current gain defined by local feedback loops. If cut out is required over a wide range of load currents, a second long-tailed pair as the comparator may be directly coupled to the pair shown. The tail resistor of the pair shown may be adjusted to give the trip action at the level of output current required.

Cheadle, Cheshire. M. HARDING

Non-resonant Loudspeaker Enclosure

I SHOULD like to thank Dr. Bailey for his reply to my letter (November issue) and would appreciate an opportunity to clarify some of the issues which are under discussion.

The principal objective which I have sought in developing the resistive reflex cabinet has been to obtain adequate damping of the loudspeaker mechanical resonance such as would be achieved by full horn loading. This implies of course a relatively flat impedance curve as well as a flatter acoustic response below 400 c/s. If the impedance variation is reduced the phase angle associated with the loudspeaker will be greatly reduced as well—hence one would avoid the introduction of perhaps a further 60° phase shift into the feedback loop of the driving amplifier.

The introduction of this additional phase shift does not render the amplifier unstable, but it can all too frequently render the transient response of the amplifier and loudspeaker oscillatory. The effect partly explains the different impressions formed when listening alternately to electrostatic and electrodynamic loudspeakers driven by the same amplifier. The resistive reflex cabinet provides a large measure of viscous damping of the cone motion and substantially reduces the extra phase shift introduced into the feedback loop. Although still imperfect I believe it to be an improvement on the small infinite baffle and conventional reflex systems. I agree entirely with Dr. Bailey's comments on the former, and also his remarks about damping them. I also agree with his remarks about diffraction from small cabinets and interference between the radiation from the cone and the port but with careful design these effects can, I think, be reduced to acceptable levels.

The damping material used in the resistive reflex cabinet is compressed woodwool. When carefully packed it produces a sensibly linear acoustic resistance which is presented as a load to the rear of the cone. It also attenuates the port output above the resonance frequency and provides a useful damping of the enclosure resonances.

Dr. Bailey has brought to light some interesting data about the sub-audible components of speech which I am in no position to comment on. However, I have concluded that the d.c. component of the distortion produced by an amplifier, be it thermionic or semiconductor, deserves some further attention. In a letter it is possible to deal with the theoretical aspects of the problem only very briefly. However, it is well known that any amplifying device with square law curvature in its transfer characteristic produces a small d.c. signal, since it possesses to a small degree the characteristics of a rectifier.

The static voltages in an amplifier stage change, albeit by a small amount, when the signal level changes, a fact which is readily observed with a voltmeter. The existence of this d.c. component is also established in the mathematical analyses published by E. W. Berth-Jones in *Wireless World*, June 1951, and also by M. V. Callendar and S. Matthews in *Electronic Engineering*, June 1951. A deeper penetration of these suggests that when the signal level changes there is a change in the level of 2nd and 3rd harmonic distortion, as well as the intermodulation tones which are reduced by negative feedback. However, the d.c. signal is not reduced unless the entire amplifier and feedback loop are d.c. coupled, but clearly, if the signal level change lasts for 20 msec the d.c. signal may be considered as a pulse which will be passed by an a.c. coupled circuit and reduced by feedback. If, however, the signal level change lasts for more than 50 msec the d.c. signal will excite the transient response of the amplifier and loudspeaker, even though it may be difficult to detect at the secondary winding. If an amplifier is offered tone bursts at a frequency of about 50 c/s and the burst is 25 c/s long, the envelope of the tone burst emerging from the amplifier is usually distorted, presumably because it contains the signal and the transient response of the system. Similarly, if a tone burst of 25 kc/s is fed into the amplifier and loudspeaker the tone is of course inaudible but the speaker usually emits a slight clicking sound which is presumably caused by the d.c. component appearing as a pulse which excites the cone resonances of the speaker. However, a more useful method of examining the behaviour of the speaker and amplifier under programme conditions is to observe the speech coil current directly with an oscilloscope. (A circuit for doing this was given in the May 1965 issue of *Hi-Fi News* in an article entitled "An improved moving coil loudspeaker.") The oscillatory response of the conventional reflex cabinet is easily observed and this I believe accounts for the boomy and chesty coloration of speech, and some music waveforms.

I think it would be reasonable to infer that the rapid changes of signal level and the d.c. signals associated with them, periodically excite the transient response of the amplifier and loudspeaker in tandem. In practice it seems that the damping effect of the feedback amplifier is not quite what we have assumed it to be in the past, and quite clearly no two amplifier designs behave in quite the same way because of differences in their low-frequency time constants, etc.

In addition there is an optimum value of bias resistance for every stage in the amplifier which produces minimum change in d.c. level and minimum second harmonic distortion, a condition which is not achieved in every commercial design.

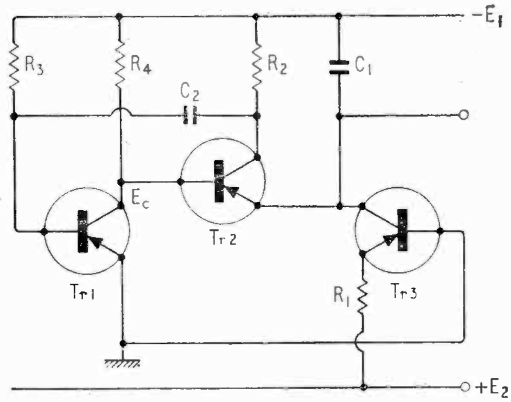
Finally, I would agree with Dr. Bailey's contention that very few loudspeakers are capable of giving back the original sound without adding their own interpretation of it. It would seem, however, that amplifiers which appear to be beyond reproach when delivering power into a pure resistance are not necesarily "whiter than white" when driving a loudspeaker.

Sevenoaks, Kent. J. R. OGILVIE

Ramp Generator

I READ with interest the article "Ramp Generator" by B. L. Hart in your July issue. I have managed to develop a rather simple free-running circuit which performs much the same function as Mr. Hart's circuits and which may be of some interest to your readers.

In the schematic circuit Tr3 and R_1 form a constant current source to charge the timing capacitor C_1. The ramp voltage appears across this capacitor with a rate



of rise given by $\frac{E_2}{R_1 C_1}$. The values of R_3 and R_1 are chosen so that Tr1 is almost bottomed, with its collector at a voltage E_c. In operation the voltage at the collector of Tr3 falls linearly until it reaches E_c, whereupon Tr2 begins to conduct and generates a voltage across R_2. This voltage is impressed on the base of Tr1 via C_2, and the resulting regenerative action of Tr1 and Tr2 keeps the former cut-off and the latter bottomed until C_1 has discharged almost completely through Tr2 and R_2. Then Tr2 is again cut off. At this point, the regenerative action ceases, and the cycle recommences. R_2 is of the order of 100Ω, and C_2 of 300pF.

The detailed operation of the circuit at the end of the discharge of C_1 is complex, but quite good amplitude and time stability can be achieved in practice. The "top" of the ramp runup can be stabilized rather better than in the circuit shown by replacing R_3 by a more complex bias circuit and by using a diode clamping circuit to fix E_c. Short flyback/runup times can be achieved by making R_2 small, the limiting factor being the peak current rating of Tr2.

As shown, the circuit will "free-run," and can be synchronized by applying a sharp pulse to the base of Tr1. Gated operation may be obtained by switching the current through R1 and Tr3, or by controlling the voltage at the base of Tr3. Output synchronizing pulses are available at the collector of Tr2, and a rectangular pulse is available at the collector of Tr1.

Brisbane, Qld., R. H. BLAIR
Australia.

Radial-tracking Arm

READERS with an interest in radial-tracking arms and with facilities for accurate work may be interested in the following scheme for what is believed to be an arrangement offering better stability to external disturbances than conventional radial arms.

Most player units are situated in the top of a cabinet placed back to a wall and since floor movements will tend to hinge about the junction of the floor and wall these will cause a slight rocking movement at right angles to the wall. The resultant components of the movement thus imparted to the player by people walking about the room, for instance, will tend to be:—

(a) an appreciable horizontal component at right angles to the wall; and
(b) a vertical component varying from a maximum at the front to a minimum at the back.

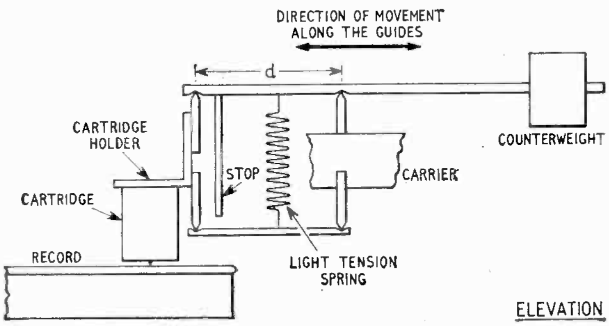
A conventional radial arm usually consists of a guide (or guides) arranged parallel with a radius of the record along which a carrier is free to move. The arm carrying the cartridge is usually counterbalanced and mounted at right angles to the guide, being fixed to the carrier via a vertical bearing. The whole is then arranged so that the arm and carrier is pulled by the stylus along a radius of the record, the arm tracking each groove tangentially.

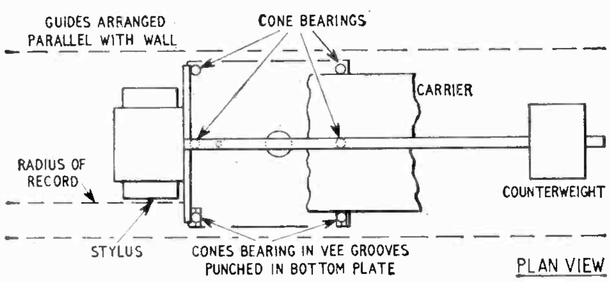
Because of the freedom of the arm and carrier to move along the guide, the arrangement is inevitably sensitive to horizontal player movements occurring in a direction parallel with the guide. So to minimize instability due to this cause the total arm and carrier mass should be kept as small as possible, and the guide arranged in a direction at right angles to the large horizontal component of the player movement (i.e. parallel with the wall).

To minimize instability due to the varying vertical component of the player motion, the stylus and pivoting centre of the arm should ideally be placed at points of identical motion, i.e. the same distance from the wall. This condition can be approximated by fixing the cartridge at right angles to the arm and then mounting the arm parallel with the guide.

A further advantage of arranging the arm thus is that the overall mass of the arm can be reduced by shortening it to a bare minimum, without danger of warps producing wow. However, large warps may tilt the head overmuch but this can be cured by having the arm in the form of a vertical parallel linkage—warps now merely causing a slight side-to-side motion of the arm along the guide. A distance for *d* of 1in in the drawings would produce a total side-to-side movement of only 0.02-0.03 in with warps of $\frac{1}{4}$ in p-p amplitude.

A suggested experimental arm is indicated in the drawings which I hope illustrate the idea clearly enough. A very lightweight structure should be possible if thin gauge aluminium alloy is used. The thin "stop" rod is merely to prevent the bottom plate leaving the carrier bearings when the cartridge holder is removed. The latter can be inserted by opening the "jaws" and locating the bearings in position.





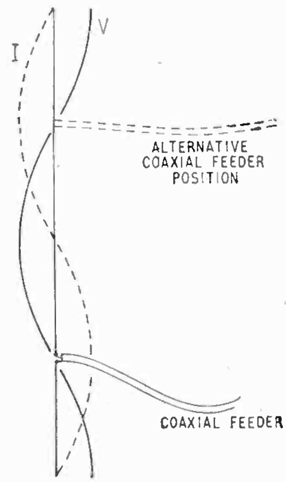
The distance of the counterweight from the vertical bearings on the carrier needs to be a compromise between total arm mass and the vertical arm inertia referred to stylus. Probably the best compromise would be to arrange the counterweight at about the same distance from the carrier bearings as the cartridge.

The carrier would need to be something in the nature of a light weight, three or four wheeled, low friction trolley running on two horizontal guides with the arm working between the latter as indicated.

Appleby, Westmorland. J. BICKERSTAFFE

An Unconventional Television Aerial

FEW television receivers are working on the "piece of wire" type aerial; most people realise that the best results are obtained by having a properly installed aerial system. However, some of your readers might be interested in a "piece of wire" aerial which, though simple, I have found to be efficient.



I had occasion to erect the system when an aerial was required rather quickly.

A piece of broadcast aerial wire one wavelength long was suspended from the eaves of the house. As the wavelength of the local B.B.C. transmitter in Band I is about 17-18 feet, the lower end of the wire reached a little above ground level. I considered that such a conductor resonates in the same way as a conventional dipole, there being, however, two low impedance points, one $\lambda/4$ from the top end, the other $\lambda/4$ from the bottom end. The feeder was fitted at the bottom low-impedance point of the aerial as the receiver was in a ground floor room, but if the set had been required upstairs, the upper low-impedance part would have been used. Either method means that a short length of feeder is required.

I appreciate that the system would lose some of its merit where a very high level of interference was present at ground level.

Aigburth, Liverpool. V. WILSON

"Where the Disciplines Meet"

I WAS very interested to read your November Editorial on the relation between disciplines in the application of physical techniques to medicine and biology.

Those of us who have had the good fortune to work in a laboratory with a high grade physicist or engineer have no doubt whatever that this is where the interface can best be placed. When this is done any question of how far either side should be educated, and by whom, largely vanishes. The process becomes continuous and mutually highly profitable.

I think it is a common experience that the issuing of a specification for equipment to be engineered away from a laboratory or hospital is unsatisfactory. It may be bad either because the intending user is unaware of what is achievable with reasonable ease, or because the engineer may lack a real understanding of and feel for the problem. In the first case serious waste and frustration may occur because the engineer is striving to meet a specification which is unnecessarily high. He may, therefore, be forced to use techniques which are near the limits of reliability, or are excessively costly. In the second case the engineer may meet the specification in a way which is technically elegant and entirely satisfactory, but which may be, in terms of bulk or cost, utterly out of proportion to the scale of the problem. When the various disciplines are brought together, not only at the growing points of a subject, but also where established techniques are being applied to routine work, these difficulties tend to disappear rapidly.

The electromechanical averaging device which you mentioned in your review of the Brighton Congress epitomizes some of the points I have made. This equipment (we missed a point in not calling it the **E**voked **P**otential **I**ntegrating **C**omputer!) was developed in my laboratory at the National Hospital for Nervous Diseases initially by myself and later, in 1950, by J. R. Pitman. At that time thermionic pulse height analysers of "kick sorters" had been made and the use of these techniques was considered. They would have given a designable degree of accuracy in the computed averages, great flexibility in operation and also adaptability. Unfortunately a thermionic digital machine for the job would have cost more than the annual budget of the department and would have squeezed out of the lab. either the experiment, the experimenter, or some of the other equipment needed for the experiment. The apparatus developed was sufficiently accurate and flexible for its job and it was appropriate both to the space and finance available. It took some ten years before digital machinery for the same purpose became sufficiently small to be acceptable in the average laboratory and its cost is still embarrassing, even when due allowance is made for the fact that it will carry out a wider range of operations more rapidly.

It seems to me that the bottle-neck at present lies in the lack of facilities, in terms of space and finance, for giving interested engineers practical experience of the problems they may meet. The course in Biological Engineering at Imperial College is a good example of what can be done in the way of joint training of biologists, physicists and engineers. But after this course it may be a matter of some difficulty finding suitable posts for those who have been trained. Until this lack can be removed the difficulty of placing the interface in the laboratories, where many of us feel it is most profitable, will remain serious.

Institute of Psychiatry, London, S.E.5.
G. D. DAWSON

BOOKS RECEIVED

Network Analysis for Telecommunications and Electronics, by R. A. Lampitt. Although the first chapter revises basic fundamental principles of the subject, the general level of the text is intended for advanced students preparing for a professional qualification. Coverage is given to four-terminal networks, design of filter networks, transmission lines and the analysis of non-sinusoidal waveforms. Mathematical treatment ranges from the use of determinants in the first chapter to Fourier's theorem for harmonic analysis in the final chapter. Pp. 269; Figs. 135. Price 63s. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

Nucleonic Instrumentation, by C. C. H. Washtell and S. G. Hewitt. Written for the user rather than the designer, the book deals with pulse-circuit techniques used in equipment for evaluating the information obtained from nuclear radiation detectors. A non-mathematical treatment is employed and the primary object of the text is to present a basic understanding of circuit functions, instrument use and maintenance. The majority of the circuits described are valve versions. Pp. 144; Figs. 59. Price 42s. George Newnes Ltd., Tower House, Southampton Street, London, W.C.2.

Understanding Digital Computers, by Ronald M. Benrey. A book which can be regarded as a stepping stone between elementary and detailed explanations of digital computers. Eight chapters are included but the arrangement is such that the reader not particularly interested in circuit techniques can omit the relevant chapter; the remainder of the text is written on the basis of considering the computer as a system of building blocks, with progressive introduction of the specialized terminology. A 13-page glossary of digital computer terms is included. Pp. 166; Figs. 90. Price 16s. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

Understanding Lasers and Masers, by Stanley Leinwoll. An informative description for those requiring a basic knowledge of the subject. The introduction includes an account of electro-magnetic radiation and laser frequencies. Successive chapters describe different types of masers and lasers and their civil and military applications, including radar, space, industry and medicine. A separate chapter deals with laser communications and describes modulation and demodulation techniques. Pp. 88; Figs. 55. Price 13s 6d. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1.

Mathematical Theory of Electromagnetism, by Bansi Lal. A mathematical exposition which develops from first principles a mathematical account, based on the c.g.s. system of units, of electricity and magnetism. A working knowledge of vector principles is assumed and the introduction contains a brief account of the fundamental physical concepts necessary for the basis of the work. Succeeding chapters cover theory of conductors and capacitors, dielectric medium and electrical image system, magnetostatics and magnetic induction, electric currents, statical problems by harmonic analysis, electromagnetism, electromagnetic induction, Maxwell's field equations and electromagnetic waves. Pp. 510; Figs. 375. Price 40s. P. S. Jayasinghe, Asia Publishing House, 447 Strand, London, W.C.2.

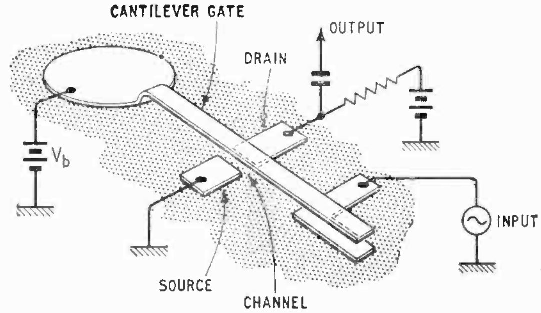
101 Ways to Use Your Oscilloscope, by Robert G. Middleton. A handy American reference book detailing many tests which can be made with the oscilloscope. Initially 12 checks for testing the oscilloscope are described; these include checks for astigmatism, amplitude distortion and phase shift and cross-talk between vertical and horizontal amplifiers. Further tests cover aerial, video, audio and sync circuits, and colour television. Most of the tests are illustrated by photographs of the test waveforms. Pp. 180; nearly 400 Figs. Price 21s. W. Foulsham & Co. Ltd., Yeovil Road, Slough, Bucks.

Radio and Audio Servicing Handbook, by Gordon J. King. The book is intended as a practical guide for the service man and deals with servicing of t.r.f. and superhet receivers, f.m. tuners, radiograms, audio amplifiers and tape recorders. Servicing is explained in three logical stages of testing, fault-finding and repairing, and six fault-tracing procedure charts are given. Pp. 256, Figs. 140. Price 25s. Odhams Books Ltd., Long Acre, London, W.C.2.

RESONANT-GATE TRANSISTOR

THE problem of producing inductive components for integrated circuits is well known. For some purposes solutions have presented themselves—in some cases inductors can be formed in a spiral manner for thin-film circuits at very high frequencies and in others inductance can be simulated or dispensed with by use of active impedance converters and filters. Piezoelectric filters have also been used as sharply tuned circuits. A novel approach to the problem for low frequency application was announced recently in *Applied Physics Letters* by Nathanson and Wickstrom. (See also *Electronics* vol. 38 no. 19.)

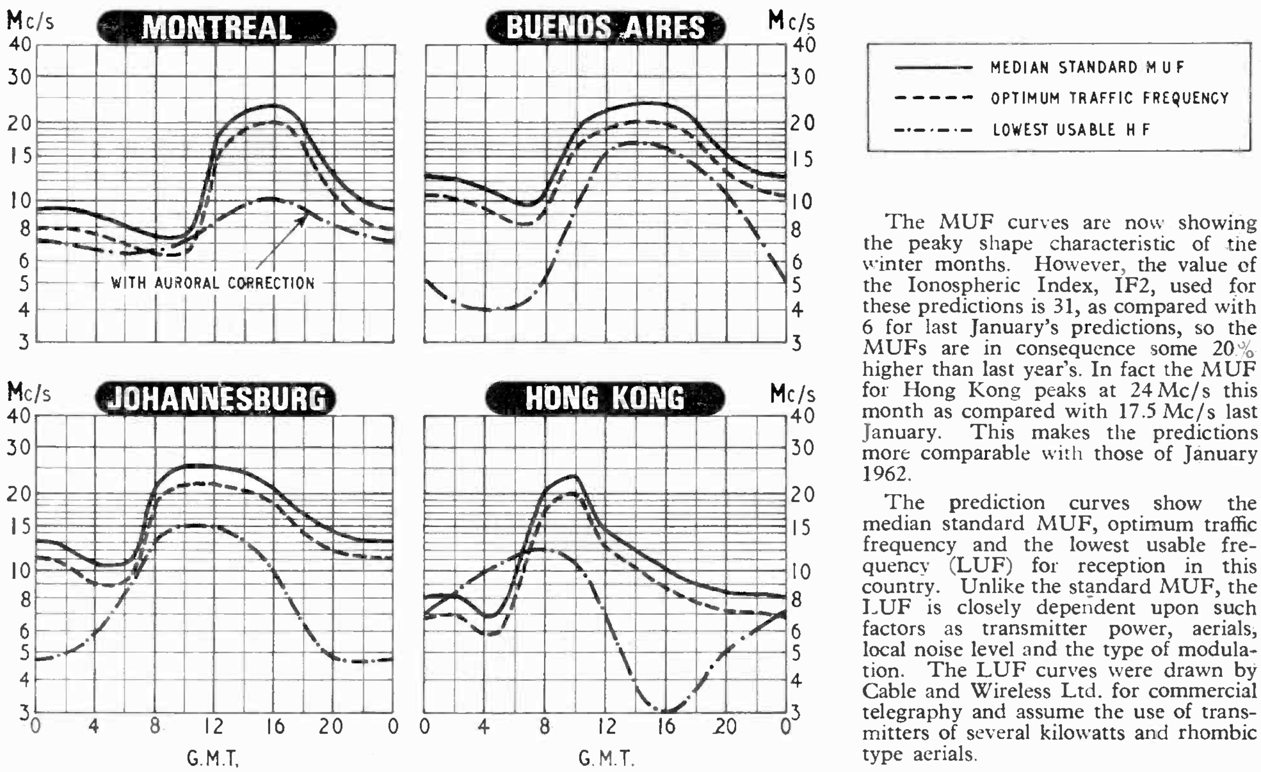
A field-effect transistor is provided with the gate electrode in the form of a cantilever (see diagram). The cantilever gate electrode can be made to vibrate by electrostatic excitation at its resonant frequency—hence the device has been termed the resonant-gate transistor. One end of the gate electrode is fixed in the silicon substrate and the free end hangs over a diffused input electrode. (Electrodes are insulated from the substrate with silicon oxide.) If an alternating voltage of the appropriate frequency, together with a bias or polarizing voltage *Vb* is applied between the input electrode and the gate, the gate will vibrate at its resonant frequency. The resultant field between cantilever and channel affects the conductivity between source and drain and the output is taken in the normal manner from the drain electrode. The polarizing voltage serves to reduce second harmonic output, which arises since, without *Vb*, the electrostatic force between cantilever and input electrode is proportional to the square of the input voltage.



A device with a gold cantilever 0.040in long, resonates at about 3 kc/s with a bandwidth of 20 c/s and has a *Q* of about 150. Devices have been produced with fundamental resonances from 1 to 7 kc/s and with *Q*s up to 400. The devices can be operated in the overtone mode of operation, the overtones not being harmonically related to the fundamental. The first and second overtones occur at 6.27 and 17.55 times the fundamental frequency, thus enabling operation up to the lower i.f. frequencies. It is thought that devices with resonant frequencies up to 1 Mc/s are feasible. Gains of up to 6 dB have been reported.

Some possible applications include microminiature comb filters, tone generators and perhaps also extremely low power relays (by the addition of a further electrode under the cantilever).

H. F. PREDICTIONS — JANUARY



The MUF curves are now showing the peaky shape characteristic of the winter months. However, the value of the Ionospheric Index, IF2, used for these predictions is 31, as compared with 6 for last January's predictions, so the MUFs are in consequence some 20% higher than last year's. In fact the MUF for Hong Kong peaks at 24 Mc/s this month as compared with 17.5 Mc/s last January. This makes the predictions more comparable with those of January 1962.

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, local noise level and the type of modulation. The LUF curves were drawn by Cable and Wireless Ltd. for commercial telegraphy and assume the use of transmitters of several kilowatts and rhombic type aerials.

A Simplified Equivalent Circuit for the Valve

By R. V. LEEDHAM,* B.Sc.Tech., A.M.I.E.E.

EQUIVALENT circuits for the vacuum valve using either a constant current or a constant voltage generator are well known and have been used for a considerable time for the design and analysis of valve circuits. These equivalent circuits do not however give an intuitive indication of the mode of operation of the circuit which is analysed. In particular, a term $1/g_m$ arises very frequently in the results of analysis, as though there were a physical resistance of this value in the circuit.

*Bradford Institute of Technology.

THE VIRTUAL CONNECTION

An equivalent circuit, which is an alternative to the commonly used forms, has been described[1] using the virtual connection. The circuit is shown in Fig. 1 together with the circuit symbol of the valve for comparison. The virtual connection, shown dashed, joins the grid g to the point g' and has the property that it maintains the points g and g' at exactly the same potential while preventing any current flow between them. The operation of the circuit is as follows. If a change of potential δv is applied to the grid g, the potential of g' will also change by δv and the current through the resistor $1/g_m$ will change by $\delta i' = \delta v \div 1g_m$. The circuit is so arranged that the same current i' which flows in $1/g_m$ also flows out of the anode terminal a. The anode slope resistance r_a is connected between anode and cathode as usual. It may be shown that this equivalent circuit is indistinguishable from the commonly used

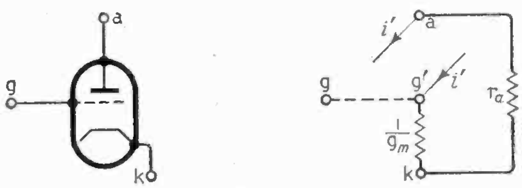


Fig. 1.

forms if they are considered as three-terminal black boxes.

As an example of the use of this equivalent circuit, some frequently used circuits will be analysed as examples. In order to show the essential mode of operation of the circuits, all bias and decoupling components are omitted, and only those circuit elements of importance at signal frequencies are shown. It is of some interest to examine the effect of the anode slope resistance r_a by considering the operation of the circuit with and without r_a ($r_a = \infty\Omega$).

[1]Leedham, R.V. "A Comparison of the Valve and the Junction Transistor Using the Concept of the Virtual Connection," *International Journal of Electrical Engineering Education*, Vol. 3, pp. 193-200, 1965.

THE CATHODE FOLLOWER

The essential elements of the cathode follower circuit and the corresponding equivalent circuit are shown in Fig. 2. If r_a is omitted, since the potential of g' is the same as that of g due to the action of the virtual connection, the output potential will be given by the input

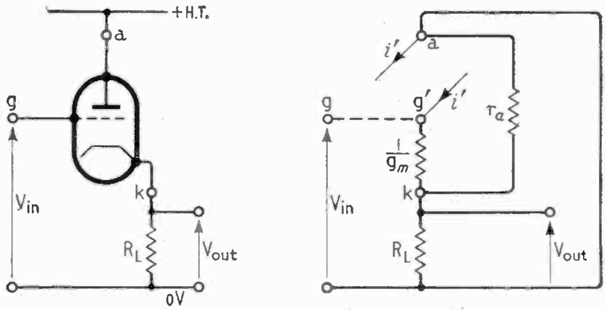


Fig. 2.

potential modified by the potentiometer $1/g_m$ and R_L. The voltage gain of the circuit m is thus

$$m = + \frac{R_L}{\frac{1}{g_m} + R_L}$$

If now the effect of r_a is considered, it may be seen merely to shunt R_L thus reducing the value of R_L to

$$R' = \frac{r_a \times R_L}{R_L + r_a}$$

The output impedance of the circuit will be seen to be given by the resistor $1/g_m$ in parallel with R_L or R'.

THE COMMON CATHODE AMPLIFIER

Fig. 3 shows the corresponding circuits for the common cathode amplifier. Omitting r_a for the moment, the current i' is given by

$$\frac{V_{in}}{\left(\frac{1}{g_m}\right)}$$

and the same current i' flows through the load resistor R_L giving an output signal of

$$V_{out} = - \frac{V_{in}}{\left(\frac{1}{g_m}\right)} \times R_L$$

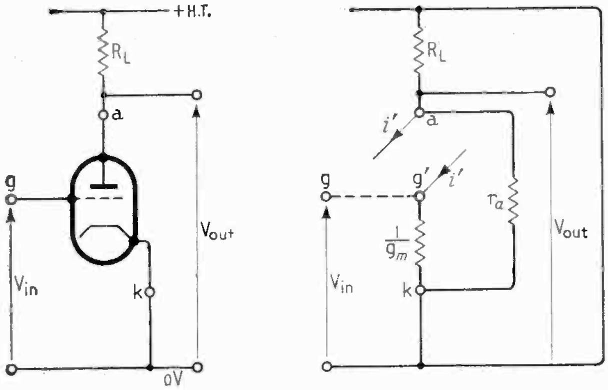


Fig. 3.

The voltage gain is thus

$$m = -\frac{R_L}{\left(\frac{1}{g_m}\right)}.$$

If the effect of r_a is now considered, it will be seen to shunt R_L giving once more a value of R'. The effect of r_a in both this and the previous circuit is to reduce the gain by reducing the value of the load resistor. The output impedance of the circuit will be seen to be R', or R_L, with and without r_a respectively.

AN AMPLIFIER WITH BOTH CATHODE AND ANODE LOADS

As a more complex example, consider the amplifier shown in Fig. 4. Without r_a, the circuit is similar to that of the common cathode circuit, except that the resistor $1/g_m$ is augmented by R_K. The voltage gain may be written by inspection as

$$m = -\frac{R_L}{\left(\frac{1}{g_m}\right) + R_K}$$

If r_a is now considered to be connected as shown, it will be seen that not only does it shunt R_L and R_K, it provides a feedback path from the output to the input. Since a positive step of voltage on g and g' will cause a negative step of voltage at a, the feedback is negative,

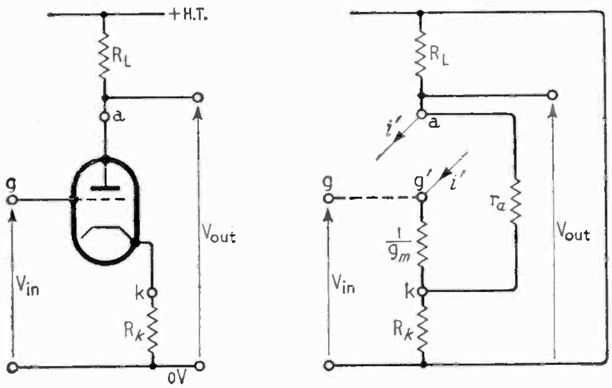


Fig. 4.

and will cause a reduction in the voltage gain of the circuit in addition to that caused by the shunting effect. Analysis of the circuit in the usual way gives an expression for the gain of

$$m = -\frac{R_K}{\frac{1}{g_m} + R_K + \frac{R_K + R_L}{g_m\ r_a}}$$

The net effect of r_a is thus to add a term

$$\frac{R_K + R_L}{g_m\ r_a}$$ in the bottom line.

THE COMMON GRID AMPLIFIER

For a final example, consider the circuit of a common grid amplifier shown in Fig. 5. Without r_a, the current i' is given by $i' = -\frac{V_{in}}{\left(\frac{1}{g_m}\right)}$

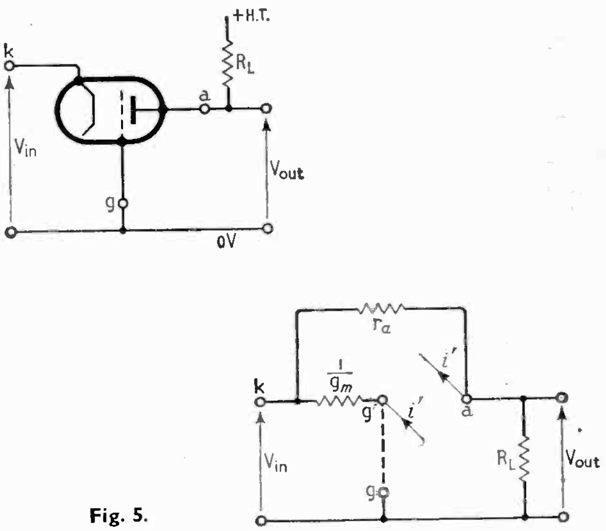


Fig. 5.

and since the same current i' flows in the anode load, the voltage gain m will be given by

$$m = +\frac{R_L}{\left(\frac{1}{g_m}\right)}$$

The input impedance may be seen by inspection to be $1/g_m$ since both g and g' are at earth potential. The effect of r_a in this circuit is threefold. Firstly it shunts R_L thus decreasing the gain. Secondly it provides a parallel forward path for the signal thus tending to increase the gain, and thirdly it provides positive feedback to the input terminal c, to modify the input impedance. Analysis of the equivalent circuit with r_a gives expressions for the voltage gain and input impedance of

$$m = +\frac{R_L\,(1 + g_m\, r_a)}{R_L + r_a}, \quad Z_{in} = \frac{R_L + r_a}{1 + g_m\, r_a}$$

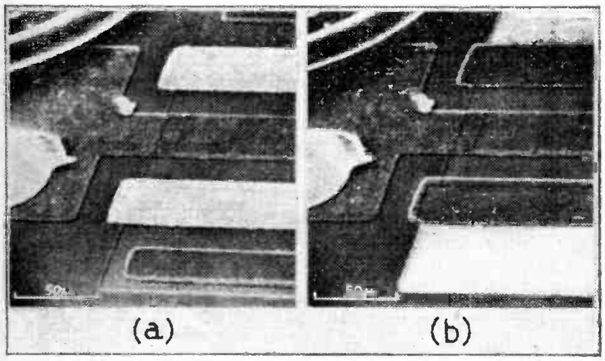
The net effect of r_a is to reduce the voltage gain since the shunting effect is more important than the positive feedback, and to increase the input impedance.

THE SCANNING ELECTRON MICROSCOPE

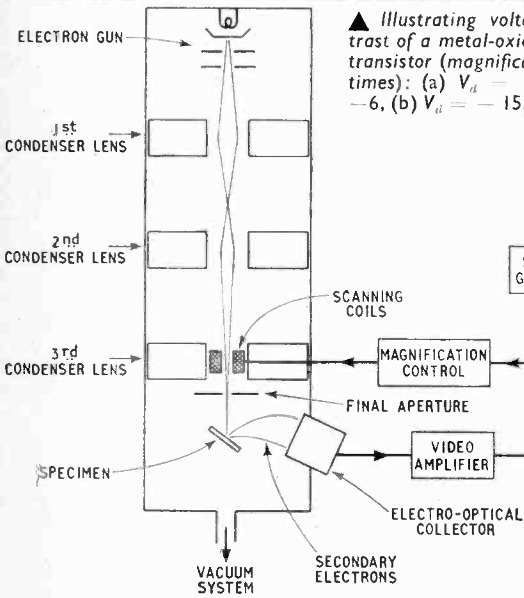
THE principle of the scanning electron microscope has been known for some time—work on this type of instrument goes back to pre-war times when von Ardenne produced the first instrument in Germany, using basic principles laid down by Knoll in 1935. Recently a British scanning microscope was introduced as a result of research by Professor Oatley and colleagues at Cambridge. The equipment is termed the Stereoscan and is manufactured by Cambridge Instruments Ltd.

In a conventional transmission electron microscope electrons must pass through the specimen before a magnified image can be formed, and in some cases thin slices of specimen must be cut for satisfactory results. Methods exist for preparation of suitable thin slices but, at best, these methods are inconvenient.

In the scanning electron microscope the electron beam is not required to pass through the specimen. The beam is caused to scan the sample in synchronism with the scanning of a display c.r.t. Secondary electrons are collected and the resulting signal is used to modulate the c.r.t. electron beam. Materials which do not emit secondary electrons can be coated with a thin conducting film by vacuum deposition.



▲ *Illustrating voltage contrast of a metal-oxide-silicon transistor (magnification 900 times): (a) $V_d = 0$, $V_c = -6$, (b) $V_d = -15$, $V_c = 0$.*



Although the resolution is less (by a factor of four) than some transmission microscopes, the advantages are such that the instrument may well supersede many existing transmission types. The resolution of optical microscopes is around 5000Å (this being a limiting figure), which compares with 200Å or better for the scanning system. The depth of focus is at least 300 times that for optical microscopes. Magnification of up to 220,000 times is provided.

The electro-optical collection system for the secondary electrons is of interest. This comprises a focusing electrode and a scintillator which is held +12 kV. The scintillator is plastic with an aluminium coating. The light emitted by the scintillator is then passed to a photomultiplier *via* a Perspex light guide. Although secondary electrons are normally used in view of their low energy, primary back-scattered electrons may be used in certain applications.

The instrument is of interest to the electronics industry—one obvious application being the inspection of micro-circuits. If parts of the specimen are at different potentials the potential contrast is superimposed on the topographical contrast of the image, as shown in the accompanying photograph. Examination of the sub-surface of insulating and conducting materials is also possible.

COMPUTER USED AS TIMER

DEVELOPMENT of peripheral units for computers is being speeded up by an accelerated testing procedure, itself using a digital computer, devised by I.C.T.'s research and development laboratories. The idea is that a standard computer (1301 central processor, plus card reader, card punch and monitoring typewriter) is used both as an electronic timer and as a means of controlling the peripheral unit under test in the normal way. By means of a counter operating at a frequency of 5 Mc/s, the time intervals between successive actions of the peripheral unit are measured to an accuracy of $\pm 0.2 \mu$sec. At the conclusion of a test an analysis of the results is printed out on the typewriter (which is also used by the operator for entering instructions). For example, a punched-card reader can be started and stopped in the manner it would operate in practice, while the times required for successive columns of a card to pass the reading head are measured. It is claimed that millions of test readings can be taken in the time previously needed for hundreds.

Specific events in the unit under test can be signalled by transducers, but in most cases the pulse signals normally generated by the unit are used. The operation of the peripheral unit and the running of the test procedure are controlled by a programme previously fed into the computer by punched cards.

Magnetic-tape units have been the principal subject of investigation, and in the past 2½ years 52 magnetic-tape units of 12 different types provided by eight different manufacturers have been tested. Programmes have been developed for assessing transport speed, start/stop times, distance moved during starting and stopping, data transfer accuracy and the effects on data reading/recording accuracy of small angular displacements of the tape as it passes the heads. Typical of these tests is one which records the speed variations of a tape running at a nominally constant velocity. Time intervals are measured between successive signal pulses previously recorded on the tape at constant intervals. The tape is started and stopped at random intervals by the computer programme to simulate practical operating conditions.

Tests have been carried out on tape decks operating at speeds of up to 150 in/sec and with data recording densities of up to 800 bits/inch.

Magnetic Frequency Divider

A RECENTLY DEVELOPED METHOD OF FREQUENCY DIVIDING AND A SUITABLE TRANSISTOR DRIVE

By F. BUTLER, O.B.E., B.Sc., M.I.E.E., M.I.E.R.E.

IN a recent paper,* two Soviet authors gave the theory of a new type of frequency divider employing two saturable core transformers, a diode and a capacitor. In its simplest form it gives a square wave output at one-half the input frequency when driven from a sinusoidal source. It can also operate in two other distinct modes in which the output is respectively at one-fourth or one-sixth of the input frequency. The basic binary divider is particularly simple and reliable. Moreover, it is easily adaptable for use in transistor circuits and this short note describes minor modifications which ensure reliable operation at low power levels.

The basic arrangement is shown in Fig. 1. In spite

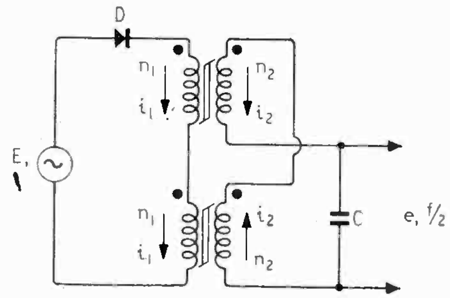


Fig. 1. Basic divider due to Rakov and Shumkov.

of its circuit simplicity, the theory is quite complex, particularly for the case of division by four or six. Even after making gross simplifications, the mathematical treatment leads to an array of transcendental equations which do not have explicit solutions and which require numerical analysis by computer. Quite obviously there are pitfalls in attempting a verbal explanation of the mode of operation, even for binary division.

Operation

Fig. 1 shows two transformers with saturable cores of a square-loop magnetic material such as mu-metal or permalloy. The two primaries, each with n_1 turns, are connected in series. The secondaries, each with n_2 turns, are connected in series-opposition so that if the transformers were operating in a linear manner with the cores unsaturated there would be zero net voltage across the second output leads. By connecting the diode D between the generator *E* and the transformer, the primary terminals are fed with half-sine voltage waveforms. So long as the cores remain unsaturated (i_1 small), nearly equal and opposite voltages will be induced in the secondaries. However, due to unavoidable minor differences between the two transformers, one voltage will exceed the other and a residual secondary current will flow into the capacitor. Let it be assumed that this current i_2 has the direction shown by the arrows on the secondary side. Inspection of the two cores will show that the upper one is magnetized in the same direction by the two currents i_1 and i_2. In the lower core, magnetization due to i_1 is opposed by that due to i_2 as in any ordinary transformer. The tendency is thus for the upper core to approach saturation while the other remains unsaturated. The progressively increasing current i_1 plus the secondary current i_2 eventually saturates the upper core and the impedances of its two windings fall to a value not much greater than the ohmic resistance of the coils. While both cores remain unsaturated, the circuit currents are negligibly small in comparison with the pulses of current which flow in both primary and secondary at the instant when the upper core becomes saturated. The pulse current i_2 charges the capacitor to a voltage which is defined by the primary current and the transformer turns ratio.

On the next half-cycle of primary voltage this action cannot be repeated due to the existence of a sustained capacitor voltage which opposes the secondary voltage developed in the lower transformer. Instead, the upper transformer comes into action. Secondary current flows in a direction opposite to that shown by the arrows, the lower core is saturated in turn and *C* becomes charged with a polarity opposite to that in the previous case. In effect, the two cores are alternately saturated and a square wave voltage is developed across *C* at a frequency which is half that of the input source.

Idealized waveforms are shown in Fig. 2. In practice, the capacitor voltage is often more nearly sinusoidal.

The frequency divider action is accurately maintained

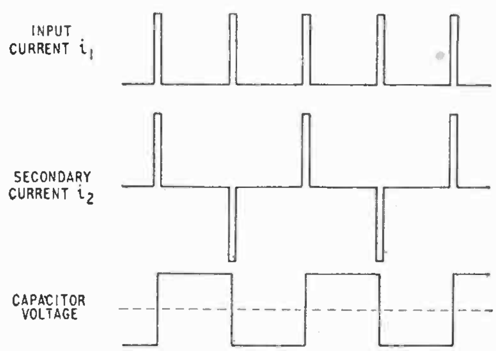


Fig. 2. Idealized Waveforms of binary divider.

*Multiple Modes in a Frequency Divider with two Non-Linear Elements, M. A. Rakov and Yu. M. Shumkov, *Radiophysics* (U.S.S.R. translation), Vol. VIII, No. 2, 1965.

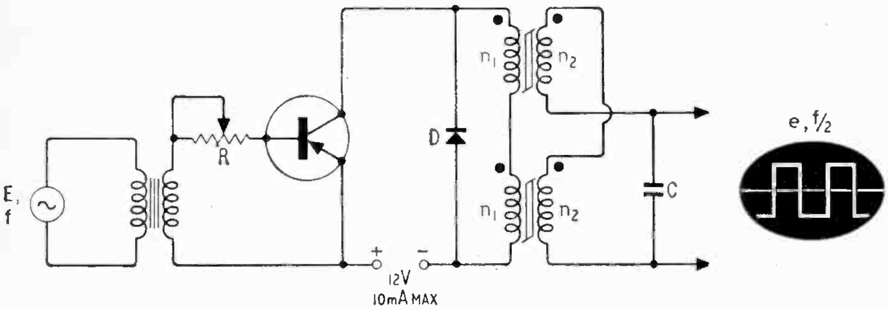


Fig. 3. Practical circuit arranged for transistor drive.

over reasonably wide ranges of frequency and is not strongly dependent on the amplitude of the input drive. Failure of the drive results in zero output so that the system is inherently of the fail-safe variety. The divider works best at audio frequencies and is particularly good at low frequencies where the quasi-sinusoidal output is more useful than say the pulse output from a blocking oscillator or the square wave from a flip-flop.

Transistor drive circuit

The simplest possible transistor drive circuit is shown in Fig. 3. The transistor is zero-biased and operates as a single-ended Class B amplifier. It is driven from a low-power source of frequency f through a small matching transformer and a variable resistance R which serves to adjust the drive level. The saturable transformers are connected in series in the collector circuit. The diode D which in the basic circuit was placed in series with the two transformers is now connected in shunt with them and acts as a damping diode. It can continue to conduct even when the transistor is cut off.

In an actual circuit built to test the divider operation the two transformers were wound on mu-metal toroids $1\frac{1}{2}$ in diameter with a core section $\frac{3}{16} \times \frac{3}{16}$ in. The primary winding $n_1 = 200$ turns and secondary $n_2 = 800$ turns of 30 s.w.g. enamelled wire. As measured at low excitation levels on a 1000 c/s impedance bridge the primary and secondary inductances were 90 mH and 1·6 H respectively. Suitable strip-wound toroidal cores are available from S.T.C. Ltd. (List No. 55, $1\frac{7}{8}$in × $1\frac{1}{4}$in × $\frac{3}{16}$in, wound from 0.002in tape of Permalloy "C" material is a recommended choice.) Almost any type of transistor, germanium or silicon, p-n-p or n-p-n, can be used in the circuit and any low-power diode, germanium or silicon, will give satisfactory operation. If n-p-n transistors are used, the diode polarity in Fig. 3 should be reversed.

Choice of the capacitor C dictates the optimum input frequency and the bandwidth over which reliable division is obtained. Some typical performance figures are given below: —

Capacitor C	*Operating Frequency Range*
0·1 μF	1400-1500 c/s
0·5	550-650
1	270-370
2	150-220
4	80-160

Satisfactory operation down to 10 c/s is possible using transformers with mumetal cores using E and I laminations instead of strip-wound toroids. Though the performance is not so good the transformers are much easier to wind. Close magnetic coupling between primary and secondary is necessary and can be obtained by interleaving the coils in sections or by multifilar winding.

The upper frequency limit is set by the available drive power and by the fundamental properties of square-loop core materials. For ferrite toroids of the type used in computer stores, the minimum switching time as around one microsecond, so that in principle it should be possible to achieve frequency-divider action up to a few hundred kilocycles per second. Unfortunately, so much drive power is required that the system compares unfavourably with alternative types of divider.

To test the possibilities, two ferrite toroids (Mullard FX 1396, 8 mm × 5·8 mm × 2 mm) were bifilar wound with 100 + 100 turns of 38 s.w.g. enamelled wire and driven from a signal generator capable of developing 4 V r.m.s. across a 50 Ω load. In the circuit of Fig. 1 and with 68 Ω in series with the generator, reliable division 200/100 kc/s and 100/50 kc/s was obtained with capacitance values $C = 0{\cdot}005\,\mu$F and $0{\cdot}01\,\mu$F respectively.

Drive requirements in the circuit of Fig. 3 would call for the use of high-power high-frequency core-driver transistors, and buffer amplifiers would be required between successive divider stages. High frequency operation is thus economically unattractive. Fortunately it is in the high frequency range that the parametric divider shows up to advantage and operation up to at least 30 Mc/s is possible using varicap diodes or reactance transistors as described previously by the writer.†

Possible applications

In one system of radio telegraph working, the mark and space conditions of the signal are represented by successive short bursts of tone or carrier which differ in phase by 180 degrees. To demodulate such signals, a phase detector is used to compare the relative phases of successive signal elements with a stable reference. This may be transmitted or may be locally generated at the receiver by frequency-doubling the input signal to remove the 180 degree shift and then frequency-dividing to recover a continuous tone of the original frequency. The circuit of Fig. 3, followed by a high-impedance buffer amplifier to avoid loading the output of the divider, is almost ideal for this purpose. It is simple, compatible with the rest of the telegraph terminal equipment, gives no output in the absence of a drive signal and is extremely reliable.

In respect of noise immunity, phase stability, invulnerability to the effects of radiation, circuit simplicity and tolerance of supply and drive-voltage variations the magnetic divider is outstanding. Its limitations for use at high frequencies appear to be fundamental whereas the economic low-frequency limit is set by the cost of the toroidal cores. It is at its best in the middle audio frequency range for which it is an acceptable alternative to the blocking oscillator, transistor toggle (flip-flop), the regenerative modulator and the parametric divider. Readers interested in computer techniques may recognise some family resemblance between the magnetic divider and the parametron. Finally, it is interesting to note that, although magnetic frequency multipliers, usually triplers, have been known for many years, it is only recently that reliable dividers have been developed.

†*Wireless World*, January, 1964.

U.H.F. TELEVISION

RECEPTION MODULATION PROPAGATION

SINCE the Stockholm Conference in 1961 and the allocation of television channels in the u.h.f. band, a great deal of operating experience has been obtained both on the Continent and in the U.K. This experience was combined at The International Conference on U.H.F. Television sponsored by the I.E.R.E., I.E.E., I.E.E.E. and the Television Society and held at the Institution of Electrical Engineers on November 22nd and 23rd. Twelve countries were represented by about 300 delegates and 28 papers were presented. A good deal of attention was given to the problems resulting from the "light-wave" behaviour of radio waves at u.h.f. Shadow areas and variation of field strength still present problems and a great number of translator or transposer stations than was at first thought necessary are obviously needed.

The first paper of the conference by F. C. McLean (B.B.C.) dealt with "Television coverage on u.h.f." and reviewed the position as regards shadow areas and gaps. In the London area, surveys are being made which utilize two methods—observations by B.B.C. engineers and analysis of questionnaires. Apparently the latter method does not provide a realistic result because the bulk of returned questionnaires are from unsatisfied viewers, whereas the satisfied viewer does not take the trouble. One of the facts revealed by the survey showed that if all the viewers questioned had used adequate receiving aerials, 93% of those within the area (excluding shadow areas) would have had satisfactory reception. It is interesting to note that satisfactory reception figures in Bands I and III in the corresponding area are 98.7% and 96.7% respectively.

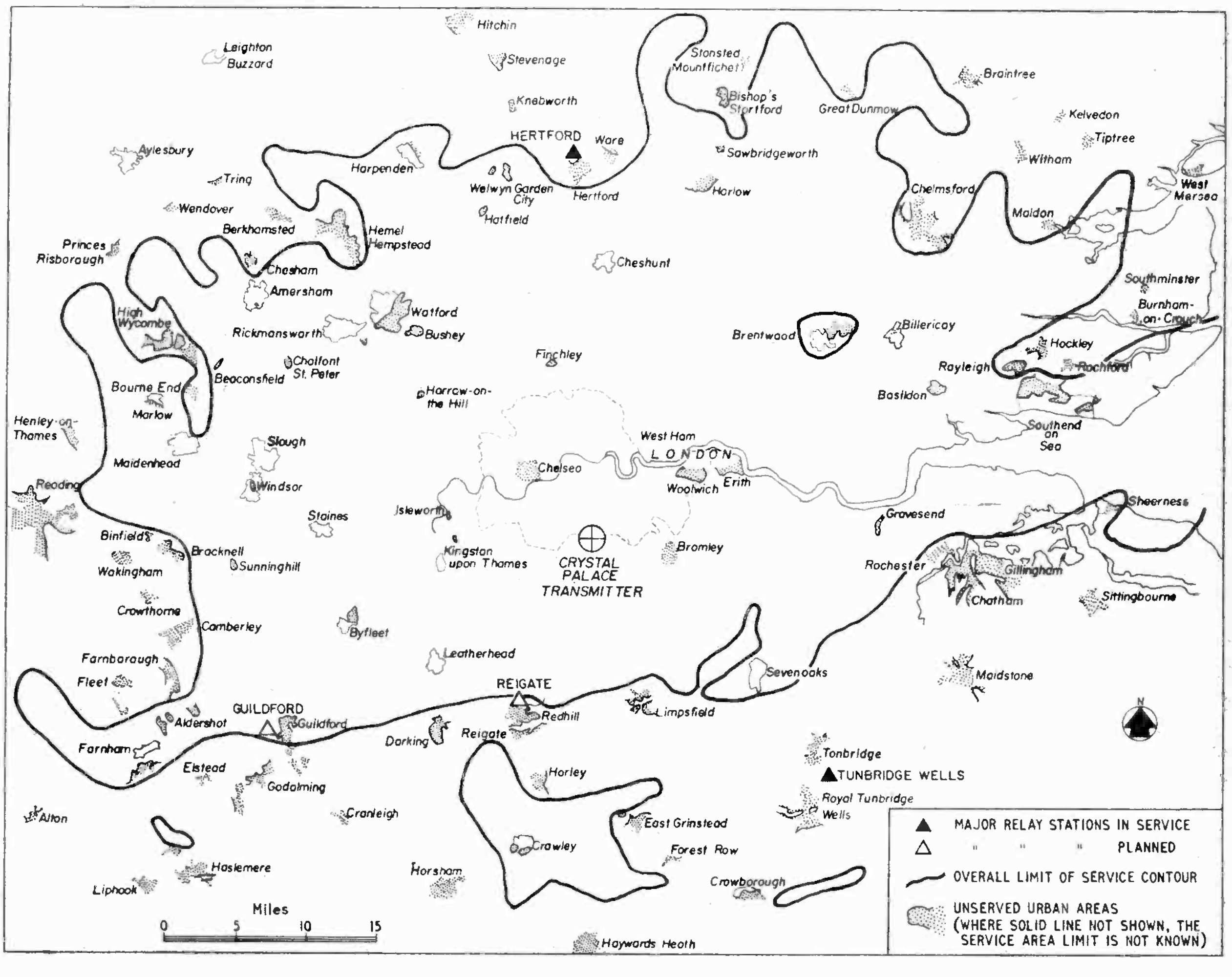


Fig. 1. The map shows the service area of the Crystal Palace transmitter in channel 33 (vision 567.25 Mc/s, sound 573.25 Mc/s). The limit of the monochrome service area is represented on the map by a heavy black line enclosing towns in which 70% of the populated area (50% in villages) has a field strength of not less than 70 dB above 1 μV per metre. Positions of existing and planned major relay stations (a major relay station has an e.r.p. of over 1 kw in any direction) are given but the coverage of the existing stations is not included on the map.

Where reception was found unsatisfactory, the principle causes were random noise and pattern interference.

In Fig. 1, a map, reproduced from the paper and based on measurements in populated areas only, shows the coverage of the u.h.f. Crystal Palace transmitter on channel 33. Existing relay stations together with those planned for future use are also shown. An interesting point made by the author was that in the future when the u.h.f. plan is fully implemented, the service area will be limited by co-channel interference and some of the relay stations will have to provide field strengths in the region of 80 to 90 dB(μV) if the service is to be adequately protected from co-channel interference.

Reception

Picture degradation due to multi-path propagation has not been as serious as was expected because of the highly directive properties of u.h.f. aerials. Television receiving aerials for u.h.f. were the subject of a paper by R. S. Roberts (Northern Polytechnic and Antiference). As is well known, in the u.h.f. scheme for national coverage, 44 channels, each 8 Mc/s wide, have been allocated and for each area there will ultimately be four co-sited stations transmitting horizontally polarized signals As the author pointed out, careful frequency selection of the four channels to be used was necessary to minimize interference and this had resulted in the use of four channels in a frequency band 88 Mc/s wide This then decided the minimum bandwith of the receiving aerial In addition, the wide variation in field strength that occurred at u.h.f. indicated that the aerial must possess gain and directivity. Several types of aerial could be used but undoubtedly the Yagi was the popular choice. However, although the gain and directivity depended upon the number of elements, the gain per element tended to decrease as the number of elements was increased and it was shown that it was uneconomical to manufacture a single Yagi for more than a gain of 13 dB although where improvement was necessitated by exacting conditions the use of a Yagi as an element in a multiple array gave a better performance.

The author commented that at u.h.f., the radio wave exhibited the characteristics of light, and effects of reflection, refraction and diffraction are marked. Outdoor siting of the aerial is obviously preferable to indoor siting, but even with an outdoor aerial at a height of 30ft, house-to-house variation of 12 dB had been measured. It is interesting to note that increasing the height to 35ft decreased the variation to 6 dB. It has been observed that where an obstacle lies in the receiving path of the aerial, diffraction effects dictate that the siting of the aerial should be in line with the top of the obstacle for maximum signal strength.

Diffraction

One of the effects dealt with by E. Sofaer and C. P. Bell (both of the B.B.C.) was diffraction. The authors considered diffraction to be one of the most important effects which cause differences in propagation at u.h.f. compared to other bands. Fresnel's knife-edge theory was used to correlate data on shadow losses, transmitting frequency and aerial height. Two receiving points, A and B, were considered at distances of two and five miles respectively in the shadow of an obstacle 500 ft high. As a basis for comparison, the signal obtained from a transmitting aerial 1,000 ft above ground level and operating on a frequency of 50 Mc/s was used. The shadow loss effect at the two receiving points when the transmitting frequency is altered to 500 and 750 Mc/s is shown in Table 1 under condition (1). The ratios of these losses provide an indication of the increases in e.r.p. necessary at the higher frequencies.

TABLE I

Condition	500 Mc/s		750 Mc/s	
	A	B	A	B
(1)	6 dB	9 dB	7.5 dB	11 dB
(2)	1,230 ft	2,025 ft	1,250 ft	2,110 ft
(3)	870 ft	1,150 ft	990 ft	1,360 ft

Raising the height of the aerial to compensate for these losses was next examined and the required height is given under condition (2). For example, at 500 Mc/s the 6 dB loss at A can be eliminated by increasing the height of the aerial by 230 ft to 1,230 ft Finally, with the aerial at 1,000 ft and the frequency 50 Mc/s, condition (3) shows the height to which the obstacle would have to be raised to produce losses comparable with those shown in (1).

The authors considered that the figures show diffraction alone imposes practical economic limits as regards e.r.p. and mast height for u.h.f. transmissions; in addition, terrain which appears gently undulating at a Band I frequency will seem quite rough at u.h.f.

Relay stations

Perhaps one of the most significant facts to emerge from the previously mentioned surveys is that no major basic alteration appears to be necessary to the 64-station network approved at the Stockholm Conference. However, in his paper dealing with frequency planning R. S. Sandell (B.B.C.) considered the additional network of low power relay stations which have been found to be necessary.

The author expects that the number of stations will exceed 1,000 and they will have e.r.p.s of 5 W to 10 kW. In planning the network, sources of interference with the main u.h.f. network have to be carefully considered. A further consideration is the generation of intermodulation products. Many spurious frequencies can arise from a station simultaneously transmitting vision and sound signals and possibly a colour sub-carrier in four channels.

Transmitter output power devices

A decision facing the u.h.f. transmitter design engineer is the choice of the power output device. Currently, tetrodes, klystrons, and travelling-wave tubes are available.

A comparison of the klystron and the tetrode was made by W. J. Morcom and J. Sutton (both of Marconi) in their paper, "A u.h.f. television transmitter." As regards reliability the klystron had several advantages over the tetrode. It was not so prone to short-circuits as would be a typical 10 kW tetrode in which cathode-to-grid spacing is typically less than 1 mm. Various blocking capacitors are required for the tetrode whereas none are required for the klystron. A tetrode amplifier in the vision chain would need more tuned circuits than the klystron and due to the cooling difficulties involved the tetrode transmitter would be less stable with regard to maintenance of performance over long periods. From the cost point of view neither device had a definite advantage. In respect of ease of operation, the authors considered maintenance of frequency response to be one of the main factors and the klystron scored on this point. Running and maintenance costs depend on power consumption, working life and replacement costs. A vision peak power of 10 kW was used as a comparison of power consumption and for this figure the power consumption of the klystron was considered to be 1.3 times that of tetrodes. Replacement costs of klystrons is 2.3 times that of tetrodes; however, the authors expected that the life of klystrons was three times that of tetrodes, thus making the klystron cheaper.

Further reference to the use of klystrons was made by D. Ingle (Pye) in a paper on "A high power u.h.f. television transmitter."

The author commented that the fundamental advantages of the klystron—robustness, low cathode loading and long life expectancy—had made the device popular with designers, and klystrons especially for television use had been developed with high perveance; the required bandwidth was obtained by stagger tuning the second and penultimate cavities. During operation the klystron drew a constant current irrespective of the output power variations with modulation. As a result, the collector current did not contain a video component and a constant impedance network for the smoothing filter was not necessary. Mr. Ingle made the point that the klystron transfer characteristic is linear for the major portion, sufficiently enough to require only a small amount of predistortion in the video amplifier. The 625-line transmission incorporated negative modulation and this meant that the klystron could be operated with the black level of the signal within the linear portion of the characteristic.

Modulation

A new method of absorption modulation was also described by Mr. Ingle. A three-port stripline circulator was used and connected as shown in Fig. 2. The r.f. drive amplifier, modulating diode and output load were connected to ports 1, 2 and 3 respectively. The system had a characteristic impedance of 50 Ω and the impedance of the modulating diode was controlled by a modulating amplifier so that the diode impedance could be varied between zero and 50 Ω. Power from the r.f. drive amplifier entered port 1 of the circulator and was diverted to the modulating diode via port 2. The forward loss was about 0.5 dB and isolation about 20 dB. When the impedance presented by the modulating diode was zero, power was reflected and re-entered the circulator where it was diverted to port 3 and thence to the output. When the impedance presented by the diode was 50 Ω all the power was absorbed and none diverted to the output load. By varying the impedance of the diode in accordance with the video signal, modulation

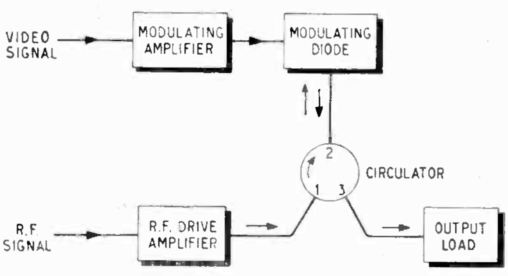


Fig. 2. Block diagram showing a three-port circulator used for the method of absorption modulation.

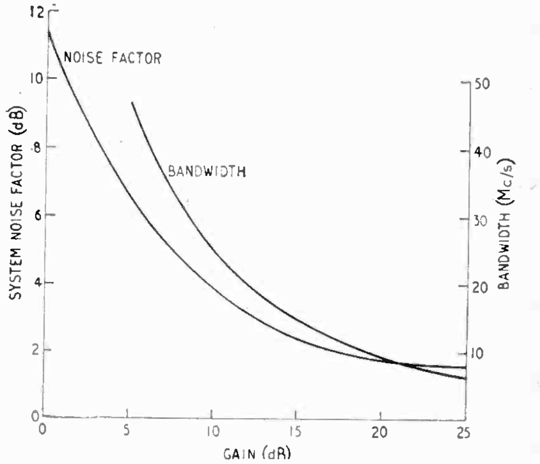


Fig. 3. Graph of the noise factor and gain bandwidth characteristic of the parametric amplifier.

of the carrier was effected. The video signal from the modulating amplifier was approximately 100 V and contained the d.c. component. The signal was fed as bias to the diode and thus the variation of impedance at port 2 was obtained as required. The diode was mounted in a short-circuited coaxial line which was used to tune out the reactance of the diode, and also provided a method of coupling r.f. energy to the diode by the use of a probe which was utilized as a matching arrangement for the diode and circulator.

Experience with a travelling-wave tube for television translator service was described by H. Heynisch and A. Rother (Siemens & Halske). The tube, type YH1020, designed for operation in the frequency range 470-960 Mc/s, has been found to be particularly suitable for use in the output stage of u.h.f. television translators and can operate at 50 W peak sync power output for combined vision and sound service. Air cooling is used and approximately 2 kW of heat is removed by an air stream of 3,000 litres/min. The tube has been subjected to tests, specified by the German broadcasting authority (A.R.D.), for intermodulation and harmonic and cross modulation. However, it has been found that the tube does not meet the specification for harmonic and cross modulation and a filter is necessary in the output circuit of the tube. Colour transmissions have been made using the N.T.S.C. and PAL systems. At 50 W peak sync power differential phase and differential gain are 1° and 0.5% respectively.

Parametric Amplifiers

Two papers on parametric amplifiers were presented at the conference. In his paper, dealing with the performance of a parametric amplifier for professional u.h.f. television and communication equipment, P. J. Gibson (Mullard) discussed noise factor and the effect, by measurement of pulse and bar waveforms, of using such an amplifier in a system. The amplifier described was based on a design which has been used at frequencies from 400 to 4,600 Mc/s. The signal circuit consisted of a varactor diode resonated with a lumped inductance coupled by a microwave transformer and circulator to the signal source and load. Tuned to a centre frequency of 658 Mc/s to receive B.B.C. experimental transmissions on channel 44, the amplifier was adjusted to a gain of 20 dB. A noise factor of 1.8 dB was measured; this took into account a noise factor of the following receiver of 9 dB.

Reproduced from the paper in Fig. 3 is a graph illustrating the bandwidth and overall noise factor of a diode parametric amplifier as a function of the gain. Bandwidth, measured at the 3 dB points for gains of 15 dB and 20 dB, was 16 Mc/s and 11 M/cs respectively. Variation of noise factor when varying the pump frequency to tune the amplifier from 540 Mc/s to 580 Mc/s is shown in Table 2 also reproduced from the paper.

Table 2

f(Mc/s) signal	f(Mc/s) pump	dB noise factor
540	8654	2·65
550	8778	1·9
560	8879	1·9
570	8953	1·9
580	9040	2·3

Under the K-rating system, used to correlate waveform distortion in a linear system with impairment of picture quality, typical values of K-rating are ½% for a video amplifier and 2% for a receiver. K-rating limits are specified on T pulse and bar waveforms (see I. F. Macdiarmid, "A testing pulse for television links," *Proc. I.E.E.*, 99 Part 3A, p. 436, 1952 and N. W. Lewis, "Waveform responses of television links," *Proc. I.E.E.* 101, Part 3, p. 258, 1954).

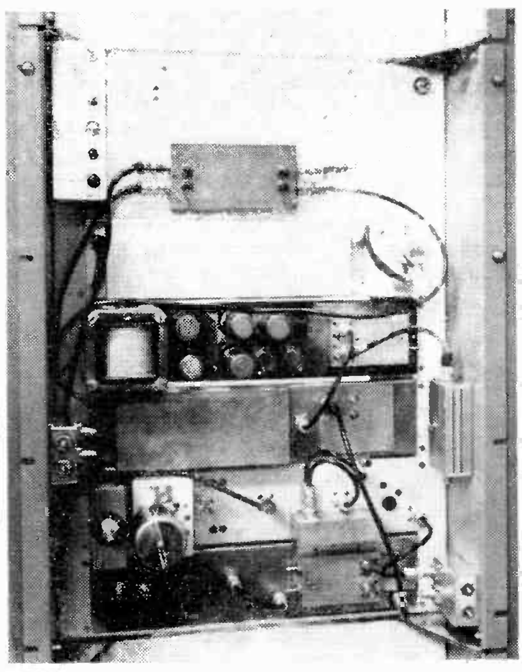
The T pulse has a sin² shape and the spectrum of the 2T pulse covers the system bandwith of 5.5 Mc/s, and a repetitive sequence of a 2T pulse and bar waveform at the line scanning frequency measures the response of the system to line and picture information frequencies. The parametric amplifier was inserted in a system which had a K rating of 2 to 2½% linearity distortion. The amplifier had no effect on the linearity distortion but there was a small increase in the pulse/bar ratio; the response however remained satisfactory below a K rating of 2%.

U.H.F. Television Relay Stations Use Solid-state Translators

THE first u.h.f. unattended relay stations for BBC2 television have now been brought into service at Hertford and Tunbridge Wells. They are of the translator type (receiving an input signal from the Crystal Palace transmitter) and provide coverage in their respective areas where reception of the main u.h.f. television station on a domestic aerial is normally difficult.

The output stages of such stations use travelling wave tubes or klystrons, and as these are very high gain stages a relatively low power input is required. This has enabled solid-state circuitry to be used for other than the final output stage. Accordingly, the B.B.C. has designed solid-state translators suitable for driving the output stages, and as far as is known these are the first to be brought into service for this purpose anywhere, in the u.h.f. field.

The solid-state circuit units are suitable for colour transmission and follow conventional translator form except for the output stages. These could not be constructed in the conventional manner as suitable transistors are not yet available for this purpose. They are therefore of the parametric amplifier type and make use of suitable diodes in association with a pump circuit.



(Above.) The Hertford station makes use of a water tower to elevate the transmitting and receiving aerials. The relay equipment is in a small building behind the trees. (Right) A solid-state translator unit.

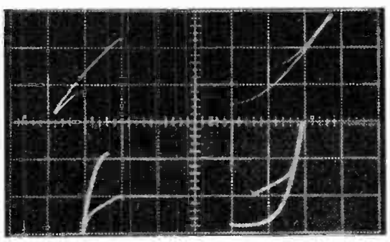
NEW PRODUCTS

equipment systems components

HIGH-SPEED STORAGE OSCILLOSCOPE

SPLIT-SCREEN storage facilities are provided on the Type 549 storage oscilloscope from Tektronix. Each half of the 6×10 cm display area can be independently controlled to allow either stored or transient information to be shown on either the upper or lower half of the screen. This feature allows a test or standard signal to be stored on one half of the screen and compared with successive signals displayed conventionally on the other half. (In the illustration a normal 5 mA tunnel diode current/voltage characteristic is stored on the lower half of the screen and an abnormal diode characteristic in the conventional mode is shown on the upper half.

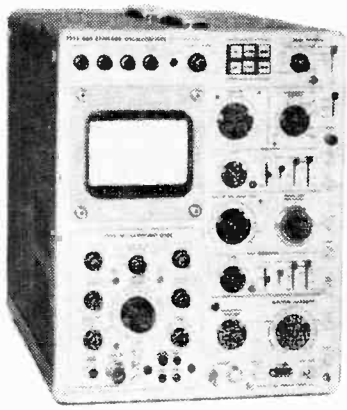
An automatic erase circuit is fitted to this scope for erasing either or both halves of the display. The viewing time before erasure of the transient information can be varied from 0.5 sec



to 5 sec; storage time is up to one hour. The basic writing speed is better than 0.5 cm/μsec, and with enhancement better than 5 cm/μsec.

Any of the established Tektronix letter-series or 1-series plug-ins for either general-purpose or specialized applications (up to 30 Mc/s) can be used in this scope. It also accepts the spectrum analyser units, making the instrument a storage-type spectrum analyser.

The calibrated sweep range of the A time base is from 0.1 μsec/cm to 5 sec/cm in 24 steps; continuously variable between steps, but uncalibrated. The B time base has 18 calibrated steps from 2 μsec/cm to 1 sec/cm.



Accuracy of both time bases is ±3%. A 5X sweep magnifier is provided on both time bases, accuracy is within ±5%.

Dimensions of the Type 549 are 17×13×24 in; weight is approximately 67lb. The address of Tektronix U.K. Ltd. is Beaverton House, Station Approach, Harpenden, Herts.

WW 301 for further details

SMALL CIRCUIT BREAKER

OCCUPYING a space of only 2×¾×1½ in, the new circuit breaker from the Heinemann Electric Company, of Germany, can be used with any current between 100 mA and 20 A, at voltages up to 250 V a.c. (50 or 400 c/s), and 50 V d.c. This magnetic circuit breaker, designated Type JA, is available with terminals for either soldered, crimped or screw type connections.

Shunt or relay trip facilities are offered and auxiliary switch contacts can be added. Series windings can be provided with a calibrating tap.

Heinemann circuit breakers are available in the United Kingdom through Austinlite Ltd., Wingate House, 93-107 Shaftesbury Avenue, London, W.1.

WW 302 for further details

INDUSTRIAL TRANSISTORS

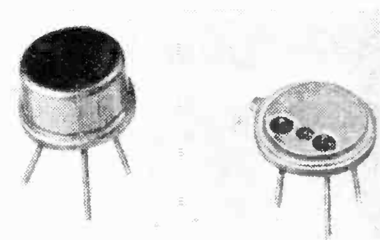
A PAIR of complementary transistors (V405A & P346A) for industrial applications have been announced by SGS-Fairchild Ltd., of 23 Stonefield Way, Ruislip, Middx. Both are silicon planar epitaxial devices and feature a low "bottoming" voltage; of the order of 180 mV at 25 mA, and 300 mV at 100 mA. Another feature of these transistors which have a 12 V collector/emitter rating, is an f_T greater than 400 Mc/s. As to price, the n-p-n device (P346A) costs 4s 6d and the p-n-p (V405A) costs 5s 11d, at 100 up.

WW 303 for further details

Marconi Marketing New Power Transistor

ONE of the transistors now in quantity production for the Myriad computer and for the recently announced E.E.L.M. System 4 computer range is now being marketed by the Microelectronics Division of the Marconi Company. The transistor, designated 203-03, is a silicon planar n-p-n device mounted in a standard TO-5 encapsulation.

The transistor has been designed for (power) driving fast ferrite core stores with cycling times of the order of 1 μsec. It has also been found useful in other applications in data processing where a number of logic elements have to be driven simultaneously. In a typical circuit, the total time to



"switch-on" the 203-03 is 14 nsec, and the total time to "switch-off" is 90 nsec.

Specification details of this device include an emitter-base voltage rating of 4.5 V (Max.), a collector-emitter and collector-base voltage rating of 50 V (Max.), peak emitter current of 1.0 A, and a maximum power dissipation at 25°C case temperature of 3.0 W. With an ambient temperature of 25°C, the maximum power dissipation is 0.8 W.

The address of the Microelectronics Division is Witham, Essex.

WW 304 for further details

STATISTICAL D.V.Ms

THE range of statistical digital voltmeters made in the United States by Non-Linear Systems Incorporated is available in the United Kingdom through Claude Lyons Ltd., of 76 Old Hall Street, Liverpool 3. Three basic statistical d.v.ms are included in the range, which the makers claim can automatically measure, classify and plot data in the form of histograms (display of electrical or physical data as a statistical plot).

The most sophisticated of the instruments is the Model 7200 which can accept up to 1,000 entries per class at a rate of three per second, classify them and store them on a magnetic drum, and within 30 seconds from command, complete the plotting of a 22-class frequency distribution graph (histogram). Accuracy is approximately ±0.01% of full scale. This instrument can plot a number of successive graphs on the same chart, to allow the user to compare successive tests, or to note changes in frequency distribution during a test or a process.

The Model 7300 provides immediate visual display through a 19-class electro-mechanical readout. Height of the 19 vertical "light bars" used in the readout is proportional to the number of readings falling into that class. Up to 100 samples (200 at extra cost) can be entered for each class at a speed of ten entries per second. Accuracy is approximately ±0.01%.

The other instrument, the 7400,

classifies information at a minimum rate of 5 samples per second and can plot a 22-class histogram on an integral strip-chart recorder within 25 seconds from command. Twenty, 50 or 100 entries per class are possible with this instrument, which has an accuracy of ±0.1%.

Electrical outputs indicating the class of each sample as it is entered are provided on each of the three instruments for operating sorting, recording or totalizing devices.

A statistical digital ohmmeter version of the 7400 is also offered. This instrument, designated 7404, can classify resistances from 1 to 111,110Ω in terms of their per cent deviation from a nominal value—selected on an integral five decade resistor network—and present a histogram depicting the statistical distribution of the deviations. Class width can be set from 0.02% to 2% of the nominal value.

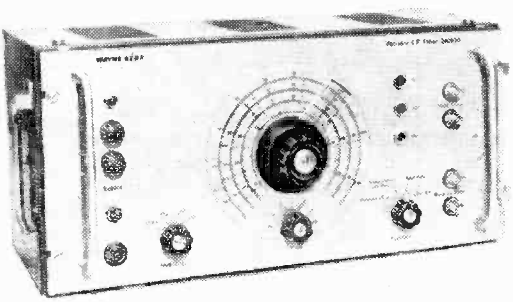
Prices range from £2,000 to £4,200.

WW 305 for further details

Twin Low-frequency Filter

TWO identical channels which can be used independently, in cascade, or in a band-pass arrangement are contained in the Model SA 500 low-frequency filter from Wayne Kerr. Twenty-eight ranges are provided covering the frequencies 0.1592 c/s to 1592 c/s. A single tuning control, operable on all ranges, is used to set the frequencies of both channels.

The input impedance of each channel is 2 MΩ (resistive) and the output impedance is less than 60Ω. Attenuation rate with the two low-pass filters in cascade is 36 dB per octave and in the band-pass condition, there is unity gain and zero phase-shift at the centre frequency. Either side of this frequency, the attenuation is 18 dB per octave.



The S.A. 500 is available in two forms, either suitable for 19-in rack mounting, or in a portable case measuring 20×9×9 in. It weighs 23 lb, and has a consumption of 20 W from normal a.c. supplies.

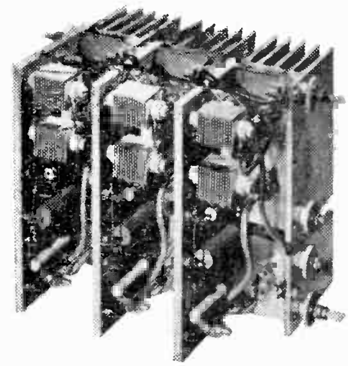
The address of Wayne Kerr Laboratories Ltd. is Sycamore Grove, New Malden, Surrey.

WW 306 for further details

Solid-state P.S.U. for Travelling-wave Tubes

SOLID-STATE stabilized d.c. power supply units to drive travelling-wave tubes have been developed by the Rectifier Division of Standard Telephones and Cables Ltd., Edinburgh Way, Harlow, Essex. The main features of these equipments is that they are smaller and cheaper than the conventional units employing transductors.

The unit illustrated is one of several to be used in u.h.f. television translators to be supplied to the B.B.C. by the company. Operating from normal

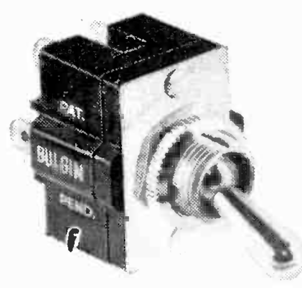


mains supplies, these units provide 3.2 kV at 0.75 A. Stablity is ±0.5%.

WW 307 for further details

Double-pole Switches

FOLLOWING the success of the single-pole moulded switches introduced by A. F. Bulgin some three years ago, the company announces a range of double-pole moulded-insulation switches. On-off and change-over, double-pole, types are available with or without biased action, and with various types of toggle

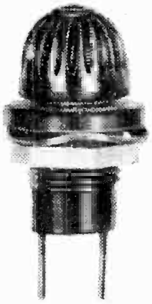


actions including ball, pear, slotted, push-push and push-pull.

The catalogue list number is S.M. 270 and the address of A. F. Bulgin & Co. Ltd. is Bye-Pass Road, Barking, Essex.

WW 308 for further details

Sub-miniature Lampholder



A NEW type of lampholder has been introduced by Thorn to meet the requirements of DEF 5201. This unit is slightly larger than the existing range of Thorn sub-miniature lampholders and more robust. The holder accepts the long-life 6 volt lamp L 1123.

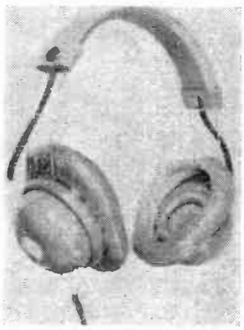
This lampholder is available with glass lenses to BS1376 in red, green, blue, orange, yellow and colourless. The two terminals are insulated from the panel and are designed for "Faston" tags or solder connection.

The address of Thorn Special Products Ltd. is Great Cambridge Road, Enfield, Middx.

WW 309 for further details

NOISE EXCLUDING HEADSET

SUITABLE for reproducing mono and stereo signals at sound levels up to 120 dB is the new noise excluding headset from the communications division of S. G. Brown Ltd., of Dukes Avenue, London, W.4. Known as the "Dynamic" 3C 1100 it contains a pair of electrodynamic transducers, each of which has



an impedance of 8Ω at 1 kc/s. One milliwatt of input power is required for a 95 dB s.l. (normal listening level) and 500 mW (maximum input power) per transducer for 120 dB s.l. Total distortion is less than 1% and 6% respectively. The frequency response (within ±6 dB) is from 20 c/s to 8 kc/s and attenuation of ambient noise is 12 dB at 1 kc/s. The retail price is £6.

WW 310 for further details

DIGITAL CAPACITANCE TESTERS

TWO instruments for production testing of capacitors and of the capacitance of other devices are being made by the Micro Instrument Company, of California. Five capacitance ranges are provided on the unit covering the lower ranges (from 0-100 pF to 0-1 μF) and six on the other (0-0.01 μF to 0-1000 μF). The instrument covering the lower ranges, the Model 5320, operates at 1 kc/s and the other, Model 5300, at 120 c/s.

A series capacitance reading is obtained with these instruments which is independent of the effective series resistance, even when additional series resistance is added to the test capacitor. On the Model 5320, a 2 V r.m.s. test voltage is used on all ranges, while the Model 5300 uses three different voltages to cover its various ranges—0.1 V r.m.s. on the 1000 μF range, 1 V on 0.1 to 100 μF ranges and 5 V on the 0.01 μF range.

Two ranges of d.c. bias (0-20 and 0-200 V) are provided on the Model 5300, with front panel meter and controls. The bias charge time is, of course, dependent upon the capacitor under test which is charged and discharges through a 500 Ω resistor. However, as an indication of charge time, a 1 μF capacitor will charge to 99% of final bias voltage in 2.5 msec. No d.c. bias is provided on the other instrument.

Accuracy is quoted as ±0.25% of reading, ±0.25% of full scale (±2 pF or 1 digit, whichever is greater). The standard models are fitted with a three digit in-line display and it is possible to convert them—at little extra cost—for 25% over-ranging with a fourth digit, or for full four digit readout. In all cases a printer readout can be provided.

A meter is provided to indicate dissipation factor. Two ranges are provided—0-10% and 0-100%—and an accuracy of ±2% is quoted. Indication is simultaneous with capacitance readout.

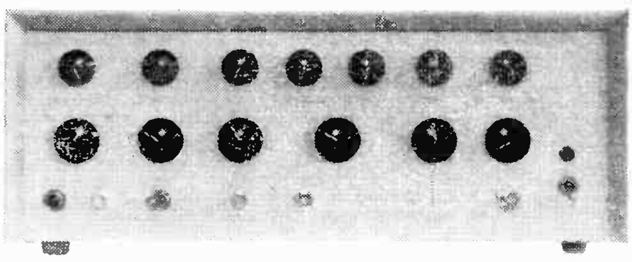
Both of these instruments are available in the United Kingdom through Claude Lyons Ltd., of 76 Old Hall Street, Liverpool 3. They are both priced at £918. A version of the Model 5300 with provisions for digital leakage current measurement costs £1,560. It carries the prefix L.

WW 311 for further details

Pulse Generator

WITH rise and fall times variable from 6 nsec to 100 msec at 10 V into 50Ω, the E-H Research Laboratories Model 139L pulse generator should be of particular interest to those concerned with logic computing circuits. Pulse repetition frequency is from 1 kc/s to 20 Mc/s, but limited to 10 Mc/s when operating in the double pulse mode.

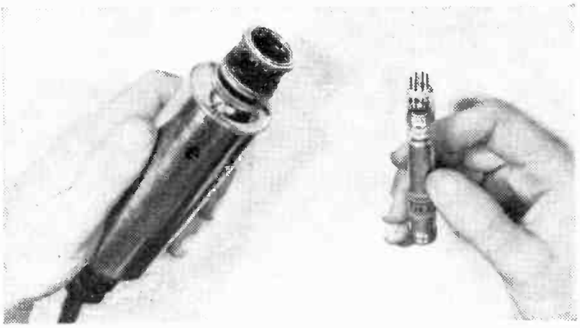
Pulse width is continuously variable from 20 nsec to 300 μsec and delay is continuously variable from 50 nsec to 100 μsec. Positive or negative pulses are available and the pulse train base line may be offset up to a maximum of ±2 V with either polarity. Maximum peak pulse amplitude is ±10 V as referenced to zero, and maximum relative is 10 V regardless of offsetting.



Other features of this instrument include a pulse top distortion figure of less than 5%, a base line distortion of less than 5% (except on the 100:1 attenuator position, but still less than 8%) and a single cycle facility.

This American designed instrument is being made in the United Kingdom and is available—price £450—from Livingstone Laboratories Ltd.

WW 312 for further details



Miniature Television Camera

THREE different cameras are offered with the latest closed circuit television system being marketed by EMI Electronics Ltd., of Hayes, Middx. Among the cameras in System 9, as it is called, is one which the manufacturers claim to be the smallest in the world.

This small camera, designated D, is in two parts, the head assembly carrying the lens, together with the vidicon tube, associated coils and the front end of the video amplifier. The rest of the video amplifier, line sawtooth amplifier and vidicon blanking and protection circuits, is incorporated into the camera lead.

The lens is focused by a micrometer adjustment to give an image size of 0.19×0.26 in on the new half-inch vidicon tube (EMI Type 9697) employed in the D camera. Separate mesh construction is used in this tube to obtain a high resolution. For the image dimensions given earlier, it is possible to obtain a 300-line resolution. Price of this camera is approximately £550. The vidicon tube can be obtained separately; the price varying from £75 to £175 according to the manufacturer's blemish specification concerning the target material. Solid state circuitry is employed throughout System 9.

WW 313 for further details

TAPE PRE-AMPLIFIER UNIT

DESIGNED for use with a three-headed stereo tape deck (record, playback and erase) is the new tape pre-amplifier unit from the Brenell Engineering Company, of 231-235 Liverpool Road, London, N.1. At least 75 mV is required to drive the unit.

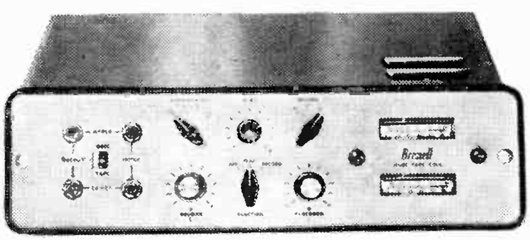
The unit, known as the Brenell Hi-Fi Tape Link, contains a pair of recording amplifiers, a 90 kc/s bias/erase oscillator and a pair of playback amplifiers. Mono and stereo recording facilities are provided, and while recording one can listen to the recorded material through the playback amplifier to enable a comparison to be made between the recorded and original signal. Recording signal levels are displayed on two edgewise scaled meters.

Frequency correction for 4 tape speeds ($1\frac{7}{8}$, $3\frac{3}{4}$, $7\frac{1}{2}$ and 15 i.p.s.) is incorporated for both record and playback and variable bias is provided for the recordist to obtain optimum results at all tape speeds with all brands of tape.

Sockets are fitted at the rear of this valve unit for connection to the associated tape deck and ancillary equipment. Four jack-sockets are also provided—on the front panel—for connecting equipment which is seldom used. The relevant sockets at the rear are automatically disconnected when those on the front panel are used.

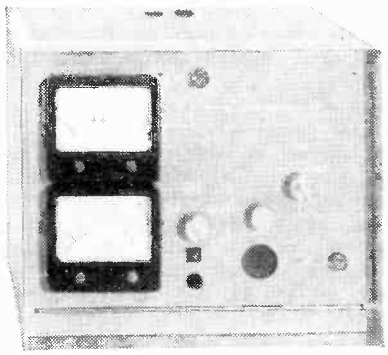
The unit, together with its separate power supply unit, costs £46.

WW 314 for further details



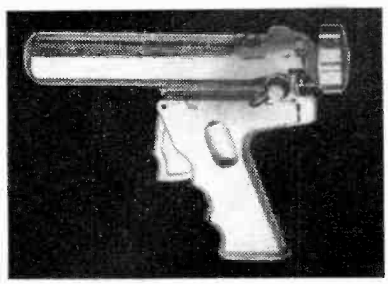
VOLTAGE AND FREQUENCY MONITOR ALARM

SPECIALLY designed for use with computers and process control systems is the voltage and frequency monitor alarm announced by Aveley Electric Ltd., of South Ockendon, Essex. The voltage and frequency meters in this equipment have tolerance indicators which may be adjusted to 1% of indicated scale reading. Once the voltage or frequency being monitored moves out of the selected limits, audio and visual alarms are automatically brought into operation. Remote alarm facilities are available.



The standard units are suitable for monitoring 50 to 150 V and 100 to 300 V at 50 c/s and 50 to 150 V at 60 c/s from single phase supplies. Units for three-phase monitoring are available to special order.

WW 315 for further details



Guns for Dispensing Sealants

AIR-OPERATED guns suitable for accurately placing sealants, such as is necessary when potting some component assemblies, etc., are now available through Bush Beach & Segner Bayley Ltd., of Marlow House, Lloyds Avenue, London, E.C.3. The guns, which are cartridge loaded and available with $2\frac{1}{2}$, 6 or 12 oz capacity ratings, are made by Pyles Industries Incorporated, of Michigan. They will operate from any pressure source ranging from 5 to 150 p.s.i.

WW 316 for further details

Leak Detector Probe

CAPABLE of detecting and pinpointing vacuum leaks to within 0.010 in is the new probe developed by the Eimac Division of Varian Associates. It is called the Ultraprobe and is designed for use with mass spectrometer leak detectors.

The device operates on the principle of coaxial gas flow, where a detecting gas (helium) is passed through the centre of a diluting gas (nitrogen or air). The presence of the diluting gas—surrounding the detecting gas—confines the helium to a small cone-shaped area at the tip of the probe, making accurate detection possible.

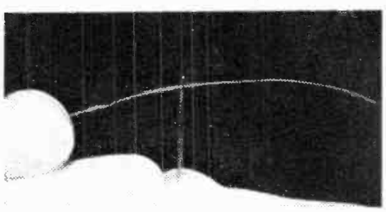
Eitel-McCullough (Eimac) are represented in the United Kingdom by Walmore Electronics Ltd., of 11-15 Betterton Street, Drury Lane, London, W.C.2.

WW 317 for further details

FINE GAUGE SOLDER

TO meet the needs of the miniature equipment manufacturer, Multicore Solders Ltd. announce that they are now able to produce solder, with five cores of flux, in gauges down to 34 s.w.g. (0.009in diameter).

The 30, 32 and 34 gauge solders are, however, only available to special order. In terms of length there is



nearly a mile of the 34 s.w.g. solder to the pound, whereas in 16 gauge there is just over 60 yards. Thirty-four gauge solder is used in the illustration.

The address of Multicore Solders Ltd., is Multicore Works, Maylands Avenue, Hemel Hempstead, Herts.

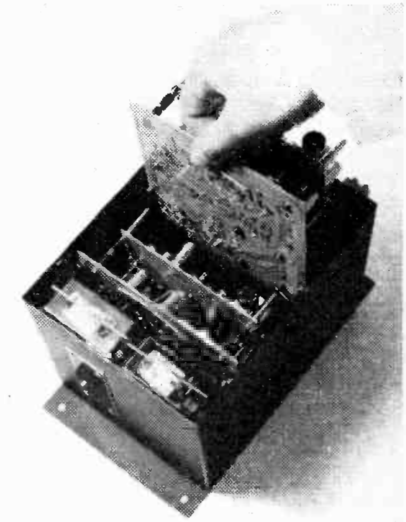
WW 318 for further details

VIBRATION MONITOR

ALTHOUGH originally designed for use in a nuclear power station, the Dawe Type 1435 vibration monitor has been found to be suitable for many other vibration measurement tasks. It consists of a solid state amplifier and is used with a velocity-sensing transducer for mounting on a selected point of the structure to be monitored.

The standard version—shown in the illustration—has two separate channels and is contained in a single case together with the associated power supplies and overload relays. Each channel provides an output for remote meter reading proportional to the peak displacement within the frequency range 15 to 800 c/s. Provision is made for the insertion of filters where a narrower band is required. The range of displacement which can be measured is from 0.001 to 0.010 in peak.

In the standard version, the overload relays are rated at 10 A at 230 V d.c., and they may be set to operate at any level from 25% to 100% of maximum output.



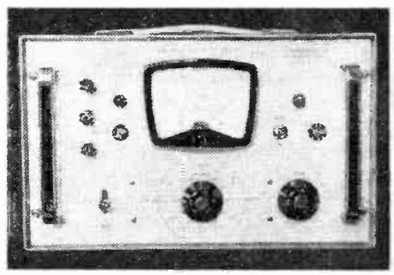
The address of Dawe Instruments Ltd. is Western Avenue, Acton, London, W.3.

WW 319 for further details

High Resistance Tester

COVERING the range 50 kΩ to 200 kMΩ, the new high resistance tester from K.S.M. Electronics Ltd., of 139 Fonthill Road, London, N.4, should be of particular interest to those concerned with the measurement of insulation resistance. Two stabilized test voltages are provided, 100 and 500 V d.c. The lower is used to measure resistance in the range 50 kΩ to 20 kMΩ and the other in the range 500 kΩ to 200 kMΩ. The accuracy is ±1% of f.s.d.

The instrument is also calibrated from 20 micromhos down to 5 picomhos for conductance tests. Short-circuit current is limited to a maximum of 10 mA from the 500 V supply.



The dimensions are 9×14 6½ in and the weight is 18 lb. The price is £98.

WW 320 for further details

INFORMATION SERVICE FOR PROFESSIONAL READERS

To expedite requests for further information on products appearing in the editorial and advertisement pages of *Wireless World* each month, a sheet of reader service cards is included in this issue. The cards will be found between advertisement pages 16 and 19

We invite professional readers to make use of these cards for all inquiries dealing with specific products. Many editorial items and all advertisements are coded with a number, prefixedby WW, and it is then necessary only to enter the number(s) on the card.

Postage is free in the U.K. but cards must be stamped if posted overseas. This service will enable professional readers to obtain the additional information they require quickly and easily.

Portable Transistor Oscilloscope

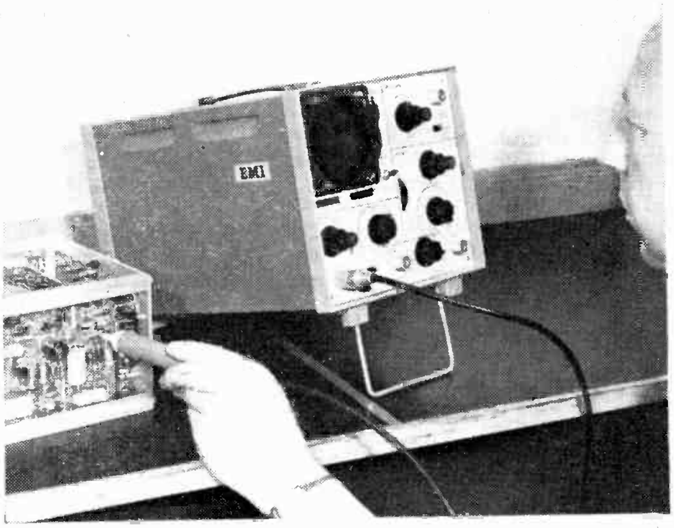
A SOLID STATE oscilloscope with a 15 Mc/s bandwidth is announced by E.M.I. Electronics Ltd., of Hayes, Middx. Known as the Oscilloscope 101, it features a new three-inch c.r.t. (Type MX54) and has a maximum sensitivity of 50 mV/cm. Minimum sensitivity is 60 V/cm and measurement accuracy is better than ±5%.

The bandwidth of the x amplifier is d.c. to 4 Mc/s and sweep speeds range from 40 nsec/cm to 100 msec/cm. A 7 kc/s square wave generator is provided for voltage calibration, having outputs adjustable from 200 mV to 40 V accurate to 2%.

This instrument can be powered from either a 12 V battery or from the mains. Consumption when battery driven is 20 W, and from the mains 25 W.

The overall dimensions are $9 \times 8\frac{1}{2} \times$ 15 in, weight is approximately 17 lb and price is £170.

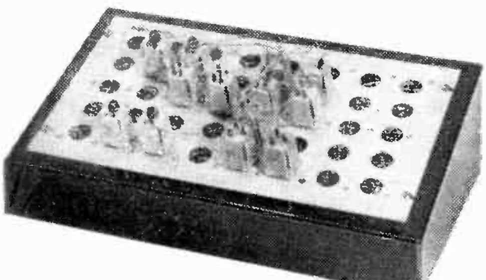
WW 321 for further details



DIGITAL LOGIC TUTOR

ALTHOUGH originally designed as an educational aid for teaching the principles of digital logic, Weir Electronics "Digi-Quip" 100 Series tutor has been found to be particularly useful in control engineering studies calling for digital logic solutions. By means of standard logic modules it is possible to simulate many problems simply by plugging-in the required modules into a desk unit which forms the basic part of the tutor and contains the power supplies. Appropriate interface modules are provided and allow control system components to be incorporated into the simulations, thus enabling the effects of various components and arrangements to be quickly assessed.

A standard arrangement consisting of a desk unit with power supply, 25 modules and ancillary items costs £115 from Weir Electronics Ltd., Durban Road, Bognor Regis, Sussex. Additional logic modules are approximately £2 5s each. Standard module assemblies may also be obtained to mount special circuits.



WW 322 for further details

FLOW-RATE INDICATOR

SUITABLE for a variety of sensing devices is the Model FK20 flow-rate indicator from Kappa Electronics Ltd., of 159 Hammersmith Road, London, W.6. This unit, which will provide a continuous indication of production flow-rate, contains a plug-in module—selected to suit the sensing arrangement—and an integrating unit to feed the panel meter and to provide 100 mV (into 150 Ω) for an external chart recorder or for control equipment.

Two versions of the FK20 are available, providing flow-rates from 200 to 1,000 objects per minute and from 200 to 3,000 per minute. Other flow-rates can be provided to order.

The dimensions of the FK20 are $13\frac{1}{2} \times 7\frac{3}{4} \times 10\frac{3}{8}$ in; weight is approximately $15\frac{1}{2}$ lb. It will operate from any 110-125 or 200-250 V, 50-60 c/s single phase mains supply.

WW 323 for further details

SOLID STATE GALVANOMETER

MANY features are claimed for the new galvanometer being produced by Airmec Ltd., of High Wycombe, Bucks. Known as the Galvamp Type 391, it comprises a d.c. chopper-type amplifier and a centre-zero meter, and is suitable for use in environments of shock and vibration that would render a conventional galvanometer inoperative.

The sensitivity of the instrument is 2 μV/mm (meter scale length is approximately 100 mm), but overload voltages of up to 20 V can be applied without causing damage. Three overlapping voltage ranges are provided: 100-0-100 μV linear; 2.5-0-2.5 mV linear; and 1-0-1 V approximately logarithmic.

Zero setting on this instrument is independent of source resistance and the drift is quoted to be "generally less than 5 μV per hour and 2 μV/°C." Ambient temperature range is from zero to 40°C. The dimensions of the Type 391 are $8 \times 5\frac{5}{8} \times 9$ in; weight is $6\frac{3}{4}$ lb, complete with battery. Price is £37.

WW 324 for further details

A Telephone Effects Unit

Transistor unit providing realistic telephone ringing in television studios. Alternative ringing codes are available and the unit allows normal telephone conversations to be held.

By M. H. LEMIN*

THE need had arisen in the studios of Associated Television (ATV) for some means of producing a ringing telephone effect in a more scientific way. The normal method had been to operate an ordinary electric bell mounted in a box, complete with batteries and pushbutton. The operator had to be within the range of the microphone, and had to simulate the well-known ringing code with a push button. There had been occasions when either the bell would not ring, or an irregular ringing code was heard. Sometimes the bell continued to ring after the telephone conversation had started.

As a result the following unit was developed, which not only rings the telephone in use to the correct code selected, but cancels automatically and allows normal telephone conversations to be held.

The distorted sound which accompanies some telephone conversations on television is produced normally by the sound effects equipment of the studio, which is automatically switched with the associated picture, but an output is available from the unit described, fully isolated by a transformer. The circuit response peaks at 2 kc/s and does not therefore need to pass *via* the effects unit before mixing into the programme.

General description

The unit provides coded ringing and speech interconnection for up to four studio floor telephones. It is mains driven and produces internally, ringing current, ringing tone, coding pulses, and the telephone energising voltage.

Three types of ringing code are available, and on cue the receiving instrument immediately rings at the start of the selected code cycle, and will continue to ring until either the handset of the receiving instrument is lifted, or the cue switch operated to reset the circuits. The sending instrument during the ringing period hears a 300 c/s ringing tone, which ceases when the receiving handset is lifted and normal telephone communication commences.

The design ensures that the unit will always commence ringing at the start of a coded sequence, even when rapidly re-cued, and will ignore such operations as the handset being fumbled and dropped back on to the cradle switch, rapid operation of the cradle switch or rotation of the dial mechanism.

The unit will operate with a wide variety of telephone instruments, a control being provided to account for differences in the loudness of various instrument bells.

While the telephone instruments share a common speech circuit, the ringing however, is individual to each instrument, and may be separately cued from any of eight selected positions on the studio floor.

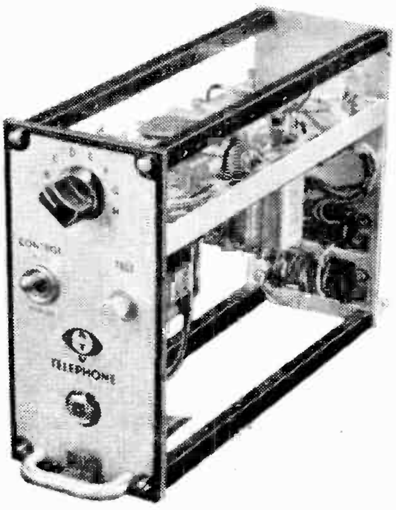


Fig. 1. Ringing module. For a two-way telephone conversation two of these modules are connected in parallel.

Design considerations

The initial design centred around an electro-mechanical system using large ratchet relays for coding. However, this was rejected due to excessive noise from the clicking ratchet wheels, and because it was necessary to change the ratchet wheels or the complete relays when a different ringing code was required. Consequently, a transistor version was developed, which includes a mains power supply unit, a 17 c/s ringing generator and a 300 c/s ringing tone generator, making the unit completely self-contained.

Essentially, two free-running multivibrators are required to produce the ringing code, the first being gated by the start switch and running at 0·33 c/s and the second running at 1·66 c/s, being gated by the first multivibrator.

The 17 c/s ringing generator was required to produce about 80 V r.m.s., and the simple inverter stage uses a standard mains transformer in reverse, this having a sufficiently high inductance to make the circuit economical at the low frequency involved.

The telephone itself was required to reset the system from the ringing condition to the speech condition. When the receiver is at rest on the cradle, an impedance of approximately 2·5 kΩ at 20 c/s is presented, and there is no d.c. path. However, when the receiver is lifted a d.c. circuit is presented with an impedance of only 100 Ω, when the telephone transformer is connected into the line. This low-resistance path operates a relay in the "ringing module" and connects the speech line to the telephone.

The total current consumed at 24 V is 600 mA and

* Anglia Television Ltd., formerly with Associated Television Ltd.

total power dissipated by the transistors is 6·2 W, of which 6 W is dissipated in the 17 c/s generator.

The unit is of modular construction and consists of a standard 19 in rack mounting frame containing one control module and four ringing modules. The style is intended to match the equipment already used in the sound control rooms (Figs. 1 & 2). The coder is assembled on stock printed circuit Veroboard, which hinges down for servicing. Each of the four ringing modules has a small chassis on which the relays are mounted.

Operation

The unit, being installed in a control room, must be remotely controlled from the studio floor by the stage manager. To enable the operator to work from any position in a large studio, each of eight wall-boxes has a position for plugging in a non-locking push switch on an extension lead. The two telephones in use are routed from the unit by normal tie-lines to other box outlets convenient to the set. The ringing module that controls the ringing telephone is connected by its selector switch to the wall-box point controlled by the studio manager.

On the appropriate cue, the switch is made and the telephone will ring until either the telephone is lifted or the switch is again operated. The two telephones are connected for normal speech as soon as the ringing ceases.

The unit may also be operated manually *via* the AUTO/MANUAL switch, or from the control room by operating the TEST switch. This switch is illuminated to the code selected, and indicates operation, both on auto or manual.

The telephones are each connected to a telephone ringing module. Each complete unit actually holds four of these modules, and so makes it possible to hold a four-way conversation, although normally only two are required. The connections of each module are joined in parallel to the control unit module.

Circuit description

Control Module

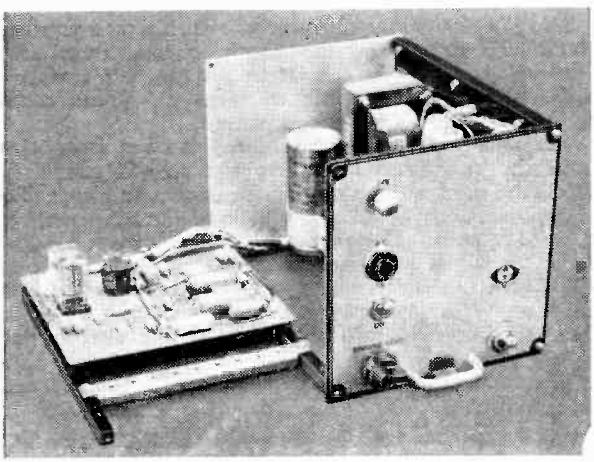
Coder.—The two transistors Tr1 and Tr2 (Fig. 3) form an astable multivibrator, oscillating at 0.33 c/s, with a 1:2 mark-space ratio. Oscillations can only start, however, when the emitter of Tr1 is grounded. Tr2 is conducting until then, and this ensures that the waveform at Tr1 collector will always commence positively, to initiate the sequence of oscillations in the next stage.

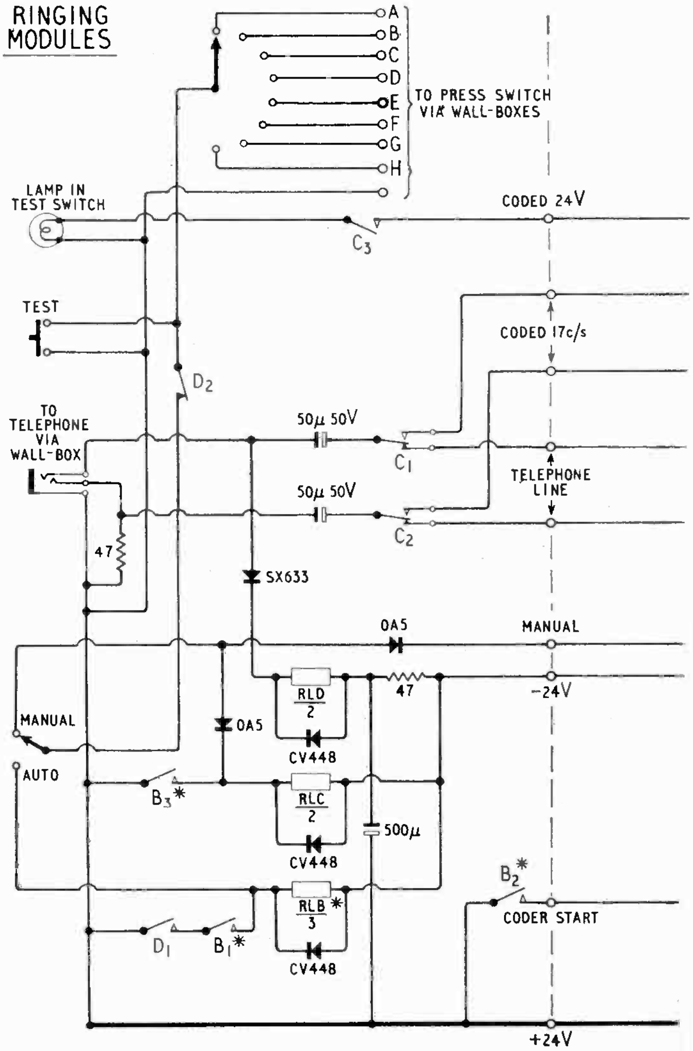
Tr3 and Tr4 also operate as an astable multivibrator, but at a frequency of 1.66 c/s and with a mark-space ratio of 2:1. The output from Tr4 collector switches Tr5 on operates relay RLA. This relay is then being coded to the P.O. standard (Fig. 4).

By switching Tr2 collector to Tr5 base, a different code (e.g., Continental single ring) may be obtained. The relay may also be coded manually by making the 24 V+ line directly to Tr5 collector.

Ringing Current Generator.—This is a symmetrical astable multivibrator with a frequency of 17 c/s. The collector loads are each half of the centre-tapped primary winding of a transformer. The transformer primary is tuned by two large-value capacitors. The voltage developed in the secondary winding when ringing a standard P.O. telephone is 80 V r.m.s. The power

Fig. 2. Control module which includes coder, 17 c/s ringing generator, 300 c/s ringing tone generator and power unit.





available is 3 W, which will ring two telephones simultaneously if the need should arise. An output level control is fitted to suit the required volume of ring.

Ringing Tone Generator.—This operates similarly to the 17 c/s circuit, but at 300 c/s and with little power. The sound is not true ringing tone, but serves to indicate to the artist that the telephone system is working.

The outputs of both the 17 c/s and 300 c/s generator stages are passed to the ringing modules, *via* the coder relay RLA.

A bridge rectifier providing 24 V at 1 A is included in this module.

Ringing Modules

Let us assume the unit is switched on, and the AUTO/MANUAL switch is set to AUTO. If the

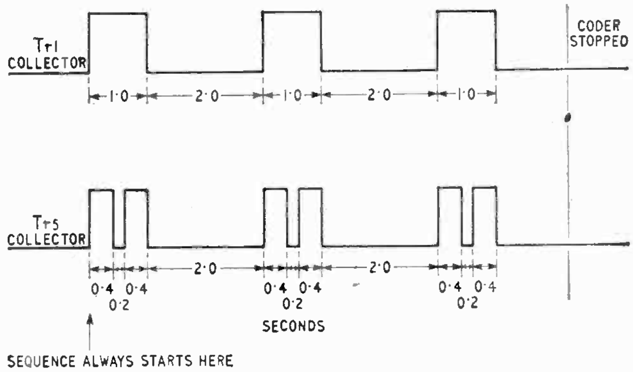
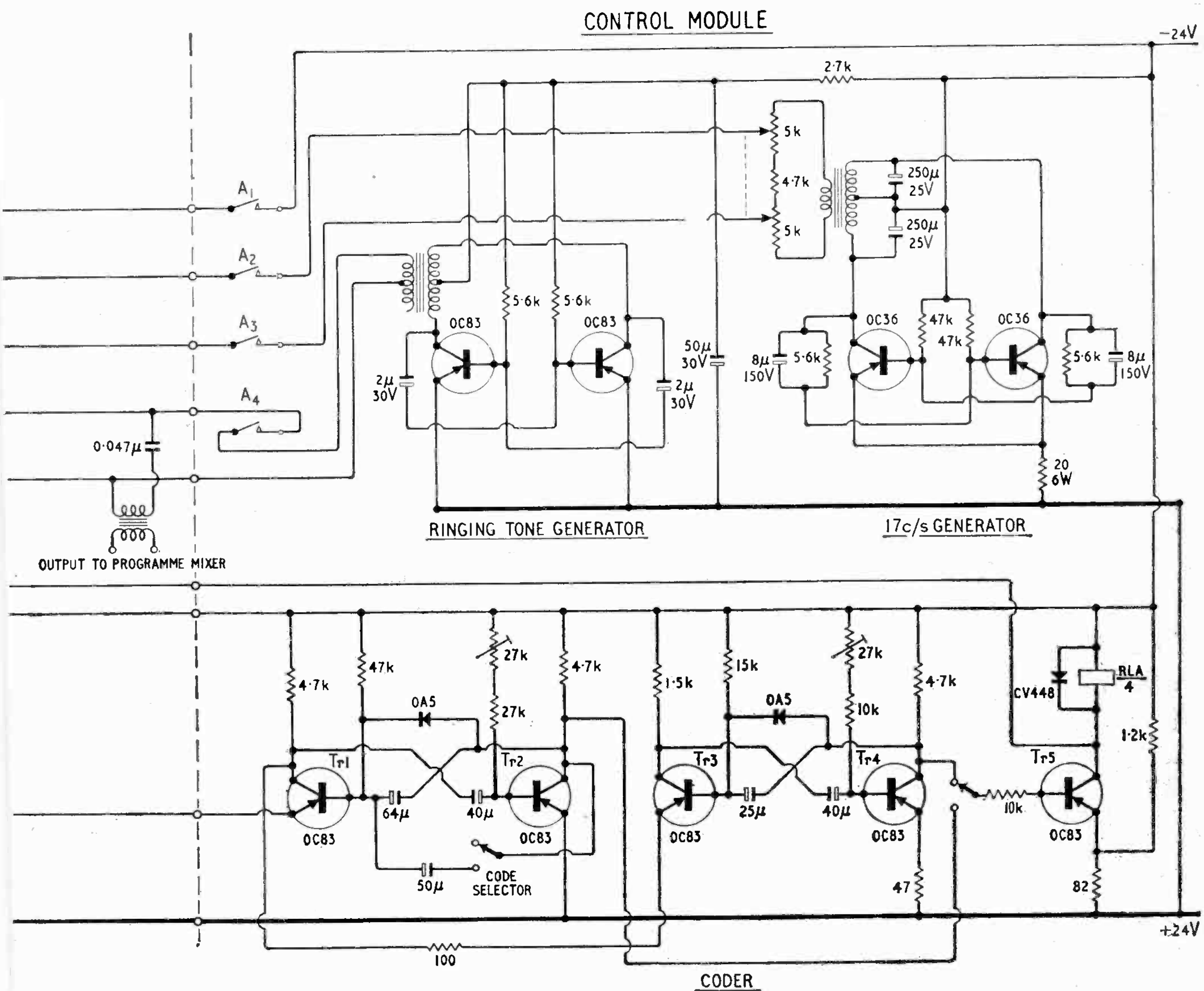


Fig. 4. Idealised coder waveforms.

*Fig. 3. Circuit of control and ringing modules. For a two-way telephone conversation two ringing modules are connected in parallel, the operating push-switch being connected to the ringing module associated with telephone to be rung. *Relay RLB is a ratchet relay (see text).*



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operator's push-switch in the studio or the TEST switch on the module are now momentarily operated, the 24 V+ line will be made to RLB. RLB is a ratchet relay, and each pulse moves the relay to the alternate condition. Contacts B1, B2 and B3 will then make. B2 starts the coder and B3 operates RLC, which changes the telephone circuit from the speech line to the 17 c/s supply. The telephone will now ring.

When the receiver is lifted, the low impedance of the telephone causes RLD to operate D1, which is in series with B1 (made), connects the 24 V+ line to RLB. RLB moves to the alternate condition (as when the unit is quiescent) and opens B2, which stops the coder. B3 opens and releases RLC, connecting the telephone back to the speech line. D2 then opens, preventing further operation of coder and ringing circuits until the receiver is replaced. B1 has opened, releasing the ratchet of RLB. A direct voltage for the telephone is applied *via* the coil of RLD, the rectifier in series with RLD preventing RLD from being operated by the 17 c/s ringing signal.

The speech and ringing functions of each telephone are separated the instant a ringing module is set into operation, when RLC changes over the telephone line from speech to coded 17 c/s. Since only the relay RLC in the ringing module has operated, all other telephones in use will remain on the speech line. During the ringing period they will hear the ringing tone *via* A4, the coder relay, in the control module.

Setting up

The whole unit may be quickly set up by connecting an oscilloscope across the telephone line and switching the coder to the standard P.O. ringing code.

The chassis of the oscilloscope must be connected to the chassis of the telephone unit *via* a 1 μF capacitor, to remove hum from the trace. With the timebase range set to 0.2 s/cm and arranged so that the signal triggers the commencement of the sweep, the 1.0 s point will be at the centre of the trace.

VR1 is set to maximum and VR2 adjusted so that the duration of each 17 c/s ringing pulse is 0.4 s. VR2 is adjusted so that it just fails to clip the second pulse of 17 c/s, i.e. at 1.0 s from commencement of the first period.

PROJECT OSCAR

By W. H. ALLEN,* M.B.E., G2UJ

THE STORY OF THE AMATEUR RADIO SATELLITES

FROM the time that the first artificial satellite, the Russian Sputnik I, was launched into orbit around the earth in 1957, radio amateurs have been interested in receiving signals from space. Some two years later the Project Oscar Association was formed in California as a result of a suggestion put forward by Donald Stoner (W6TNS) that a satellite designed and constructed by radio amateurs and transmitting some form of signal in one of the amateur bands, should be launched.

Many of those in Project Oscar were connected in various ways with the electronics side of satellite and missile research so that no particular problem existed in the design or the construction of a suitable package: the stumbling block was how to get it launched. Those conversant with the subject realised that few launch vehicles left the ground with their instrument compartments completely filled with apparatus—there was usually some small vacant space into which yet another piece of electronic gear might be fitted: the difficulty lay in obtaining the necessary authority.

Eventually representations made by the American Radio Relay League to the State Department resulted in the Air Force granting facilities for an amateur constructed satellite to be taken up in one of their vehicles in the Discoverer series from the Vandenberg Air Force Base in California, and Project Oscar was in business.

It was decided that Oscar (Orbiting Satellite Carrying Amateur Radio) should incorporate a low powered battery driven transmitter radiating a distinctive signal on 145 Mc/s in the amateur two-metre band. The signal would consist of the letters HI in Morse, this combination being chosen as both distinctive and giving the greatest effect for the least expenditure of power. A simple form of telemetry was devised to indicate the temperature inside the package by the time taken to transmit the signal; the slower the speed of sending the lower the temperature.

The Discoverer firings were subject to official secrecy, so that although some broad indication could be given to the world's amateurs, no definite launch date or orbit parameters could be divulged until the satellite was actually in orbit. It was known that Discoverer satellites were normally placed into approximately polar orbits and assurance was obtained that this particular firing would be no exception to the rule.

Oscar I

The Oscar I package weighed approximately ten pounds and consisted of a gold-plated magnesium-alloy box (12×10×8 in) painted with black stripes in an attempt to equalize heat absorption and loss. The box was curved along the longer side to fit into the allotted space in the Agena capsule of the Thor/Agena B launch vehicle.

The transmitter comprised a crystal oscillator on a frequency of 72.5 Mc/s using a fifth-overtone crystal and a 2N1493 transistor. This was followed by a base-driven 2N1506 buffer amplifier developing 180 mW which in turn drove a Varicap-diode frequency doubler which delivered 100 mW on 145 Mc/s to a quarter-wave aerial set in the centre of one of the larger surfaces of the box. Including the telemetry system the package contained 16 transistors and a number of diodes and was powered by a mercury battery, connected when the flexible aerial rod sprang into a vertical position as the package was ejected from the Agena capsule.

The launch took place on December 12th, 1961, in

(*Continued on page* 51)

*U.K. Co-ordinator for Project Oscar.

a south-westerly direction over the Pacific and signals from the satellite were first reported from the amateur station KC4USB at the United States Antarctic Base in Marie Byrd Land.

The orbit had an inclination of 81° to the equator, a period of 92 min. and apogee of 275 miles and a perigee of 150 miles.

Oscar I first came within radio range of the United Kingdom just before 1 a.m. on December 13th and was first reported by Angus McKenzie (G3OSS). The signal was very strong and as the satellite passed from SSE to ENE a Doppler shift in frequency of approximately 7 kc/s was measured by L. V. Dent (G3GDR). The phenomenon of Doppler shift is, of course, a feature of satellite signal reception, the signal appearing to fall sharply in frequency at the moment of nearest approach to the observer.

Oscar I was received by many hundreds of amateurs in all parts of the world during its life of 22 days and 339 orbits. With a receiver possessing a good noise factor—3 to 4 dB—and a directional beam having a gain of 6 dB or more, the signal could be read at ranges of well over 1,200 miles and on near passes was audible for nearly ten minutes during which period the satellite would have travelled upwards of 2,500 miles.

The transmitter functioned well for 261 orbits but the heat balance of the package proved to be imperfect with the result that both transistors and battery suffered from the effects of high temperature and signals became erratic for the last few days of the satellite's life.

Oscar II

The second Oscar project was a duplicate of its predecessor except for minor changes in the epoxy resin foam filling of the interior of the case and a different pattern of absorbing and reflecting surfaces on the case in an endeavour to overcome the overheating which had damaged Oscar I.

Launch was effected from Vandenberg on June 6th, 1962 and was subject to a considerable degree of secrecy, so that the necessary details of the orbit were not divulged for some days after the satellite was in orbit and predictions of its appearances were almost impossible to make except on a strictly day-to-day basis. The inclination was 74° and the height approximately 130 miles. The period of 89 min did not augur a long life and Oscar II burnt up somewhere over northern Europe on June 20th, 1962 after completing 295 orbits. The transmitter continued operating until the end.

Oscar III

As will be realised from a previous article* Oscar III was a far more sophisticated device designed to receive signals over a 50 kc/s segment of the two-metre band centred on 144·1 Mc/s and to radiate them without intermediate demodulation between 145·875 and 145·925 Mc/s.

This satellite was launched from Vandenberg on March 9th, 1965, into a nearly circular 570 mile orbit with an inclination of 70° and a period of 103·5 min approximately.

Considerable interest was evoked among amateurs operating on the two-metre band and thanks to the extremely accurate predictions by W. Browning (G2AOX), made available through the R.S.G.B. weekly broadcasts on two-metres, no difficulty need have been experienced by anyone wishing to listen to the signals retransmitted by the satellite or to the telemetry radiated by the separate 25 mW transmitter operating on 145·85 Mc/s.

*Wireless World, January 1965, p.17.

Unfortunately Oscar III had certain technical difficulties. The sensitivity of the receiver was at least 10 dB lower than the design figure due partly, it is thought, to a partial failure of the 145·95 Mc/s tracking beacon, which resulted in its acting as a mixing device causing the translator transmitter to inject noise into the receiver, and thus reducing the sensitivity of the latter by a.g.c. action. From the telemetry readings, it was deduced that all was not well with the battery, a fault which could have been caused by a leaky seal. (Information on decoding the telemetry signals was made available and by observing the signals on an oscilloscope the pulse duty cycle and pulse rate could be estimated, yielding battery and amplifier temperatures and battery voltage.)

Despite these shortcomings a total of 176 two-way contacts were effected *via* the translator during 247 orbits of active operation. These included transatlantic contacts between DL3YBA (Germany) and W1BU in Massachusetts on orbit 61 and between EA4AO (Spain) and W2AZL in New Jersey during orbit 157. The distance record fell to KL7CUH in Alaska and K2IEJ in New York. Of the 98 different stations which succeeded in making two-way contacts, 31 were in Europe. As a result of the reduced sensitivity of the satellite's receiver, only those operators able to concentrate a powerful signal *via* a high-gain aerial array generally were successful in two-way operation, but a far greater number were heard on the translated band, not less than 401 calls being logged by one American amateur and 136 by another American resident in this country. All but five contacts made through the translator were on c.w., the balance being effected by single-sideband telephony.

The low-powered telemetry transmitter ran from a separate battery recharged by a small number of solar cells and this continued to operate for some time after the translator battery failed and was still working, although somewhat erratically, on July 12th, by which time Oscar III had completed 1,486 orbits.

Oscar IV & V

As announced recently,† Oscar IV was due for launch on December 2nd, 1964, into a near-synchronous orbit, but this date has been changed to December 21st. Its track is intended to be immediately over the equator and the satellite will progress 30° per day in an easterly direction, taking twelve days to complete one passage round the globe. Stations situated anywhere up to 81° north or south latitude should be within radio range for several days at a time.

At the time of writing, the equipment to be carried in the 19-in cube covered with solar cells which will be Oscar IV had not been decided. Four sets of equipment have been developed by groups of radio amateurs in the United States, but it seems likely that a two- or three-band beacon transmitting on approximately 144, 432 and possibly 1,296 Mc/s will be chosen together with some form of telemetry transmitter.

Fired by the success of Oscar III, plans are already well advanced for another and better translator for Oscar V (to be launched later in 1966) which might retransmit signals received on a small segment of the two-metre band on a channel around 29·5 Mc/s and incorporate in addition two or more beacons also on different bands.

Advanced designs for amateur satellites are also in course of development in Australia, Germany and Holland and it could well be that the facilities enjoyed by Project Oscar might be employed to launch one of these in the course of the next year or two.

†Wireless World, December 1965, p.618.

JANUARY MEETINGS

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

LONDON

4th. I.E.E.—"Satellite control" by E. G. C. Burt at 5.30 at Savoy Pl., W.C.2.

4th. I.E.E.—"Naturally occurring thermal radiation in the range 1-10 Gc/s" by Dr. D. L. Croom and "Aerial noise temperature at 5,650 Mc/s" by E. Denison and G. L. Rogers at 5.30 at Savoy Pl., W.C.2.

5th. S.E.R.T.—"Dual standard time bases" by L. H. Briggs at 7.0 at Royal Society of Arts, John Adam Street, W.C.2.

6th. I.E.E.—Hunter Memorial Lecture "Lasers and associated devices" by Dr. G. G. MacFarlane at 5.30 at Savoy Pl., W.C.2.

10th. I.E.E.T.E.—"Future developments in television" by F C. McLean at 6.0 at Savoy Pl., W.C.2.

11th. I.E.E.—Discussion on "Alphanumeric cathode-ray-tube displays" at 5.30 at Savoy Pl., W.C.2.

13th. Television Soc.—"Problems connected with the use of colour film for colour television" by F. P. Gloyns at 7.0 at I.T.A., 70 Brompton Rd., S.W.3.

17th. I.E.E.—Colloquium on "Active filters" at 2.30 at Savoy Pl., W.C.2.

17th, 24th and 31st. R.S.A.—Three Cantor lectures on "The place of the technologist in modern society" by Prof. M. W. Thring at 6.0 at John Adam St., Adelphi, W.C.2.

19th. I.E.E.—"Industrial applications of electro-luminescence" by D. Reaney at 5.30 at Savoy Pl., W.C.2.

19th. I.E.R.E.—"Improved radar visibility of small targets in sea clutter (through decorrelation by a rapidly rotating antenna)" by J. Croney at 6.0 at 9 Bedford Sq., W.C.1.

21st. Inst. of Navigation.—"Loran C" by C. Powell and A. Woods at 5.30 at the Royal Aeronautical Society, 4 Hamilton Pl., W.1.

24th. I.E.E.—"Recent studies of dispenser cathodes" by Dr. H. Ahmed, C. E. Maloney, J. D. Sankey and A. H. Beck at 5.30 at Savoy Pl., W.C.2.

25th. I.E.E.—"Method for the prediction of the fading performance of a multisection microwave link" by K. W. Pearson at 5.30 at Savoy Pl., W.C.2.

25th. I.E.E.—Discussion on "The use of programmed learning for remedial work in higher education" at 5.30 at Savoy Pl., W.C.2.

26th. I.E.R.E. & I.E.E.—Discussion on "Linking of computers" at 6.0 at 9 Bedford Sq., W.C.1.

27th. I.E.E.—"Optical surface waves" by C. Kao at 5.30 at Savoy Pl., W.C.2.

28th. I.E.E.—Colloquium on "Microwave noise-measuring techniques" at 2.0 at Savoy Pl., W.C.2.

28th. Television Soc.—"U.H.F. translators" by W. J. Morcom at 7.0 at I.T.A., 70 Brompton Rd., S.W.3.

31st. I.E.E.—"The definition and properties of the delta function" by R. F. Hoskins at 5.30 at Savoy Pl., W.C.2.

31st. I.E.E.—Colloquium on "The problems of radiation pressure and associated mechanical forces" at 5.30 at Savoy Pl., W.C.2.

BELFAST

11th. I.E.E.—"Field effect transistors—their properties and application possibilities" by Prof. A. R. Boothroyd at 6.30 at Ashby Institute, Stranmillis Rd.

BIRMINGHAM

3rd. I.E.E.—Discussion on "The Council for National Academic Awards—its affect on the education of technologists" at 6.30 at M.E.B., Summer Lane.

18th. I.E.E.—Faraday Lecture "Computers, control and automation" by P. D. Hall at 7.0 at the Town Hall.

19th. Television Soc.—"The development of a broadcasting centre" by J. H. D. Madin and W. A. Roberts at 7.0 at Broadcasting House, Carpenter Rd., Edgbaston.

26th. I.E.R.E.—"Digital voltmeters" by J. N. Coombes at 7.30 at the College of Technology, Gosta Green, 1.

27th. I.E.R.E.—"Recent advances in measuring techniques" by A. F. Boff at 6.30 at the University.

BOURNEMOUTH

12th. I.E.E.—"Vision, colour vision, colour television" by V. J. Cooper at 6.30 at Municipal College of Technology and Commerce.

BRIGHTON

12th. I.E.E.—"Radar—present and future trends" by Dr. E. V. D. Glazier at 6.30 at Brighton College of Technology.

BRISTOL

11th. Television Soc.—"The testing of mass-produced television receivers" by D. Maguire at 7.30 at Royal Hotel, College Green.

26th. I.E.R.E. & I.E.E.—"Polaris nuclear submarines" by Capt. C. W. A. Shepherd at 7.0 at the University's Engineering Laboratories.

CAMBRIDGE

27th. I.E.R.E.—"Television standards conversion by electronic methods" by E. R. Rout at 8.0 at the University Engineering Department.

CARDIFF

12th. I.E.R.E.—"Electron microscopy" by B. L. Rees at 6.30 at the Welsh College of Advanced Technology.

21st. Television Soc.—"Television sound techniques" by E. G. N. Alkin at 7.30 at Royal Hotel.

CHELTENHAM

28th. I.E.R.E.—"Coal face automation" by E. J. Ferrier at 7.0 at the North Gloucestershire Technical College.

COVENTRY

28th. I.E.E.—"What is wrong with the training of electronics engineers?" by Prof. J. E. Flood and A. Asbury at 6.15 at Lanchester College of Technology.

EDINBURGH

11th. I.E.E.—"Microwave solid state acoustic and plasma devices" by J. H. Colins at 6.0 at Carlton Hotel, North Bridge.

12th. I.E.R.E.—"Radio astronomy" by Dr. R. C. Jennison at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

24th. I.E.E. & I.E.R.E.—"Respiration monitoring" by Dr. Greer at 6.0 at Carlton Hotel, North Bridge.

GLASGOW

10th. I.E.E.—"The precise measurement of the velocity of sound in liquids and solids" by Dr. A. J. Barlow at 6.0 at University of Strathclyde.

13th. I.E.R.E.—"Radio astronomy" by Dr. R. C. Jennison at 7.0 at the Institution of Engineers and Shipbuilders, 39 Elmbank Cres., C.2.

LEICESTER

12th. I.E.R.E.—"Comparison of colour television systems" by H. V. Sims at 6.30 at the University.

LIVERPOOL

19th. I.E.R.E.—"The manufacture of modern magnetic materials" by H. G. Thackery at 6.30 at the Walker Art Gallery, William Brown St.

LOUGHBOROUGH

18th. I.E.E.—"The future of integrated electronics" by Dr. J. Fortes at 6.30 at Edward Herbert Building, College of Technology.

MALVERN

24th. I.E.E.—"Trends in the design of computer systems" by Prof. M. V. Walker at 7.30 at Winter Gardens.

MANCHESTER

18th. I.E.E.—"Research and development in control engineering" by Prof. J. H. Westcott at 6.15 at the College of Science and Technology.

20th. I.E.R.E.—"The use of semiconductors in the protection circuit for high-voltage direct current transmission systems" by Prof. C. Adamson at 7.0 at Renold Building, College of Science and Technology.

NEWCASTLE-ON-TYNE

5th. S.E.R.T.—"Manufacture and test of resistors" by E. Chicken at 7.15 at the Charles Trevelyan Technical College, Maple Terrace, 4.

NEWPORT, I.o.W.

28th. I.E.E.—"Recent applications of semiconductor devices" by N. Bridgeman at 6.30 at Isle of Wight Technical College.

PORTSMOUTH

19th. I.E.E.—"Radio interference problems in the Royal Navy" by B. N. Amos at 6.30 at College of Technology, Anglesea Road.

READING

12th. I.E.R.E.—"The automatic control of cranes using digital circuit elements" by B. G. Starr at 7.15 at the Technical College.

RUGBY

20th. I.E.E.—Faraday Lecture, "Computers, control and automation" by P. D. Hall at 7.30 at Granada Theatre.

SHEFFIELD

12th. I.E.E.—"Field effect devices" by Dr. R. E. Hayes at 6.30 at the University.

19th. I.E.E.—"Sound reproduction" by J. Moir at 7.0 at Grand Hotel.

SOUTHAMPTON

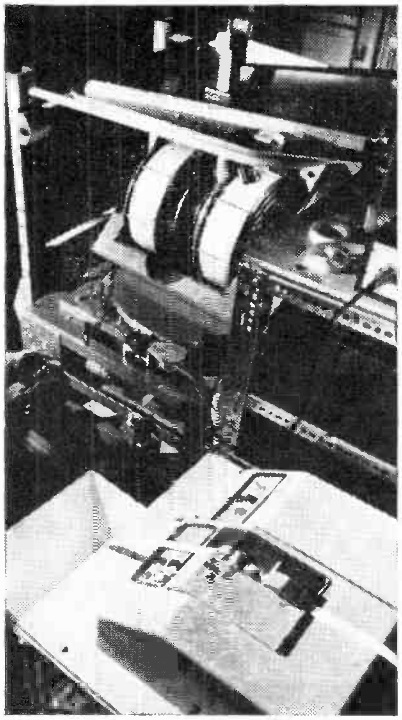
5th. I.E.E.—"Speech compression" by Dr. J. Swaffield at 6.30 at the University.

20th. S.E.R.T. — "Record playing units" by R. Poulton and E. W. Mortimer at 7.30 at the College of Technology, East Park Terrace.

25th. I.E.R.E.—"Travelling-wave tubes" by C. H. Dix at 6.30 at Lancaster Theatre, The University.

STOKE

14th. I.E.E.—"The U.K.3 Satellite" by B. J. Sketch at 7.0 at North Staffordshire College of Technology.



The Mullard Research Laboratories are investigating the potential of magnetic thin film for computer storage purposes. The illustration shows an automatic magnetometer in use during the investigation of the anisotropic behaviour (measurement of the variation of the magnetic properties with the direction of an external field applied in the plane of the film) of the material. Results of the measurements are recorded on punched tape and subsequently analysed by a computer. For computer applications, the magnetic thin film elements would be approximately 0.5 mm square and 1,000 Å thick. Elements of this size would be single domain structures having very fast (1 or 2 nanoseconds) magnetisation switching properties.

CONFERENCES AND EXHIBITIONS

**Latest information on events during 1966 in the U.K. is given below.
Further details are obtainable from the addresses in parentheses.**

LONDON

Jan. 3-7 — Imperial College
Datafair
(British Computer Society, Finsbury Pavement, E.C.2)

Jan. 12-14 — Savoy Place
V.H.F. & U.H.F. Mobile Communication Systems and Equipment
(I.E.E., Savoy Pl., W.C.2)

Jan. 20-21 — 1, Birdcage Walk
Accuracy of Electronic Measurement in I.C. Engines Development
(Inst. of Mechanical Engrs., 1, Birdcage Walk, S.W.1)

Mar. 15-17 — King's Head, Harrow
Public Address Exhibition
(A. J. Walker, 394, Northolt Road, South Harrow, Middx.)

Mar. 28-31. — Alexandra Palace
Physics Exhibition
(Inst. of Physics & Phys. Soc., 4 Belgrave Sq., S.W.1)

Mar. 23-30 — Earls Court
Electrical Engineers Exhibition
(A.S.E.E. Exhibition, 25 Museum Street, W.C.1)

Apr. 14-17 — Hotel Russell
Audio Festival & Fair
(C. Rex-Hassan, 42 Manchester St., W.1)

Apr. 19-21 — Imperial College
Environmental Engineering & Its Role in Society
(Soc. of Environmental Eng'g, Radnor House, London Rd., S.W.16)

May 23-28 — Olympia
I.E.A.—Instruments, Electronics & Automation Exhibition
(Industrial Exhibitions, 9 Argyll St., W.1)

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

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

Aug. 22-26 — Earls Court
Television & Radio Show
(Industrial & Trade Fairs, 1-19 New Oxford St., W.C.1)

BRIGHTON

Sept. 20-22 — Hotel Metropole
Battery Symposium
(F. J. L. Copping, c/o Min. of Aviation, Room 413, St. Giles Ct., London, W.C.2)

BRISTOL

July 7-8 — The University
Spectroscopy and Automation
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

CAMBRIDGE

Sept. 12-16 — The University
Microwave and Optical Generation and Amplification
(I.E.E., Savoy Pl., London W.C.2)

CRANFIELD

Mar. 21-24 — College of Aeronautics
Aerospace Instrumentation Symposium
(M. A. Perry, College of Aeronautics, Cranfield, Beds.)

DURHAM

Sept. 5-7 — The University
Rare-Earths
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

EASTBOURNE

May 3-5 — Congress Theatre
British Joint Computer Conference
(Joint Conference Secretariat, I.E.E., Savoy Pl., London, W.C.2)

GLASGOW

Apr. 12-15 — University of Strathclyde
Electronics & Shipping (I.E.E./I.E.R.E.)
(K. A. Murphy, 50 Holeburn Rd., Newlands, Glasgow, S.3)

MANCHESTER

Jan. 4-7 — College of Science & Technology
Solid State Physics
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

OXFORD

Mar. 30-Apr. 1 — The University
Nuclear and Particle Physics
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

SHEFFIELD

Apr. 15-17 — The University
Integration of Physics and Chemistry Teaching
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

SOUTHAMPTON

Sept. 19-22 — The University
Electronic Engineering in Oceanography
(I.E.R.E., 8-9 Bedford Sq., London, W.C.1)

SWANSEA

Sept. 21-23
Physics of Semiconducting Compounds
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

YORK

Apr. 4-7 — The University
Scattering, Non-linear Optics & Electro Magneto-Optics
(Inst. of Physics & Phys. Soc., 47 Belgrave Sq., London, S.W.1)

JANUARY TO MARCH
CONFERENCES & EXHIBITIONS OVERSEAS

Jan. 25-27 — San Fransisco
Reliability & Quality Control
(R. Brewer, Mullard Southampton Works, Southampton, Hants)

Jan. 31-Feb. 2 — Los Angeles
Information Theory Symposium
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

Feb. 2-4 — Los Angeles
Aerospace and Electronic Systems
(I.E.E.E., 345 East 47th St., New York 10017)

Feb. 3-8 — Paris
Electronic Components Show
(F.N.I.E., 16 rue de Presles, Paris 15)

Feb. 3-8 — Paris
Audio Equipment Exhibition
(F.N.I.E., 16 rue de Presles, Paris 15)

Feb. 9-11 — Philadelphia
Solid-State Circuits Conference
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

Feb. 25-Mar. 6 — Copenhagen
International Electronics Fair
(Secretariat, Julius Thomsens Plads 1, Copenhagen V)

Mar. 2-4 — Washington
Scintillation & Semiconductor Counter Symposium
(I.E.E.E., 345 East 47th St., New York, N.Y. 10017)

Mar. 3-12 — Hong Kong
British Week
(British National Export Council, 27/28 Northumberland Ave., London, W.C.2)

Mar. 6-15 — Leipzig
Spring Fair
(Leipziger Messeamf, Post Box 329, Leipzig)

Mar. 21-25 — New York
I.E.E.E. International Convention & Exhibition
(I.E.E.E., 345 East 47th St., New York, N.Y.10017)

Mar. 23-25 — Berlin
Stress Analysis Conference
(Inst. of Civil Engineers, Gt. George Street, London, S.W.1)

Mar. 28-31 — Paris
Electronic Switching
(Société Française des Electroniciens et des Radioélectriciens, 16 rue de Presles, Paris 15)